



# Blade Repair Training Standard

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V4

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## 1. LIST OF ABBREVIATIONS

Biax	Biaxial
CS	Chopped Strand
GWO	Global Wind Organisation
LOTO	Lock Out Tag Out
PPE	Personal Protective Equipment
SDS	Safety Data Sheet
TDS	Technical Data Sheet
TG	Glass Transition
Triax	Triaxial
UD	Unidirectional
WI	Work Instructions
WINDA	GWO training record database

## 2. TERMS AND DEFINITIONS

Term	Definition
Hardback	A thin, pre-cured sheet of fibre reinforced composite material. Usually consisting of 1 layer of 600 gsm biax glass fibre.
Must	For clarity where the word 'must' is used in this standard it shall have the same meaning as 'shall'.
Shall	Verbal form used to indicate requirements strictly to be followed in order to conform to this training standard and from which no deviation is permitted.
Should	Verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.



### 3. CHANGE LOG

Amendment date	Version	Approved by & date	Description of changes
2 May 23	4	GWO 2023	

#### Changes throughout:

- New layout

#### Section 4. Scope:

- Revised and updated

#### Section 5.3. Guidance on delivering lesson elements:

- Deleted

#### Section 5.6. Participants prerequisites for the blade repair module:

- Text simplified with “All personnel participating must meet the participant prerequisites described in the GWO Requirements for Training.”

#### Section 5.7. Physical demands:

- Deleted

#### Section 7. Understanding the GWO taxonomy:

- The section Understanding the GWO taxonomy has been replaced with a general instruction and referral to the GWO taxonomy found in the GWO Requirements for Training

#### Blade Repair Module

##### Section 9.2 Duration of the Blade Repair Module:

- Text updated

##### Section 9.4. Blade Repair timetable:

- Text updated

##### Element 15.6

- Number formatting updated



## 4. SCOPE

Global Wind Organisation is a non-profit body founded by the wind turbine manufacturers and owners. Our members strive for an injury free work environment in the wind turbine industry, setting common international standards for safety training and emergency procedures.

This standard describes the requirements for blade repair training that are recommended by the members of GWO. The standard comprises of one module.

GWO recognises trained persons as competent within blade repair in the wind industry. GWO accepts the trained person as possessing the required knowledge, skills, and abilities to stop an unsafe work situation where they, as duty holders, are accountable for safety.

This standard has been developed in response to the demand for recognisable blade repair training in the industry and has been prepared in co-operation between the members of GWO based on risk assessments, in-depth descriptions of job roles and tasks relevant to blade repair in the wind industry as well as factual incident and accident statistics from G+ and the wind industry.

Training is verified through GWO's WINDA database.

General feedback on this document can be sent to [info@globalwindsafety.org](mailto:info@globalwindsafety.org). See [globalwindsafety.org](http://globalwindsafety.org) on how to raise a complaint about a training provider or report a safety incident occurring during training.

## 5. GENERAL REQUIREMENTS FOR THE GWO BLADE REPAIR

Upon completion of the GWO Blade Repair Standard (BR), participants will be aware of the risks and hazards encountered when working with blade inspection and repair within the wind industry. Furthermore, they will be able to control and mitigate those risks and hazards.

The GWO Blade Repair Standard training will also equip participants with the knowledge, skills, and confidence to appropriately respond in the event of a hazardous situation and to increase their safety through proper use of personal protective equipment, emergency equipment, procedures and safe craftsmanship.

### 5.1 Target Group

Personnel who will be working in the wind industry, specifically in relation to composite inspection and repair work. Personnel that perform job functions (that have been risk assessed by their employer or their workplace duty holder) that are defined as functions where composite work training, according to this standard, may mitigate some of the identified hazards and risks.

### 5.2 Aims and Objectives

Training in accordance with this standard will enable participants to support and care for themselves and others working in the wind industry by possessing the knowledge and skills of composite inspection and repair work. Upon completion of the GWO Blade Repair Standard training course, participants will be able to work safely with composite materials while conducting inspection and basic blade repair procedures, thereby supporting an overall improvement of the safety for personnel with job functions focussing on composite repair work and inspection in the wind industry.



### 5.3 Validity Period

The blade repair training is an enduring qualification and therefore a validity period does not apply to this training. This assumes that the participants are actively working with composite inspection and repair.

### 5.4 Course Codes

Module	Course Code
Blade Repair	BR

Table 5.4.1 – GWO Blade Repair module course code

### 5.5 Participant Prerequisites for the Blade Repair Module

All personnel participating in Blade Repair Module training shall be medically fit and capable of fully participating. Specifically, the participants must be made aware of the risks and hazards related to completing this course while being allergic to the materials used in the module. This also applies for participants suffering from asthma and hyperhidrosis manuum (excessive hand sweating).

In addition to the above, all personnel participating must meet the participant prerequisites described in the GWO Requirements for Training.

## 6. GENERAL RESOURCES REQUIRED TO DELIVER BLADE REPAIR MODULE

The training provider shall ensure that the instructors, facilities, and equipment are in place to support the training of the participants.

### 6.1 Instructors

The instructor shall possess appropriate qualifications and experience to ensure that all training and supportive activities are carried out in accordance with current legislation and the requirements outlined in GWO's Requirement for Training document. In addition to these requirements instructors for this training standard shall have the following:

The instructor must:

1. Hold valid certificates for GWO BST/BSTR First Aid and GWO BST/BSTR Manual Handling
2. Be able to demonstrate knowledge and practical skills in blade repair methods, techniques, and craftsmanship comparable to those executed by the participants during the practical exercises of the Blade Repair Module
3. Act as first responder in the case of an accident

Supporting staff:

1. A person with a valid first aid qualification shall be present during all practical training. This can be the instructor or an assigned emergency response team





## 6.2 Practical Training Facilities

All facilities shall be maintained and, where appropriate, inspected and tested in accordance with current national legislation and manufacturers' specification. It is recommended that the facilities reach European standards.

Risk assessments shall be conducted and documented for all training facilities. The training provider shall hold the required permits to operate the facilities.

The learning process is facilitated by comparable elements, comparing the training environment and the participants' working environment. Comparable elements enhance the application of what is learned. The practical training facilities and the training environment are therefore expected to incorporate as many elements comparable to a real wind turbine working environment as is reasonably practicable.

The practical training facility should enable each participant to, individually and/or as part of a team, see, hear and practise the taught subject matter in such a way that it resembles the working practices in a real wind turbine environment.

The following training facility items will be required for the blade repair training:

A workshop area with sufficient:

1. dust extraction to ensure that the amount of dust in the air is kept below 10 milligrams per cubic metre
2. filtration of extracted air to prevent environmental contamination
3. exposure control measures to limit exposure limits for the instructor and participants to those as stated in the safety data sheet for all materials being used
4. temperature and humidity control to ensure that all materials being used are used within the usage limits specified in the technical data sheet for those materials
5. segregation from classrooms and administrative areas to prevent cross contamination of chemicals
6. waste segregation to prevent cross contamination

The training provider must ensure that chemical waste is disposed of in accordance with national legislation.

The training provider must provide a changing area between workshop areas and clean areas like classrooms and administration areas where participants and staff can change their shoes to prevent contamination of clean areas with chemicals.

The above are the minimum requirements, if national legislation and regulations supersedes this, then they must be followed.

## 6.3 Training Equipment

The equipment required for training as listed in Annex 1 must be available and must fulfil national legal requirements in the country where the training is taking place.





## 7. USING THIS STANDARD TO DEVELOP TRAINING

The training in this standard is designed around the GWO taxonomy described in the GWO Requirements for Training. Theoretical and practical activities must be delivered according to the defined taxonomic level in order to reach the described learning objectives.

When teaching equipment, a generic approach shall be applied aiming to avoid additional potential product specific formal training after completion of this training. However, national or regional legislation, company gap analysis and location specific risk assessments may require additional product specific familiarisation which is the responsibility of the duty holder.

In addition to this, all training based on this standard including all related resources shall, as a minimum, meet the requirements described in the GWO Requirements for Training.

## 8. ADMINISTRATION AND CERTIFICATION OF MODULE

### 8.1 Participant Performance Assessment

Participants will be assessed by means of direct observation and supplementary oral questions where appropriate (formative evaluation). The participants will also be subjected to written phase tests after theory elements, and again after the close of the training course (summative evaluation).

The written tests can consist of multiple choice or descriptive answer questions and shall be set at the same taxonomy level as the objective that they are testing. There shall be at least one question for each lesson in the module.

The written tests shall be conducted in accordance with the following criteria:

1. there shall be an instructor present in the room where written tests are being conducted for the entire duration of the written test
2. the participants shall not communicate with each other during the test
3. the participants shall not communicate with any persons via email, telephone, Skype (or similar) or social media during the test
4. the participants shall be allowed to use training material, handouts, and their own notes during the test
5. where a participant does not understand the meaning of a question or a multiple-choice option, the instructor shall be allowed to help the participant to understand the meaning of the question or the multiple-choice options. The instructor shall not give the participants the correct answers to any test questions
6. there shall be a time limit of 1½ minutes per question
7. the written test questions cannot be used during the training in such a way that the participants could recognise that they will be test questions
8. each participant must answer at least 70% of written test questions correctly to pass the test



If a participant does not reach the passing criteria in written or observational tests, the instructor shall discuss this with the participant to find out the reason. If this is due to a misunderstanding of a question or due to language difficulties, then the instructor can mark a question as correct provided that the participant is able to demonstrate understanding of the lesson element being tested. This must be documented by the instructor and stored with the tests, control measures and evaluations for the course.

Training providers shall have a documented procedure in place for dealing with participants not meeting the stated learning objectives.

Throughout the entire GWO blade repair course, the instructor will use the participant assessment form (see Requirements for Training) to evaluate the participants' knowledge and skills, with a high focus on evaluating the participants' safety awareness and craftsmanship skills.

The instructor shall keep a participant assessment form (or adaptation) for each participant until the completion / evaluation of the blade repair training module.

The participant assessment form (or adaptation) is a final evaluation tool for the instructors to assess participants during practical elements. It allows measurement of the number of violations regarding safety, competency or ability.

The participant assessment form shall be used as a progressive evaluation tool to discuss the performance of a participant to guide them to success. It also serves as supporting documentation if a participant passes or fails the module. If a participant fails to meet the demands of the blade repair training module, they can attend a new blade repair training in accordance with the contractual agreement when ordering the training course. The re-entry point is dictated by the stage where the participant left the course or where the instructor deems constructive.

Training providers may adapt the participant assessment form to other media. Training providers must have a documented procedure in place for dealing with participants not meeting the stated learning outcomes.



GLOBAL WIND  
ORGANISATION

# Blade Repair Module

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(BR)



## 9. MODULE – BLADE REPAIR

### 9.1 Aims and Objectives of the Blade Repair Module

The aim of this module is to enable participants, through theoretical and practical training, to support and care for themselves and others working in the wind industry by possessing the necessary knowledge, skills, and ability for blade repair.

Upon successful completion of the blade repair training course, the participants will be able to perform and document a wind turbine blade inspection, and execute repair work in accordance with a work instruction while maintaining the aerodynamic profile and structural integrity in glass fibre reinforced composite parts of a wind turbine within the following dimensions:

1. laminate repairs including leading edge and trailing edge repairs affecting a maximum amount of five layers and a maximum repair area size of 500cm<sup>2</sup>
2. core material replacement up to 200cm<sup>2</sup>
3. surface repair to paint and gelcoat

The GWO blade repair training course is intended as an entry level course and the participants will not therefore be expected to perform repairs in major structural elements of blades like spars, spar caps and carbon fibre.

After having successfully complete this GWO Blade Repair module, the participants will have the ability to:

- 1) **Take responsibility** for working safely with applicable chemicals, while utilising the applicable personal protective equipment in a controlled manner throughout all phases of blade inspection and repair work (Ability, intermediate level)
- 2) **Explain typical** types of blade construction, materials and the importance of surface finish relating to aerodynamic performance and efficiency (Knowledge, intermediate level)
- 3) **Distinguish** between and work safely in a controlled manner with epoxy, polyester, polyurethane, vinyl ester, methacrylate, reinforcement materials and solvents related to composite inspection and repair work (Skills, intermediate level)
- 4) **Take responsibility** for preparing, operating, and maintaining the correct tools and equipment, be it electrical or mechanical (Ability intermediate level)
- 5) **Take responsibility** for safely performing and documenting laminate, sandwich panel and surface layer repairs in accordance with a work instruction in glass fibre reinforced composite parts (Ability, intermediate level)

### 9.2 Duration

The total contact time for completing the Blade Repair module is estimated to be 70 hours and 0 minutes.

The training provider must not exceed the time per day given in the table 9-2.1 below.



	Maximum Duration Per Day
Contact time	8 hours
Total training day	10 hours

Table 9.2.1 – Maximum duration for training day

**Note** *Contact time includes delivery of course lesson content, practical exercises and activities directly related to these.*

*The total training day includes contact time, meals and breaks and travel between training sites (where applicable).*

### 9.3 Blade Repair Module Participant Ratio

The ratio shown for theory sessions indicates the maximum number of participants per instructor attending the course.

Practical ratios indicate the maximum number of participants to be supervised by an instructor during each activity.

Module	Session	Instructor to Participant Ratio
Blade Repair	Theory	1:12
	Practical	1:6

Table 9.3.1 – Instructor to participant ratio

### 9.4 Blade Repair Module Timetable

The order in which elements of this module training are delivered may vary according to the didactical choices of the delivering training provider.

The delivery of this module must comply with the requirements described in the GWO Requirements for Training.

Lesson	Element	Duration
1. Introduction to the training	1.1	Safety instructions and emergency procedures
	1.2	Facilities
	1.3	Introduction
	1.4	Scope and main learning objectives
	1.5	Ongoing assessment (participant assessment form)
	1.6	Motivation
	1.7	Human factors



		TOTAL	20 min.
2. Safety data sheets	2.1	Safety data sheets	
	2.2	Safety data sheet location	
	2.3	Safety instructions	
	2.4	Hazard labels and symbols	
	2.5	Personal protective equipment	
		TOTAL	15 min.
3. Work instruction	3.1	The work instruction (WI)	
	3.2	Locate work instruction	
		TOTAL	10 min.
4. Risk assessment	4.1	The risk assessment	
	4.2	Updated risk assessment	
		TOTAL	20 min.
5. Secure an area	5.1	Locate procedures	
	5.2	Securing the area	
		TOTAL	10 min.
6. Contamination	6.1	Characteristics	
	6.2	Work instructions as mitigation	
	6.3	Avoiding contamination	
		TOTAL	15 min.
7. Waste segregation	7.1	Why segregate waste?	
	7.2	Correct waste segregation	
	7.3	Waste segregation information	
		TOTAL	10 min.
8. Ergonomics	8.1	Classroom	
	8.2	Workshop	
	8.3	Bladework	
		TOTAL	15 min.
9. Lock Out Tag Out (LOTO)	9.1	Lock Out Tag Out	
		TOTAL	10 min.
10. Personal protective equipment	10.1	Purpose	
	10.2	Application	
	10.3	Limitations	
	10.4	Task specific	



	10.5	Disposal	
		TOTAL	100 min.
11. Masks and filters	11.1	Purpose	
	11.2	Filter categories	
	11.3	Categories and lifetime	
	11.4	Masks	
	11.5	Apply filters	
		TOTAL	45 min.
12. Chemical safety	12.1	Purpose	
	12.2	Transfer procedures	
	12.3	Information about chemicals	
	12.4	Equipment check	
	12.5	Prevention and mitigation	
		TOTAL	90 min.
13. Composites and blade construction	13.1	Aerodynamics	
	13.2	Blade construction	
	13.3	Sandwich panel	
	13.4	Blade enhancements	
	13.5	Faults, implications and mitigations	
		TOTAL	60 min.
14. Materials	14.1	Reinforcement materials	
	14.2	Matrix materials	
	14.3	Adhesives	
	14.4	Surface coatings	
	14.5	Chemical handling and application	
	14.6	Curing	
		TOTAL	75 min.
15. Tools and equipment	15.1	Mechanical, electrical and pneumatic principles	
	15.2	Utilisation of tools and materials	
	15.3	Calibration	
	15.4	Lamination tools	
	15.5	Heating blankets	
	15.6	Checking electrical tools and equipment	





	15.7	Vibrating tools	
	15.8	Electrical safety devices	
	15.9	Documentation types	
		TOTAL	40 min.
16. Phase test	16.1	Phase test	
		TOTAL	30 min.
17. Lamination skills	17.1	Fibre orientation	
	17.2	Kinked or bent fibres	
	17.3	Overlaps	
	17.4	Dry fibres and air voids	
	17.5	Mixing ratio	
	17.6	Calculation of matrix material	
	17.7	Curing at elevated temperatures	
	17.8	Ascertaining correct curing	
	17.9	Ambient temperature and humidity	
	17.10	Recording ambient temperature and humidity	
		TOTAL	150 min.
18. Basic lamination	18.1	Minimise risks associated with fibre work	
	18.2	Fibreglass mats	
	18.3	Fibre orientation and moulding theory	
		TOTAL	290 min.
19. Sandwich panel	19.1	Minimise risks associated with composite fibre work	
	19.2	Sandwich construction	
	19.3	Curing of fibre reinforced composite laminate	
	19.4	Producing a composite sandwich panel	
	19.5	Trailing edge section	
		TOTAL	420 min.
20. Painting	20.1	Completion of blade	
		TOTAL	120 min.
21. Blade inspection	21.1	Typical failures	
	21.2	Reactions to damage categories	
	21.3	Focused and scaled photographs	
	21.4	Tap test	



	21.5	Lighting	
	21.6	Inspection tools and methods	
	21.7	Types of damage	
		TOTAL	230 min.
22. Inspecting lightning protection system	22.1	Surface components	
	22.2	Visual conductivity inspection	
	22.3	Measure resistance	
		TOTAL	50 min.
23. Sanding skills	23.1	Sanding	
		TOTAL	45 min.
24. Grinding skills	24.1	Grinding	
		TOTAL	100 min.
25. Surface repairs	25.1	Minimise risks associated with composite fibre work	
	25.2	Filler adhesion	
	25.3	Reproduce surface profile	
	25.4	Paint adhesion	
	25.5	Layer thickness	
	25.6	Apply paint with a roller	
	25.7	Layer thickness with wet film	
	25.8	Record ambient temperature and humidity	
	25.9	Inspection and documentation	
		TOTAL	180 min.
26. Laminate repairs	26.1	Minimise risks associated with composite fibre work	
	26.2	Safe removal of damaged material	
	26.3	Identifying fibre direction	
	26.4	Reinforcement overlaps and matrix adhesion	
	26.5	Mixing	
	26.6	Repair layers	
	26.7	Wetting out fibres using appropriate tools	
	26.8	Wetting out fibres with matrix material	
	26.9	Vacuum consolidation	
	26.10	Curing the repair using heating blankets	



	26.11	Verifying the curing	
	26.12	Recording the ambient temperature and humidity	
		TOTAL	600 min.
27. Filling and shaping	27.1	Filler	
		TOTAL	180 min.
28. Trailing edge repairs	28.1	Minimise the risks associated with composite fibre work	
	28.2	Repair task	
	28.3	Crack repairs	
	28.4	Recreating blade profile	
	28.5	Record ambient temperature and humidity	
		TOTAL	380 min.
29. Leading edge repairs	29.1	Minimise risks associated with composite fibre work	
	29.2	Repair task	
	29.3	Leading edge repair	
	29.4	Relocate leading edge	
		TOTAL	440 min.
30. Sandwich panel repair	30.1	Minimise risks associated with composite fibre work	
	30.2	Repair task	
	30.3	Repair inner and outer laminate	
	30.4	Replacement core	
	30.5	Inspection and documentation	
		TOTAL	180 min.
31. Bond line repairs	31.1	Debonding	
	31.2	Injection of adhesive	
	31.3	Injecting material in the trailing edge	
		TOTAL	180 min.
32. Summary and final test	32.1	Summary	
	32.2	Final test	
		TOTAL	60 min.
33. Training review	33.1	Training review	
	33.2	Feedback session	
		TOTAL	30 min.




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 GRAND TOTAL
 

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4200 min.

## 9.5 Detailed Description of the Blade Repair Module

### LESSON 1 - INTRODUCTION TO THE TRAINING

20 min.

The aim of this lesson is for the participants to be motivated and to engage in the training safely at a training facility, while recognising what is expected of them during the training.

After having successfully completed lesson 1 of the Blade Repair Module, the participants can:

- 1) **Recognise** what is expected of them throughout the module (Knowledge, basic level)
- 2) **Name** and point out local emergency procedures and facilities (Knowledge, basic level)
- 3) **Discuss** the relevant human factors and explain their implications (Knowledge, intermediate level)

#### ELEMENT 1.1 - SAFETY INSTRUCTIONS AND EMERGENCY PROCEDURES

Learning objective:

- 4) The participants **show interest** or curiosity in the safety and emergency procedures at the training facility (ability, basic level)



The instructor shall:

1.1.1 Explain and ask involving questions aiming at:

- a. safety instructions according to internal procedures
- b. emergency procedures and emergency exits in the areas where the participants can be expected to be located during the course



The participants shall:

1.1.2 Engage in answering questions on local safety and emergency procedures



## ELEMENT 1.2 - FACILITIES

Learning objective:

- 5) The participants can **recognise** the location of facilities at the training location (Knowledge, basic level)



The instructor shall:

- 1.2.1 Present a general description of the facilities at the training location (administration, dining area, restrooms, toilets, etc.)
- 1.2.2 Alternative activity: lead a tour and point out facilities



The participants shall:

- 1.2.3 Note relevant facilities and ask question when in doubt

## ELEMENT 1.3 - INTRODUCTION

Learning objective:

- 6) The participants **show interest** in fellow participants and the course content and design (Ability, basic level)



The instructor shall:

- 1.3.1 Explain and ask involving questions on the blade repair training module programme, including about breaks and mealtimes
- 1.3.2 Give a short introduction to themselves including their backgrounds as instructors
- 1.3.3 Ask for participants' expectations of the training, their learning and development



The participants shall:

- 1.3.4 Give a short introduction to themselves, including job function, expected primary geographic work location and share expectations on the training



## ELEMENT 1.4 - SCOPE AND MAIN LEARNING OBJECTIVES

Learning objective:

- 7) The participants can **recognise** the scope and main objectives of the Blade Repair Training Module (knowledge, basic level)



The instructor shall:

- 1.4.1 Present the scope and main learning objectives of the Blade Repair Module training
- 1.4.2 Involve participants in questions on understanding and individual experiences on blade repair



The participants shall:

- 1.4.3 Engage in answering the above questions and share experiences of blade repair

## ELEMENT 1.5 - ONGOING ASSESSMENTS (PARTICIPANT ASSESSMENT FORM)

Learning objective:

- 8) The participants can **recognise** the assessment procedure and the aim of the ongoing assessment (Knowledge, basic level)



The instructor shall:

- 1.5.1 Explain the reasons for the ongoing assessment
- 1.5.2 Explain the layout of the GWO participant assessment form and how it will be used



The participants shall:

- 1.5.3 Engage themselves in discussions and ask questions when in doubt in relation to the assessment procedure

## ELEMENT 1.6 - MOTIVATION

Learning objective:



- 9) The participants **show interest** and willingness to engage in the learning activities (Ability, basic level)



**The instructor shall:**

- 1.6.1 Explain and lead discussion on:
- a. the importance of personal involvement in the course
  - b. the definition of and the need for blade repair understandings and abilities

**Note** *Positive motivation is the driving force for commitment. The instructor should make a focused effort to support growth of the necessary attitude and motivation in the participants.*



**The participants shall:**

- 1.6.2 Engage themselves in discussion and share experiences on blade repair

**Note** *When the participants succeed by trying out on their own, bring their relevant experience into play and apply learning points from the instructor's feedback, they develop a positive attitude and responsibility towards the subject and the performance in the work situation.*

## ELEMENT 1.7 - HUMAN FACTORS

The aim of the element is to draw the participant's attention to how human behaviour and taking responsibility influences a safe work environment. The aim is additionally to prepare for a focus on human factors during practical training and exercises.

### Learning objectives:

- 10) The participants can **describe** the relevant human factors, and their implications (Knowledge, basic level)
- 11) The participants **show interest** and willingness to focus on human factors during the following practical exercises (Ability, basic level)



**The instructor shall:**

- 1.7.1 Present how human factors influence accidents in the wind industry (relevant statistics may be presented)





- 1.7.2 Lead a discussion about the role of the individual in improving human behaviour and how this can improve the safety of offshore operations
- 1.7.3 Ensure that constructive feedback on the participant's performance involves human factors criteria when these are defined in the learning objective such as the ability to take responsibility or to act independently

Facts and human factors criteria:

The consequences of human factors in accidents in wind turbine environments are influenced by the following terms and conditions:

- a. attention and perception
- b. group behaviour and peer pressure
- c. weather conditions
- d. weather delays
- e. noise levels
- f. site layout and housekeeping
- g. fitness and health
- h. domestic and work-related stress
- i. workload (both overload and underload)
- j. fatigue
- k. time pressure and deadlines
- l. alcohol, medication, and substance abuse



**The participants shall:**

- 1.7.4 Engage in discussions and share experiences on how human factors influence blade repair accidents. Engage in and reflect on received feedback and take responsibility for their own performance and development during the training

## LESSON 2 - SAFETY DATA SHEETS

15 min.

The aim of the lesson is to enable the participants to read, explain and use the information obtained from a safety data sheet (SDS) in a wind turbine environment.



After having successfully completed this lesson, the participants can:

- 12) **Show interest** in always obtaining the most up-to-date safety data sheet in the applicable language before initiating work (Ability, basic level)

## ELEMENT 2.1 - SAFETY DATA SHEETS

Learning objectives:

- 13) The participants can **describe** the purpose and content of safety data sheets (Knowledge, basic level)
- 14) The participants can **recognise** that specific companies or country specific requirements can mean additional sources of safety information (Knowledge, basic level)



The instructor shall:

- 2.1.1 Describe the requirement for chemical manufacturers to produce safety data sheets for the chemicals they produce
- 2.1.2 Explain the purpose of safety data sheets
- 2.1.3 Briefly emphasise that specific companies or country specific requirements can mean additional sources of safety information such as material safety data sheets or safety information being summarised in the work instruction
- 2.1.4 Show examples and explain the contents of safety data sheets with emphasis on sections 1.4, 2, 4 and 5
- 2.1.5 Ask the participants relevant questions about the purpose and content of the safety data sheets



The participants shall:

- 2.1.6 Share their understandings of the purpose and content of safety data sheets

## ELEMENT 2.2 - SAFETY DATA SHEET LOCATION

Learning objectives:

- 15) The participants can **describe** the importance of always finding the most up to date safety data sheet in the applicable language (Knowledge, basic level)



- 16) The participants **show interest** in always finding the most up to date safety data sheet in the applicable language before initiating work (Ability, basic level)



The instructor shall:

- 2.2.1 Emphasise the importance of obtaining the most up-to-date company specific safety information, such as safety data sheets or material safety data sheets, from e.g. a site lead or company representative before initiating work
- 2.2.2 Facilitate a discussion on the importance of locating safety data sheets written in local languages



The participants shall:

- 2.2.3 Engage in discussions about the importance of locating safety data sheets written in local languages

### ELEMENT 2.3 - SAFETY INSTRUCTIONS

Learning objectives:

- 17) The participants can **recognise** the importance of following safety instructions according to internal and national procedures (Knowledge, basic level)
- 18) The participants can **describe** how to locate one example of a chemical from the safety data sheet (Knowledge, basic level)



The instructor shall:

- 2.3.1 Emphasise the importance of finding company specific safety instructions
- 2.3.2 Emphasise the requirement to follow national safety procedures
- 2.3.3 Explain how to locate one example of a chemical from the safety data sheet
- 2.3.4 Assign the participants into groups and ask them to describe to each other how to locate at least one example of a chemical, topic, or content from the safety data sheet, which will be used during the course, including the mitigation steps



The participants shall:



- 2.3.5 In groups, describe to each other how to locate at least one example of a chemical, topic or content from the safety data sheet which will be used during the course, including the mitigation steps

#### ELEMENT 2.4 - HAZARD LABELS AND SYMBOLS

##### Learning objectives:

- 19) The participants can **recognise** the different types of hazard labels and their implications, covering at least toxic, flammable, and hazardous environment symbols (Knowledge, basic level)
- 20) The participants can **recognise** different types of safety labels (Knowledge, basic level)
- 21) The participants can **describe** the implications of different types of safety labels (Knowledge, basic level)
- 22) The participants **show interest** in complying with the different types of hazard labels and safety labels and their implications (Ability, basic level)



##### The instructor shall:

- 2.4.1 Show examples:
- a. from a safety data sheet and explain the meaning of hazard identification labels and their implications
  - b. of, and explain, the meaning of toxic, flammable, and hazardous symbols
- 2.4.2 Ask the participants relevant questions about the different types of safety labels and their implications



##### The participants shall:

- 2.4.3 Share their understanding of the different types of safety labels and their implications

#### ELEMENT 2.5 - PERSONAL PROTECTIVE EQUIPMENT

##### Learning objective:

- 23) The participants can **explain** what type of personal protective equipment to use with the applicable chemical (Knowledge, Intermediate level)



##### The instructor shall:



- 2.5.1 Demonstrate how to identify the personal protective equipment to be used with a chemical from the safety data sheet
- 2.5.2 Facilitate practice for the participants in how to identify the personal protective equipment to be used with the applicable chemical from the safety data sheet
- 2.5.3 Give constructive feedback on the participants' identification of the personal protective equipment to be used with the applicable chemical from the safety data sheet



The participants shall:

- 2.5.4 Practise how to identify the personal protective equipment to be used with the applicable chemical from the safety data sheet

## LESSON 3 - WORK INSTRUCTION

10 min.

The aim of the lesson is to enable the participants to seek and locate the correct company specific work instruction and understand the implications of not seeking the latest information from the work instruction before initiating work.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 24) **Show interest** in always locating the most up to date and correct company specific work instruction before initiating work (Ability, basic level)

### ELEMENT 3.1 - WORK INSTRUCTION (WI)

Learning objectives:

- 25) The participants can **describe** the content of a work instruction (Knowledge, basic level)
- 26) The participants can **describe** the reasons for using a work instruction during blade repair (Knowledge, basic level)



The instructor shall:

- 3.1.1 Facilitate a discussion on the reasons for using a work instruction during blade repair
- 3.1.2 Explain the risks and hazards posed by not following a work instruction



- 3.1.3 Show an example and explain the content of a work instruction
- 3.1.4 Ask the participants relevant questions about the content of a work instruction



The participants shall:

- 3.1.5 Engage in discussions about the reasons for using a work instruction during blade repair
- 3.1.6 Describe in their own words the content of a work instruction

### ELEMENT 3.2 - LOCATE WORK INSTRUCTION

Learning objectives:

- 27) The participants can **describe** the importance of locating the most up-to-date company specific work instruction before initiating work (Knowledge, basic level)
- 28) The participants can **describe** the risks and hazards associated with NOT working with an updated company specific work instruction (Knowledge, basic level)



The instructor shall:

- 3.2.1 Facilitate a discussion about:
  - a. the importance of obtaining the most up-to-date company specific WI by e.g. contacting a site lead or a company representative before initiating work
  - b. the risks and hazards associated with NOT working with the most up-to-date company WI (e.g. what are some potential real life consequences if the most updated company specific WI is not followed?)



The participants shall:

- 3.2.2 Engage in discussions about the importance of obtaining the most up-to-date company specific WI and the risks and hazards associated with NOT working with the most up-to-date company WI

## LESSON 4 - RISK ASSESSMENT

20 min.

The aim of the lesson is to introduce the participants to the content, purpose, and use of risk assessments.



After having successfully completed this lesson, the participants can:

- 29) **Show interest** in always obtaining the most up-to-date risk assessments before initiating work (Ability, basic level)

#### ELEMENT 4.1 - RISK ASSESSMENTS

Learning objective:

- 30) The participants can **describe** the content and purpose of a risk assessment (Knowledge, basic level)



The instructor shall:

- 4.1.1 Explain the purpose of risk assessments
- 4.1.2 Show examples of, and explain, the contents of risk assessments
- 4.1.3 Ask the participants relevant questions about the purpose and content of a risk assessment



The participants shall:

- 4.1.4 Share their understanding of the purpose and content of a risk assessment

#### ELEMENT 4.2 - UPDATED RISK ASSESSMENT

Learning objectives:

- 31) The participants can **describe** the importance of obtaining the most up-to-date company specific risk assessment (Knowledge, basic level)
- 32) The participants can **describe** the risks and hazards associated with NOT working with the most up-to-date company specific risk assessment (Knowledge, basic level)



The instructor shall:

- 4.2.1 Facilitate a discussion on:
- a. the importance of obtaining the most up-to-date company specific risk assessment from e.g. a site lead or company representative before initiating work





- b. the risks and hazards associated with using outdated risk assessments



The participants shall:

- 4.2.2 Engage in discussions about the importance of obtaining the most up-to-date company specific risk assessment, and the risks and hazards associated with using outdated risk assessments

## LESSON 5 - SECURE AN AREA

10 min.

The aim of the lesson is to introduce the participants to how to secure a blade repair work area.

After having successfully completed this lesson, the participants can:

- 33) **Show interest** in securing a blade repair work area (Ability, basic level)

### ELEMENT 5.1 - LOCATE PROCEDURES

Learning objective:

- 34) The participants can **recognise** how to find the procedures for securing a blade repair work area (Knowledge, basic level)



The instructor shall:

- 5.1.1 Explain how to locate the specific information for securing a blade repair work area

### ELEMENT 5.2 - SECURING THE AREA

Learning objectives:

- 35) The participants can **explain** how to locate specific information for securing a blade repair work area (Knowledge, intermediate level)
- 36) The participants can **explain** how to secure a blade repair work area (Knowledge, intermediate level)



### The instructor shall:

- 5.2.1 Explain the reasons for securing a blade repair work area
- 5.2.2 Explain how to secure a blade repair work area
- 5.2.3 Ask the participants relevant questions about how to locate specific information for securing a blade repair work area and how to secure a blade repair work area
- 5.2.4 Give constructive feedback on the participants' explanations of how to locate specific information for securing a blade repair work area and how to secure a blade repair work area



### The participants shall:

- 5.2.5 Share their understanding of:
  - a. how to locate specific information for securing a blade repair work area
  - b. how to secure a blade repair work area

## LESSON 6 - CONTAMINATION

15 min.

The aim of the lesson is to enable the participants to mitigate contamination risks by introducing them to contamination characteristics, implications, and mitigations in a wind turbine environment.

After having successfully completed this lesson, the participants can:

- 37) **Show interest** in how to mitigate contamination risks by understanding contamination characteristics, implications, and mitigations (Ability, basic level)
- 38) **Show interest** in understanding the information of a risk assessment / work instruction (Ability, basic level)

### ELEMENT 6.1 - CHARACTERISTICS

#### Learning objectives:

- 39) The participants can **recognise** the characteristics of chemical cross contamination during all phases of blade repair (preparation, transport, inspection, repair and leaving site) (Knowledge, basic level)



- 40) The participants can **recognise** the characteristics of chemical contamination of adjacent work areas during all phases of blade repair (preparation, transport, inspection, repair and leaving site) (Knowledge, basic level)
- 41) The participants can **recognise** the risks and implications of chemical contamination (Knowledge, basic level)
- 42) The participants can **recognise** how to prevent chemical contamination (Knowledge, basic level)



The instructor shall:

#### 6.1.1 Explain:

- a. the characteristics of chemical cross contamination during all phases of blade repair (preparation, transport, inspection, repair and leaving site)
- b. the characteristics of chemical contamination of adjacent work areas during all phases of blade repair (preparation, transport, inspection, repair and leaving site)
- c. the risks and implications of chemical contamination
- d. how to prevent chemical contamination



The participants shall:

- 6.1.2 Share their understanding of how to prevent chemical contamination based on the explanations provided

## ELEMENT 6.2 - WORK INSTRUCTIONS AS MITIGATION

Learning objective:

- 43) The participants can **recognise** how to mitigate the risk of chemical contamination with information from a work instruction and/or a safety data sheet (Knowledge, basic level)



The instructor shall:

- 6.2.1 Explain how to mitigate the risk of chemical contamination with information from work instructions, risk assessments and/or other documents



## ELEMENT 6.3 - AVOIDING CONTAMINATION

### Learning objectives:

- 44) The participants can **explain** how to locate specific information in a work instruction and a safety data sheet to avoid contamination (Knowledge, intermediate level)
- 45) The participants can **explain** specific contamination control information in the work instruction and safety data sheet (Knowledge, intermediate level)
- 46) The participants can **explain** the characteristics of cross contamination and adjacent work area contamination (Knowledge, intermediate level)
- 47) The participants can **explain** the risks and implications of contamination (Knowledge, intermediate level)
- 48) The participants can **explain** how to mitigate the risk of contamination (Knowledge, intermediate level)



### The instructor shall:

- 6.3.1 Explain how to locate specific information in a work instruction and a safety data sheet to avoid contamination
- 6.3.2 Ask the participants relevant questions about:
  - a. how to locate specific information in a work instruction and a safety data sheet to avoid contamination
  - b. specific contamination control information in the work instruction and safety data sheet
  - c. the characteristics of cross contamination and adjacent work area contamination
  - d. the risks and implications of contamination
  - e. how to mitigate the risk of contamination
- 6.3.3 Give constructive feedback on the participants' explanations of the above



### The participants shall:

- 6.3.4 Share their understanding of:
  - a. how to locate specific information in a work instruction and a safety data sheet to avoid contamination
  - b. specific contamination control information in the work instruction and safety data sheet
  - c. the characteristics of cross contamination and adjacent work area contamination



- d. the risks and implications of contamination
- e. how to mitigate the risk of contamination

## LESSON 7 - WASTE SEGREGATION

10 min.

The aim of the lesson is to enable the participants to perform waste segregation correctly in a wind turbine environment.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 49) **Show interest** in performing correct segregation and disposal of chemical and ordinary waste (Ability, basic level)

### ELEMENT 7.1 - WHY SEGREGATE WASTE?

Learning objective:

- 50) The participants can **recognise** the reasons for performing waste segregation correctly (Knowledge, basic level)



The instructor shall:

- 7.1.1 Explain the risks to the public posed by chemical waste
- 7.1.2 Explain the reasons for performing waste segregation correctly

### ELEMENT 7.2 - CORRECT WASTE SEGREGATION

Learning objectives:

- 51) The participants can **recognise** the difference between ordinary waste and chemical waste (Knowledge, basic level)
- 52) The participants can **describe** how to segregate waste correctly (Knowledge, basic level)



The instructor shall:



- 7.2.1 Explain the difference between ordinary waste and chemical waste
- 7.2.2 Explain and demonstrate how to segregate waste correctly
- 7.2.3 Ask the participants relevant questions about how to segregate waste correctly:



The participants shall:

- 7.2.4 Share their understanding of how to segregate waste correctly

### ELEMENT 7.3 - WASTE SEGREGATION INFORMATION

Learning objective:

- 53) The participants can **perform** correct segregation and disposal of chemical and ordinary waste per national regulations or e.g. information in a safety data sheet during the practical exercises (Skills, Intermediate level)



The instructor shall:

- 7.3.1 Demonstrate how to locate information about waste segregation in a work instruction and a safety data sheet
- 7.3.2 Facilitate practice to improve the participants' ability to correctly segregate chemical and ordinary waste during practical exercises
- 7.3.3 Give constructive feedback on the participants' ability to correctly segregate chemical and ordinary waste during practical exercises



The participants shall:

- 7.3.4 Practise the ability to correctly segregate chemical and ordinary waste during practical exercises

## LESSON 8 - ERGONOMICS

15 min.

The aim of the lesson is to enable the participants to mitigate the ergonomic ramifications of work during the Blade Repair Module and later on in a work specific task.

After having successfully completed this lesson of the Blade Repair Module, the participants can:



- 54) **Show interest** in maintaining correct ergonomics when working on a blade, or equivalent structure (Ability, basic level)

#### ELEMENT 8.1 - CLASSROOM

Learning objective:

- 55) The participants can **recognise** the correct ergonomics during training in the classroom (Knowledge, basic level)



The instructor shall:

- 8.1.1 Explain correct ergonomics during training in the classroom

#### ELEMENT 8.2 - WORKSHOP

Learning objective:

- 56) The participants can **recognise** the correct ergonomics during training in the workshop (Knowledge, basic level)



The instructor shall:

- 8.2.1 Explain correct ergonomics during training in the workshop



The participants shall:

- 8.2.2 Share their understanding of correct ergonomics during training in the workshop

#### ELEMENT 8.3 - BLADEWORK

Learning objectives:

- 57) The participants can **act independently** in maintaining correct ergonomics when receiving training in the classroom (Ability, intermediate level)



- 58) The participants can **act independently** in maintaining correct ergonomics when working in the workshop (Ability, intermediate level)
- 59) The participants can **act independently** in maintaining correct ergonomics when working on a blade or equivalent structure (Ability, intermediate level)



#### The instructor shall:

- 8.3.1 Explain correct ergonomics when working on a blade
- 8.3.2 Give constructive feedback on the participants' abilities to maintain correct ergonomics, when receiving training in the classroom, when receiving training in the workshop and when working on a blade, or equivalent structure



#### The participants shall:

- 8.3.3 Practise the ability to:
- maintain correct ergonomics when receiving training in the classroom
  - maintain correct ergonomics when receiving training in the workshop
  - maintain correct ergonomics when working on a blade, or equivalent structure

## LESSON 9 - LOCK OUT TAG OUT (LOTO)

10 min.

The aim of the lesson is to introduce the participants to the meaning and purpose of Lock Out Tag Out as well as to enable them to follow the requirement of always using company specific Lock Out Tag Out procedures prior to starting work.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 60) **Show interest** in the meaning and purpose of LOTO in the wind industry (Ability, basic level)
- 61) **Show interest** in always following company specific lock out tag out procedures before initiating work (Ability, basic level)





## ELEMENT 9.1 - LOCK OUT TAG OUT

### Learning objectives:

- 62) The participants can **describe** the meaning and purpose of Lock Out Tag Out (Knowledge, basic level)
- 63) The participants can **recognise** that additional, company specific, Lock Out Tag Out training may be required regarding LOTO (Knowledge, basic level)
- 64) The participants can **recognise** that there are different laws, standards and company specific rules that apply and need to be followed regarding Lock Out Tag Out (Knowledge, basic level)
- 65) The participants can **describe** importance of always following company specific Lock Out Tag Out procedures before initiating work (Knowledge, basic level)



### The instructor shall:

- 9.1.1 Explain the meaning and purpose of Lock Out Tag Out (LOTO)
- 9.1.2 Briefly emphasise the requirement to use company specific LOTO procedures before initiating work
- 9.1.3 Briefly mention that additional, company specific, LOTO training may be required regarding LOTO
- 9.1.4 Briefly mention that there are different laws, standards and company specific rules that apply and need to be followed regarding LOTO (covered in company specific trainings)
- 9.1.5 Ask the participants relevant questions about meaning and purpose of LOTO
- 9.1.6 Ask the participants relevant questions about the importance of always following company specific LOTO procedures before initiating work



### The participants shall:

- 9.1.7 Share their understanding of:
  - a. the meaning and purpose of LOTO
  - b. the importance of always following company specific LOTO procedures before initiating work

## LESSON 10 - PERSONAL PROTECTIVE EQUIPMENT

100 min.



The aim of the lesson is to introduce the participants to the limitations of PPE and enable them to correctly select and use personal protective equipment (PPE).

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 66) **Act independently** in selecting and using personal protective equipment (PPE) correctly (Ability, intermediate level)

#### ELEMENT 10.1 - PURPOSE

Learning objective:

- 67) The participants can **discuss** the reasons for using PPE (Knowledge, intermediate level)



The instructor shall:

- 10.1.1 Describe the hierarchy of control and where PPE fits into this
- 10.1.2 Facilitate group discussions about the reasons for using PPE
- 10.1.3 Give constructive feedback on the participants' group discussion about the reasons for using PPE



The participants shall:

- 10.1.4 Engage in a group discussion about the reasons for using PPE

#### ELEMENT 10.2 - APPLICATION

Learning objective:

- 68) The participants can **recognise** how to apply PPE correctly (Knowledge, basic level)



The instructor shall:

- 10.2.1 Explain and, where appropriate, demonstrate how to apply PPE correctly including, but not limited to, masks, gloves, filters, suits, cut-resistant gloves, and anti-vibration gloves



## ELEMENT 10.3 - LIMITATIONS

Learning objective:

- 69) The participants can **recognise** the limitations of PPE (Knowledge, basic level)



The instructor shall:

- 10.3.1 Explain the limitations of PPE by considering breakthrough times of gloves

## ELEMENT 10.4 - TASK SPECIFIC

Learning objectives:

- 70) The participants can **explain** the reasons for using PPE (Knowledge, intermediate level)
- 71) The participants can **explain** the limitations of the applied PPE (Knowledge, intermediate level)
- 72) The participants can **apply** the PPE correctly including (but not limited to) masks, gloves, filters, suits, cut-resistant gloves etc. (Skills, intermediate level)
- 73) The participants can **act independently** in selecting the correct types of PPE to be used during training with the applicable chemicals (Ability, intermediate level)



The instructor shall:

- 10.4.1 Demonstrate how to select the correct types of PPE to be used during training with the applicable chemicals
- 10.4.2 Ask the participants relevant questions about the purpose for using PPE
- 10.4.3 Facilitate practice for the participants in applying PPE correctly including (but not limited to) masks, gloves, filters, suits, cut-resistant gloves etc.
- 10.4.4 Ask the participants relevant questions about the limitations of the applied PPE
- 10.4.5 Facilitate practice for the participants to be able to select the correct types of PPE to be used during training with the applicable chemicals
- 10.4.6 Give constructive feedback on the participant actions (described below in 10.4.7-10.4.910) about PPE



The participants shall:

- 10.4.7 Share their understanding of the purpose for using PPE
- 10.4.8 Practise applying PPE correctly including (but not limited to) masks, gloves, filters, suits, cut-resistant gloves
- 10.4.9 Share their understanding of the limitations of the applied PPE
- 10.4.10 Practise the ability to select the correct types of PPE to be used during training with the applicable chemicals

**Note** *These skills and abilities must be assessed during practical training exercises in the workshop.*

## ELEMENT 10.5 - DISPOSAL

Learning objectives:

- 74) The participants can **explain** the purpose of disposing of contaminated PPE correctly and safely (Knowledge, intermediate level)
- 75) The participants can **take responsibility** for disposing of contaminated PPE correctly and safely (Ability, intermediate level)



The instructor shall:

- 10.5.1 Explain the purpose of disposing of contaminated PPE correctly and safely
- 10.5.2 Explain how to dispose of contaminated PPE correctly and safely
- 10.5.3 Ask the participants relevant questions about the purpose of disposing of contaminated PPE correctly and safely
- 10.5.4 Facilitate practice to improve the participants' ability to dispose of contaminated PPE correctly and safely
- 10.5.5 Give constructive feedback on the participants' explanations of the purpose of disposing of contaminated PPE correctly and safely and on the participants' ability to dispose of contaminated PPE correctly and safely



The participants shall:

- 10.5.6 Share their understanding of the purpose of disposing of contaminated PPE correctly and safely
- 10.5.7 Practise the ability to dispose of contaminated PPE correctly and safely



**Note** *These skills and abilities must be assessed during practical training exercises in the workshop.*

## LESSON 11 - MASKS AND FILTERS

45 min.

The aim of the lesson is to enable the participants to select, categorise, use masks and filters safely and correctly.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 76) **Take responsibility** and **act independently** in selecting, categorising, and safely using masks and filters (Ability, intermediate level)

### ELEMENT 11.1 - PURPOSE

Learning objective:

- 77) The participants can **discuss** the purpose of categorising filters and masks (Knowledge, intermediate level)



**The instructor shall:**

- 11.1.1 Explain the purpose of categorising masks and filters
- 11.1.2 Facilitate group discussions about the purpose of categorising masks and filters
- 11.1.3 Give constructive feedback on the participants' group discussion on the purpose of categorising masks and filters



**The participants shall:**

- 11.1.4 Engage in a group discussion about the purpose of categorising masks and filters

### ELEMENT 11.2 - FILTER CATEGORIES

Learning objective:

- 78) The participants can **explain** the correct filter for a given application (Knowledge, intermediate level)

**The instructor shall:**

- 11.2.1 Present the filter categories, and the applications and chemicals intended for each category
- 11.2.2 Ask the participants relevant questions about the filter categories, and the applications and chemicals for intended for each category
- 11.2.3 Give constructive feedback on the participants' explanations about the filter categories, and the applications and chemicals intended for each category

**The participants shall:**

- 11.2.4 Explain and share their understanding of the filter categories, and the applications and chemicals intended for each category

**ELEMENT 11.3 - CATEGORIES AND LIFETIME****Learning objective:**

- 79) The participants can **explain** the lifetime of the filter for a given application (Knowledge, intermediate level)

**The instructor shall:**

- 11.3.1 Demonstrate how to identify the lifetime of the filter for a given application or chemical
- 11.3.2 Explain how to recognise when a filter needs to be replaced
- 11.3.3 Facilitate practice for the participants on how to identify the lifetime of the filter for a given application or chemical
- 11.3.4 Give constructive feedback on the participants' identification of the lifetime of the filter for a given application or chemical

**The participants shall:**

- 11.3.5 Practise how to identify the lifetime of the filter for a given application or chemical



## ELEMENT 11.4 - MASKS

### Learning objectives:

- 80) The participants can **explain** how masks are categorised and their life expectancy for different applications and chemicals (Knowledge, intermediate level)
- 81) The participants can **explain** how long a mask can be used for in each work situation (Knowledge, intermediate level)



### The instructor shall:

#### 11.4.1 Explain:

- a. how masks are categorised and their life expectancy for different applications and chemicals
- b. the maximum working times for different types of masks
- c. the limitations for using masks by considering the effect of facial hair

#### 11.4.2 Ask the participants relevant questions about:

- a. how masks are categorised, and about their life expectancy for different applications and chemicals
- b. the maximum working times for different types of masks

#### 11.4.3 Give constructive feedback on the participants' explanations about how masks are categorised, about their life expectancy for different applications and chemicals, and the maximum working times for different types of masks



### The participants shall:

#### 11.4.4 Share their understanding of:

- a. how masks are categorised and their life expectancy for different applications and chemicals
- b. the maximum working times for different types of masks

## ELEMENT 11.5 - APPLY FILTERS

### Learning objective:



82) The participants can **perform** the installation and replacement of a mask filter (Skills, intermediate level)



The instructor shall:

- 11.5.1 Explain and demonstrate how to correctly install and replace mask filters
- 11.5.2 Facilitate practice for the participants' in how to correctly install and replace mask filters
- 11.5.3 Give constructive feedback on the participants' explanations about and practice of installing and replacing mask filters



The participants shall:

- 11.5.4 Explain in their own words and practise how to correctly install and replace mask filters

## LESSON 12 - CHEMICAL SAFETY

90 min.

The aim of the lesson is to enable the participants to handle chemicals at all stages of blade repair work.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

83) **Take responsibility** for handling chemicals in a correct and safe manner at all stages of blade repair work (Ability, intermediate level)

### ELEMENT 12.1 - PURPOSE

Learning objectives:

- 84) The participants can **explain** the reasons for handling chemicals in a correct and safe way (Knowledge, intermediate level)
- 85) The participants can **explain** the consequences of the incorrect handling of chemicals (Knowledge, intermediate level)





#### The instructor shall:

- 12.1.1 Explain the reasons for handling chemicals in a correct and safe way
- 12.1.2 Explain the consequences of incorrect handling by considering exothermic reactions, faulty mixing and storage of chemicals, spillages etc.
- 12.1.3 Ask the participants relevant questions about the reasons for handling chemicals in a correct and safe way
- 12.1.4 Ask the participants relevant questions about the implications of incorrect handling, including exothermic reactions, faulty mixing and storage of chemicals, spillages etc.
- 12.1.5 Give constructive feedback to the participants' individual explanations about the reasons for handling chemicals in a correct and safe way and the implications of incorrect handling, including exothermic reactions, faulty mixing and storage of chemicals, spillages etc.



#### The participants shall:

- 12.1.6 Share their understanding of:
  - a. the reasons for handling chemicals in a correct and safe way
  - b. share their understanding of the implications of incorrect handling, including exothermic reactions, faulty mixing and storage of chemicals, spillage etc.

## ELEMENT 12.2 - TRANSFER PROCEDURES

### Learning objective:

- 86) The participants can **explain** the safe procedures before, during and after the transfer of chemicals (Knowledge, intermediate level)



#### The instructor shall:

- 12.2.1 Explain the safe procedures before, during and after the transfer of chemicals
- 12.2.2 Ask the participants relevant questions about the safe procedures before, during and after the transfer of chemicals
- 12.2.3 Give constructive feedback on the participants' explanations about the safe procedures before, during and after the transfer of chemicals



The participants shall:

- 12.2.4 Explain the safe procedures before, during and after the transfer of chemicals

### ELEMENT 12.3 - INFORMATION ABOUT CHEMICALS

Learning objective:

- 87) The participants can **explain** how to locate information about the chemicals before, during and after handling and transportation, storage, usage, and disposal/discarding (Knowledge, intermediate level)



The instructor shall:

- 12.3.1 Demonstrate how to locate information about the chemicals before, during and after handling and transportation, storage, usage, and disposal/discarding
- 12.3.2 Facilitate practice for the participants in explaining and locating information about the chemicals before, during and after handling and transportation, storage, usage, and disposal/discarding
- 12.3.3 Give constructive feedback on the participants' explanations and locating of information about the chemicals before, during and after handling and transportation, storage, usage and disposal/discarding



The participants shall:

- 12.3.4 Explain in their own words and practise how to locate information about the chemicals before, during and after handling and transportation, storage, usage and disposal/discarding

### ELEMENT 12.4 - EQUIPMENT CHECK

Learning objective:

- 88) The participants can **perform** an equipment check before transferring chemicals (Skills, intermediate level)



The instructor shall:

- 12.4.1 Demonstrate how to conduct an equipment check before transferring chemicals
- 12.4.2 Facilitate practice for the participants on how to conduct an equipment check before transferring chemicals



12.4.3 Give constructive feedback on the participants' equipment check before transferring chemicals



The participants shall:

12.4.4 Practise how to conduct an equipment check before transferring chemicals

## ELEMENT 12.5 - PREVENTION AND MITIGATION

### Learning objectives:

- 89) The participants can **explain** how to prevent and mitigate the incorrect handling of chemicals (Knowledge, Intermediate level)
- 90) The participants can **explain** the health risks posed by epoxy, polyester, and polyurethane materials (Knowledge, Intermediate level)
- 91) The participants can **discuss** how to mitigate risks related to chemicals including curing (Knowledge, Intermediate level)



The instructor shall:

12.5.1 Explain:

- a. how to correctly handle chemicals, including exothermic reactions, faulty mixing and storage of chemicals, spillages etc.
- b. the health risks posed by epoxy, polyester, and polyurethane materials

12.5.2 Ask the participants relevant questions about:

- a. how to correctly handle chemicals, including exothermic reactions, faulty mixing and storage of chemicals, spillages etc.
- b. the health risks posed by epoxy, polyester, and polyurethane materials

12.5.3 Facilitate group discussions on how to mitigate the health risks posed by epoxy, polyester, and polyurethane materials

12.5.4 Give constructive feedback on:

- a. the participants' explanations about how to prevent and mitigate incorrect handling, including exothermic reactions, faulty mixing and storage of chemicals, spillages etc and the health risks posed by epoxy, polyester, and polyurethane materials



- b. the participants' group discussion about how to mitigate the health risks posed by epoxy, polyester, and polyurethane materials



The participants shall:

12.5.5 Share their understanding of:

- a. how to prevent and mitigate incorrect handling, including exothermic reactions, faulty mixing and storage of chemicals, spillage etc.
- b. the health risks posed by epoxy, polyester, and polyurethane materials

12.5.6 Engage in a group discussion about how to mitigate the health risks posed by epoxy, polyester, and polyurethane materials

## LESSON 13 - COMPOSITES AND BLADE CONSTRUCTION

60 min.

The aim of the lesson is to introduce the participants to basic knowledge about blade construction, components, and aerodynamics.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 92) **Show interest** in understanding how blade construction, components, and aerodynamics influence blade performance and in mitigating blade damage (Ability, basic level)

### ELEMENT 13.1 - AERODYNAMICS

Learning objective:

- 93) The participants can **describe** basic aerodynamic principles and how these causes a wind turbine rotor to turn (Knowledge, basic level)



The instructor shall:

13.1.1 Describe the aerodynamic principles of a wind turbine blade

13.1.2 Explain how blade aerodynamics causes the rotor of a wind turbine to turn



- 13.1.3 Describe typical aerodynamic and safety add-ons used on wind turbine blades
- 13.1.4 Explain how aerodynamic performance and safety add-ons change blade performance
- 13.1.5 Explain how blade surface defects affect blade noise and productivity
- 13.1.6 Ask the participants relevant questions about basic aerodynamic principles and how these causes a wind turbine rotor to turn



The participants shall:

- 13.1.7 Share their understanding of basic aerodynamic principles and how these causes a wind turbine rotor to turn

## ELEMENT 13.2 - BLADE CONSTRUCTION

### Learning objectives:

- 94) The participants can **describe** blade construction parts and enhancements using correct terms (Knowledge, basic level)
- 95) The participants can **explain** how to use radius measurements to determine the position and size of blade damage (Knowledge, intermediate level)
- 96) The participants can **explain** the importance of weight and balance in terms of both blade and turbine performance (Knowledge, intermediate level)



The instructor shall:

- 13.2.1 Define the following blade elements:
  - a. leading edge
  - b. trailing edge
  - c. shell
  - d. root
  - e. tip
  - f. webs (chambers)
  - g. bolts



- h. bulkhead
- i. suction side/leeward side
- j. pressure side/windward side
- k. spar
- l. chord
- m. bond line

13.2.2 Describe how a blade is constructed by considering:

- a. manufacturing techniques
- b. materials used

13.2.3 Explain how to define positions on a blade using radius measurements and use them as vantage points for measuring damage

13.2.4 Explain the importance of weight and balance in terms of both blade and turbine performance

13.2.5 Create a short activity where the participants shall define all the parts of a blade

13.2.6 Ask the participants relevant questions about how to use radius measurements to determine the position and size of blade damage

13.2.7 Ask the participants relevant questions about the importance of weight and balance in terms of both blade and turbine performance

13.2.8 Give constructive feedback on the participants' explanations about how to use radius measurements to determine the position and size of blade damage and the importance of weight and balance in terms of both blade and turbine performance



The participants shall:

13.2.9 Engage in an activity to correctly define all the parts of a blade

13.2.10 Share their understanding of:

- a. how to use radius measurements to determine the position and size of blade damage
- b. the importance of weight and balance in terms of both blade and turbine performance



## ELEMENT 13.3 - SANDWICH PANEL

Learning objectives:

- 97) The participants can **describe** the loading on a sandwich panel (Knowledge, basic level)
- 98) The participants can **describe** typical materials used for core material (Knowledge, basic level)



The instructor shall:

- 13.3.1 Show an example of, and describe, the parts that make up a sandwich panel
- 13.3.2 Describe how a sandwich construction creates a lightweight, stiff panel by considering the tensile and compression loads in the laminate and the shear loads in the core material
- 13.3.3 Explain the function of typical materials used for core material: PVC foam, PET foam and balsa wood
- 13.3.4 Ask the participants relevant questions about:
  - a. the loading on a sandwich panel
  - b. the typical materials used for core material



The participants shall:

- 13.3.5 Share their understanding of:
  - a. the loading on a sandwich panel
  - b. typical materials used for core material

## ELEMENT 13.4 - BLADE ENHANCEMENTS

Learning objective:

- 99) The participants can **describe** typical aerodynamic performance and protection systems used in blades (Knowledge, basic level)



The instructor shall:



#### 13.4.1 Describe:

- a. typical aerodynamic upgrades that can be applied to a blade surface like vortex generators, trailing edge serrations etc.
- b. the function of the lightning protection system
- c. the function of de-icing equipment
- d. the hazards posed by electrical de-icing systems
- e. the function and hazards of stall strips, Gurney flaps, anti-icing systems
- f. typical blade protection systems like leading edge tape

#### 13.4.2 Ask the participants relevant questions about typical aerodynamic performance and protection systems used in blades



The participants shall:

#### 13.4.3 Share their understanding of typical aerodynamic performance and protection systems used in blades

### ELEMENT 13.5 - FAULTS, IMPLICATIONS AND MITIGATIONS

Learning objective:

- 100) The participants can **discuss** typical blade faults, damage, causes, implications, and mitigations (Knowledge, intermediate level)



The instructor shall:

#### 13.5.1 Show examples of, and facilitate group discussions on, typical blade faults, damages, possible causes and the subsequent performance implications:

- a. erosion
- b. lightning
- c. delamination
- d. foreign object collisions
- e. cracks





13.5.2 Facilitate group discussions on the role of the following in reducing blade damage:

- a. proper handling
- b. lightning protection systems
- c. inspection and maintenance
- d. leading edge protection
- e. temporary repairs which can protect the blade against additional damage before final repairs
- f. final repair using proper materials in an approved weather condition according to work instruction (grinding, lamination, leading edge protection etc.)

13.5.3 Give constructive feedback on the participants' group discussions about typical blade faults, damages, causes, implications, and mitigations



The participants shall:

13.5.4 Engage in a group discussion on:

- a. typical blade faults, damages, possible causes and the subsequent performance implications
- b. the role of listed mitigations (a-f) in element 13.5.2 (above) in reducing blade damage

## LESSON 14 - MATERIALS

75 min.

The aim of the lesson is to enable the participants to handle various materials safely and efficiently when working with blade inspection and repair.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 101) **Act independently** when working with various materials during blade inspection and repair (Ability, intermediate level)
- 102) **Explain** the differences in characteristics and application of the material types when working with inspection and repair (Knowledge, intermediate level)



## ELEMENT 14.1 - REINFORCEMENT MATERIALS

Learning objective:

- 103) The participants can **explain** the reinforcement materials used in composite laminates and how those materials resist tensile loads in the blade (Knowledge, intermediate level)



The instructor shall:

- 14.1.1 Explain that reinforcement materials give strength to the composite by resisting tensile loads in a laminate structure
- 14.1.2 Describe the different types of reinforcement materials used in blade production (glass fibre and carbon fibre)
- 14.1.3 Define the terms 'UD', 'Biax' and 'Triax' in relation to reinforcement materials
- 14.1.4 Show examples of, and explain the characteristics of, UD, Biax and Triax glass fibre mats
- 14.1.5 Explain how a laminate is constructed from multiple layers of fibres
- 14.1.6 Show an example of, and explain the characteristics of, 'hardback' materials
- 14.1.7 Define the term 'prepreg'
- 14.1.8 Explain how prepreg materials are used during production
- 14.1.9 Ask the participants relevant questions about the reinforcement materials used in composite laminates, and how those materials resist tensile loads in the blade
- 14.1.10 Give constructive feedback on the participants' explanations about the reinforcement materials used in composite laminates, and how those materials resist tensile loads in the blade



The participants shall:

- 14.1.11 Share understandings about the reinforcement materials used in composite laminates and how those materials resist tensile loads in the blade

## ELEMENT 14.2 - MATRIX MATERIALS

Learning objective:



- 104) The participants can **describe** matrix materials used in composite laminates and how the matrix resists compression loads in a blade (Knowledge, basic level)



**The instructor shall:**

- 14.2.1 Explain that matrix materials give shape, and distribute and transfer loads on reinforcement by resisting compression loads in blades
- 14.2.2 Define the terms 'base resin', 'hardener' and 'accelerator'
- 14.2.3 Describe the component parts of and, at a basic level, the chemical reactions that take place during curing in the following materials: epoxy, polyester vinyl ester and polyurethane

**Note** *The description of chemical reactions should be kept to a basic level such as when base material and hardener are mixed, they react together causing cross links to form which create a thermo-set plastic material, and during the reaction process, heat is produced.*

- 14.2.4 Describe the differences between the curing process of epoxy materials and polyester materials.
- 14.2.5 Show examples of typical matrix materials used during blade repair
- 14.2.6 Ask the participants relevant questions about the matrix materials used in composite laminates and how the matrix resists compression loads in a blade



**The participants shall:**

- 14.2.7 Share their understanding of matrix materials used in composite laminates and how the matrix resists compression loads in a blade

### ELEMENT 14.3 - ADHESIVES

**Learning objectives:**

- 105) The participants can **explain** typical materials used for adhesives and **explain** where they are used in blade construction (Knowledge, intermediate level)
- 106) The participants can **discuss** the difference between adhesives for blade construction and blade enhancement (Knowledge, intermediate level)



#### The instructor shall:

- 14.3.1 Explain the difference between adhesives for blade construction and blade enhancement adhesives
- 14.3.2 Explain where adhesives are used during blade construction
- 14.3.3 Describe typical materials used for adhesives: polyurethane, epoxy, methacrylate
- 14.3.4 Show examples of typical adhesives used during blade repair
- 14.3.5 Ask the participants relevant questions about typical materials used for adhesives and explain where they are used in blade construction
- 14.3.6 Ask the participants relevant questions about the difference between adhesives for blade construction and for blade enhancement
- 14.3.7 Give constructive feedback on the participants' explanations about typical materials used for adhesives and where they are used in blade construction, and the difference between adhesives for blade construction and for blade enhancement



#### The participants shall:

- 14.3.8 Share their understanding of:
  - a. typical materials used for adhesives and where they are used in blade construction
  - b. the difference between adhesives for blade construction and for blade enhancement

### ELEMENT 14.4 - SURFACE COATINGS

#### Learning objective:

- 107) The participants can **recognise** the purpose of the typical materials used in, and examples of, gelcoat and paint on a blade surface (Knowledge, basic level)



#### The instructor shall:

- 14.4.1 Explain why gelcoat and paint are used on a blade surface
- 14.4.2 Describe typical materials used in paint and gelcoat
- 14.4.3 Show examples of typical paints and gelcoats used during blade repair



The participants shall:

- 14.4.4 Share their understanding of the purpose of the typical materials used in and examples of gelcoat and paint on a blade surface

#### ELEMENT 14.5 - CHEMICAL HANDLING AND APPLICATION

Learning objectives:

- 108) The participants can **explain** the procedures for handling and applying chemicals (Knowledge, intermediate level)
- 109) The participants can **recognise** how to properly apply chemicals (Knowledge, basic level)



The instructor shall:

- 14.5.1 Explain how to properly store chemicals by considering the following:
- separation list (which materials can't be stored together)
  - temperature condition
  - proper labels
  - transportation rules
  - how to prevent spills
  - how to neutralise spills
- 14.5.2 Explain how to properly apply chemicals by considering the following:
- which chemicals can/must be mixed before use
  - correct mixing ratio (percentage or weighing)
  - how to properly apply chemicals
  - what to do with excess materials
  - how to dispose of chemical waste by conducting correct waste segregation
- 14.5.3 Ask the participants relevant questions about how to properly store and apply chemicals
- 14.5.4 Give constructive feedback on the participants' explanations of how to properly store and apply chemicals



The participants shall:

- 14.5.5 Share their understanding of how to properly store and apply chemicals and, in practical exercises, practise how to properly apply chemicals to a repair

#### ELEMENT 14.6 - CURING

Learning objectives:

- 110) The participants can **explain** the characteristics of curing material types and their application (Knowledge, intermediate level)
- 111) The participants can **recognise** that different companies can have their own work instruction to determine curing methods and that participants should always follow applicable work instructions (Knowledge, basic level)
- 112) The participants can **act independently** to use a technical data sheet to find the correct curing method and duration for a given material (Ability, intermediate level)



The instructor shall:

- 14.6.1 Explain different methods for curing blade repair materials by considering the following:
- a. ambient curing
  - b. curing using heat
  - c. curing using UV source
- 14.6.2 Explain how to find and use the technical datasheet to determine the curing method and duration for a given chemical
- 14.6.3 Emphasise that different companies can have their own work instruction to determine curing methods, and that participants should always follow applicable work instructions
- 14.6.4 Ask the participants relevant questions about the difference between the curing methods listed in 14.6.1
- 14.6.5 Facilitate practice to improve the participants' ability to use a technical data sheet to find the correct curing method and duration for a given material
- 14.6.6 Give constructive feedback on:
- a. the participants' explanations of the differences between the curing methods listed in 14.6.1



- b. the participants' ability to use a technical data sheet to find the correct curing method and duration for a given material



The participants shall:

- 14.6.7 Explain the differences between the curing methods listed in 14.6.1
- 14.6.8 Practise the ability to use a technical data sheet to find the correct curing method and duration for a given material

## LESSON 15 - TOOLS AND EQUIPMENT

40 min.

The aim of the lesson is to enable the participants to handle tools and equipment correctly in accordance with the task at hand during blade inspection and repair.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 113) **Show an interest** in handling tools and equipment required for blade inspection and repair safely and correctly (Ability, basic level)

### ELEMENT 15.1 - MECHANICAL, ELECTRICAL AND PNEUMATIC PRINCIPLES

Learning objectives:

- 114) The participants can **recognise** basic mechanical, electrical, hydraulic principles, and associated risks (Knowledge, basic level)
- 115) The participants can **explain** how to utilise the tools required for blade inspection and repair in a correct and safe manner (Knowledge, intermediate level)



The instructor shall:

- 15.1.1 Describe which tools are required for blade inspection and repair processes
- 15.1.2 Describe the principle of the operation of electrical and pneumatic grinders, sanders, and drills
- 15.1.3 Explain:
  - a. the risks associated with electrical and pneumatic grinders, sanders, and drills



- b. how to safely and correctly use electrical and pneumatic grinders, sanders and drills by considering guarding, personal protective equipment and ergonomic practices
- c. how to safely and correctly use a pneumatic glue gun
- d. how to safely and correctly use a manual glue gun

15.1.4 Describe the principle behind vacuum pump operation

15.1.5 Explain how to use a vacuum pump and how to protect the pump from excess resin using a resin trap

15.1.6 Explain the risks and hazards associated with working with a low resistance ohmmeter or equivalent

15.1.7 Explain how to safely and correctly use a low resistance ohmmeter or equivalent

15.1.8 Ask the participants relevant questions about how to correctly and safely use the tools required for blade inspection and repair

15.1.9 Give constructive feedback on the participants' explanations about how to correctly and safely use the tools required for blade inspection and repair



The participants shall:

15.1.10 Share their understanding of how to correctly and safely use the tools required for blade inspection and repair

## ELEMENT 15.2 - UTILISATION OF TOOLS AND MATERIALS

### Learning objectives:

- 116) The participants can **recognise** examples of, and the correct use of, the tools required for a repair activity or application (Knowledge, basic level)
- 117) The participants can **explain** how to select and correctly use tools appropriate to the repair activity or application (Knowledge, intermediate level)



The instructor shall:

15.2.1 Show examples of, and explain the correct use of, the tools required for the following activities and applications:

15.2.2 Core steps:

- a. blade inspection





- b. removal of paint, gelcoat, and fibre layers
- c. sanding
- d. grinding
- e. finishing
- f. taking samples
- g. aerodynamic upgrades, such as vortex generator, trailing edge serration etc.
- h. lightning protection equipment
- i. de-icing equipment
- j. blade protection systems i.e. leading-edge tape

15.2.3 Ask the participants relevant questions about how to select and correctly use tools appropriate to the repair activity or application

15.2.4 Give constructive feedback on the participants' explanations about how to select and correctly use tools appropriate to the repair activity or application



The participants shall:

15.2.5 Share their understanding of how to select and correctly use tools appropriate to the repair activity or application

### ELEMENT 15.3 - CALIBRATION

Learning objectives:

118) The participants can **recognise** the importance of calibration (Knowledge, basic level)

119) The participants can **explain** how to verify the validity of the calibration on tools used during practical exercises (Knowledge, intermediate level)



The instructor shall:

15.3.1 Explain how to verify the validity of the tool calibration status on: Shore D and Barco hardness testers, thermocouple thermometers and temperature / humidity data loggers



- 15.3.2 Ask the participants relevant questions about how to verify the validity of the calibration on tools used during practical exercises
- 15.3.3 Give constructive feedback on the participants' explanations about how to verify the validity of the calibration of tools used during practical exercises



The participants shall:

- 15.3.4 Explain in their own words how to verify the validity of the calibration of tools used during practical exercises

#### ELEMENT 15.4 - LAMINATION TOOLS

Learning objective:

- 120) The participants can **recognise** lamination tools and their application (Knowledge, basic level)



The instructor shall:

- 15.4.1 Explain the different types of hand tools, their characteristics and functions used during lamination

#### ELEMENT 15.5 - HEATING BLANKETS

Learning objectives:

- 121) The participants can **recognise** risks and hazards associated with working with heating blankets (Knowledge, basic level)
- 122) The participants can **recognise** when a heating blanket needs to be used (Knowledge, basic level)
- 123) The participants can **recognise** how to store a hot heating blanket (Knowledge, basic level)
- 124) The participants can **apply** heating blankets safely and correctly (Skills, intermediate level)



The instructor shall:

- 15.5.1 Explain:
- a. the risks and hazards associated with working with heating blankets
  - b. how to find the correct temperature and time used for the applicable repair



- c. when a heating blanket needs to be used

- 15.5.2 Explain and demonstrate how to use a heating blanket
- 15.5.3 Explain why temperature is important
- 15.5.4 Demonstrate how to control the temperature under the blanket
- 15.5.5 Explain how to store a hot heating blanket
- 15.5.6 Give constructive feedback on the participants' use of a heating blanket



The participants shall:

- 15.5.7 Practise how to use a heating blanket safely and correctly

## ELEMENT 15.6 - CHECKING ELECTRICAL TOOLS AND EQUIPMENT

Learning objectives:

- 125) The participants can **describe** the reasons for performing a pre-use check on electrical tools and equipment (Knowledge, basic level)
- 126) The participants can **perform** pre-use checks on electrical and pneumatic tools and equipment (Skills, intermediate level)



The instructor shall:

- 15.6.1 Lead a discussion about the reasons for performing a pre-use check on electrical tools and equipment
- 15.6.2 Explain how to perform a pre-use check for:
  - a. electrical tools, specifically:
    - a.i tool integrity
    - a.ii check the plug and socket (must be the same standard)
    - a.iii check electrical cable
    - a.iv check allowed voltage (110 or 230V) if cabled tool
    - a.v check battery package integrity (if applicable)
    - a.vi check emergency switch/residual current device



- b. pneumatic equipment, specifically:
  - b.i tool integrity
  - b.ii check hose and connector (air spill)
  - b.iii check maximum pressure allowed

15.6.3 Facilitate practice for the participants in performing pre-use checks on electrical and pneumatic tools and equipment

15.6.4 Give constructive feedback on the participants' pre-use checks on electrical and pneumatic tools and equipment



The participants shall:

15.6.5 Engage in a discussion about the reasons for performing a pre-use check on electrical tools and equipment

15.6.6 Practise performing pre-use checks on electrical and pneumatic tools and equipment

#### ELEMENT 15.7 - VIBRATING TOOLS

##### Learning objectives:

- 127) The participants can **explain** the risks and hazards of working with vibrating tools (Knowledge, intermediate level)
- 128) The participants can **explain** the implications of working with vibrating tools (Knowledge, intermediate level)
- 129) The participants can **explain** how to reduce the risks associated with working with vibrating tools (Knowledge, intermediate level)



The instructor shall:

15.7.1 Explain the risks, hazards, and implications of working with vibrating tools

15.7.2 Explain how to reduce the risks associated with working with vibrating tools using personal protective equipment and work breaks

15.7.3 Ask the participants relevant questions about the risks, hazards, and implications of working with vibrating tools. In addition, questions on how to reduce the risks associated with working with vibrating tools



- 15.7.4 Give constructive feedback on the participants' explanations about the hazards, risks, and implications of working with vibrating tools, and how to reduce the risks associated with working with vibrating tools



The participants shall:

- 15.7.5 Share their understanding of:
- the risks and hazards of working with vibrating tools
  - the implications of working with vibrating tools
  - how to reduce the risks associated with working with vibrating tools

## ELEMENT 15.8 - ELECTRICAL SAFETY DEVICES

### Learning objectives:

- 130) The participants can **recognise** electrical safety devices like residual current devices (Knowledge, basic level)
- 131) The participants can **recognise** where to place a residual current device with regards to extension leads (Knowledge, basic level)
- 132) The participants can **explain** the importance of using a residual current device (Knowledge, intermediate level)
- 133) The participants can **perform** a pre-use check of a residual current device (Knowledge, intermediate level)



The instructor shall:

- 15.8.1 Describe typical electrical safety devices like residual current devices
- 15.8.2 Explain the importance of using a residual current device when using electrical tools
- 15.8.3 Explain where to place a residual current device with regards to extension leads
- 15.8.4 Explain and demonstrate how to perform a pre-use check of a residual current device
- 15.8.5 Ask the participants relevant questions about the importance of using a residual current device
- 15.8.6 Facilitate practice for the participants to perform a pre-use check of a residual current device
- 15.8.7 Give constructive feedback on the participants' explanations about the importance of using a residual current device and performing a pre-use check of a residual current device



### The participants shall:

- 15.8.8 Share their understanding of the importance of using a residual current device
- 15.8.9 Practise how to perform a pre-use check of a residual current device

**Note** *Where a residual current device is used in this element it has the same meaning as 'ground fault circuit interrupter'.*

## ELEMENT 15.9 - DOCUMENTATION TYPES

### Learning objectives:

- 134) The participants can **recognise** for the importance of risk assessments, work instructions and safety data sheets for blade repair work (Knowledge, basic level)
- 135) The participants can **recognise** the importance of using a photocard when taking photographs of damage and repair steps (Knowledge, basic level)
- 136) The participants can **explain** documentation types, content, and their application (Knowledge, intermediate level)



### The instructor shall:

- 15.9.1 Recap on the importance of risk assessments for blade repair work
- 15.9.2 Recap on the importance of work instructions for blade repair work
- 15.9.3 Explain the principles of a technical drawing of a blade to determine the number of layers, the fibre orientation and the materials used at a given radius
- 15.9.4 Explain the importance of using a photo card when taking photographs of damage and repair steps
- 15.9.5 Explain the information that is required in inspection and repair reports
- 15.9.6 Describe the information contained in material lists / bills of materials
- 15.9.7 Recap on the importance of safety data sheets
- 15.9.8 Explain the information contained in a technical data sheet
- 15.9.9 Ask the participants relevant questions about the different types of documentation that are required during blade inspection and repair activities



- 15.9.10 Give constructive feedback on the participants' explanations about the different types of documentation that are required during blade inspection and repair activities



The participants shall:

- 15.9.11 Explain in their own words the different types of documentation that are required during blade inspection and repair activities

## LESSON 16 - PHASE TEST

30 min.

The aim of this lesson is to test the participants' understanding of the theoretical parts of the GWO Basic Blade Repair Module until this point and to assist the instructor in planning focus areas for the remainder of the course.

To successfully complete this lesson, the participants must:

- a. Successfully **complete** the phase test

### ELEMENT 16.2 - PHASE TEST



The instructor shall:

- 16.2.1 Introduce the phase test and explain the criteria for the test with reference to the participants performance assessment
- 16.2.2 Conduct the test in accordance with the participants performance assessment criteria
- 16.2.3 Upon completion of the test, check the participants answers and give feedback on the participants' test results
- 16.2.4 In the case that a participant does not pass the test, conduct an interview with the participant in accordance with the participant performance assessment for craftsmanship

## LESSON 17 - LAMINATION SKILLS

150 min.

The aim of the lesson is to give the participants the ability to explain and perform laminate repairs.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 137) **Take responsibility** for performing laminate repairs in a safe and efficient manner (Ability, intermediate level)



## ELEMENT 17.1 - FIBRE ORIENTATION

### Learning objectives:

- 138) The participants can **recognise** how a composite laminate structure is built up of multiple layers of reinforcement material (Knowledge, basic level)
- 139) The participants can **recognise** how each layer of reinforcement material resists tensile loads in a specific direction (Knowledge, basic level)
- 140) The participants can **discuss** the importance of fibre orientation in a laminate structure (Knowledge, intermediate level)



### The instructor shall:

- 17.1.1 Explain how a composite laminate structure is built up of multiple layers of reinforcement material
- 17.1.2 Explain how each layer of reinforcement material resists tensile loads in a specific direction
- 17.1.3 Facilitate group discussions about the importance of aligning repair fibres with the existing fibres in each layer that is being repaired
- 17.1.4 Give constructive feedback on the participants' understanding of the importance of aligning the repair fibres in the direction of the fibres in each layer of the existing fibres in the context of tensile load transfer through the repair



### The participants shall:

- 17.1.5 Engage in a group discussion and share their understanding of the importance of aligning the repair fibres in the direction of the fibres in each layer of the existing fibres in the context of tensile load transfer through the repair

## ELEMENT 17.2 - KINKED OR BENT FIBRES

### Learning objective:

- 141) The participants can **explain** the consequences of kinked or bent fibres in a laminate structure (Knowledge, intermediate level)





#### The instructor shall:

- 17.2.1 Show an example and explain how easily glass fibres will break if they are kinked
- 17.2.2 Explain how bent fibres in a laminate will lead to uneven load transfer in the laminate and how this can lead to premature failure of the laminate
- 17.2.3 Explain how to carefully handle and lay-up dry fibreglass mats to keep the fibres as straight as possible
- 17.2.4 Ask the participants relevant questions about the consequences of, and how to reduce the possibility of, kinked and bent fibres in a laminate repair
- 17.2.5 Give constructive feedback on the participants' explanations about the consequences of, and how to reduce the possibility of, kinked and bent fibres in a laminate repair



#### The participants shall:

- 17.2.6 Share their understanding of the consequences of, and how to reduce the possibility of, kinked and bent fibres in a laminate repair

### ELEMENT 17.3 - OVERLAPS

#### Learning objectives:

- 142) The participants can **recognise** the terms 'overlap' and 'scarfing' and the difference between scarfing and overlap (Knowledge, basic level)
- 143) The participants can **recognise** that different approaches will be used in different companies' dependent on company specific procedures (Knowledge, basic level)
- 144) The participants can **explain** the importance of overlaps between the repair material and existing material (Knowledge, intermediate level)



#### The instructor shall:

- 17.3.1 Define the terms 'overlap' and 'scarfing' in the context of blade repair fibre materials
- 17.3.2 Explain the difference between scarfing and overlap
- 17.3.3 Emphasise that different approaches will be used in different companies, dependent on company specific procedures



- 17.3.4 Explain how the strength of the repair depends on each layer of repair fibres overlapping the corresponding layer of existing fibres to ensure the correct load transfer through the repair
- 17.3.5 Explain that each layer of damaged fibres must be repaired
- 17.3.6 Ask the participants relevant questions about the importance of maintaining the correct overlaps between each repair layer and the corresponding existing layer in the damaged composite laminate
- 17.3.7 Give constructive feedback on the participants' explanations about the importance of maintaining the correct overlaps between each repair layer and the corresponding existing layer in the damaged composite laminate



The participants shall:

- 17.3.8 Share their understanding of the importance of maintaining the correct overlaps between each repair layer and the corresponding existing layer in the damaged composite laminate

#### ELEMENT 17.4 - DRY FIBRES AND AIR VOIDS

Learning objective:

- 145) The participants can **explain** the effect of dry fibres and air voids on the strength of a laminate structure (Knowledge, intermediate level)



The instructor shall:

- 17.4.1 Define the word 'matrix' in the context of blade repair materials
- 17.4.2 Define the term 'fibre content', and explain how this affects the properties of the cured laminate
- 17.4.3 Explain how the matrix material resists compression loads in the laminate structure and how air voids will create localised weak spots, and how dry fibres will be able to bend and kink leading to failure of the laminate structure
- 17.4.4 Ask the participants relevant questions about the function of the matrix material, how air voids and dry fibres can lead to failure of the laminate structure, and how the fibre content can affect the properties of the laminate
- 17.4.5 Give constructive feedback on the participants' explanations about the function of the matrix material and how air voids and dry fibres can lead to failure of the laminate structure, and how the fibre content can affect the properties of the laminate



The participants shall:



#### 17.4.6 Share their understanding of:

- a. the function of the matrix material, and how air voids and dry fibres can lead to failure of the laminate structure
- b. how the fibre content can affect the properties of the laminate

### ELEMENT 17.5 - MIXING RATIO

#### Learning objectives:

- 146) The participants can **explain** the term 'mixing ratio' (Knowledge, intermediate level)
- 147) The participants can **explain** how the incorrect mixing ratio of a multi-component material will affect the properties of the cured material (Knowledge, intermediate level)
- 148) The participants can **explain** where to find the mixing ratio for a given material (Knowledge, intermediate level)
- 149) The participants can **describe** the chemical reaction between the base resin and hardener in epoxy, polyester, and polyurethane materials (Knowledge, basic level)



#### The instructor shall:

- 17.5.1 Recap on the terms 'mixing ratio', 'two components' and 'three components' materials, 'base resin', 'hardener' and 'accelerator'
- 17.5.2 Describe the chemical reaction between the base resin and hardener in epoxy, polyester, vinyl ester and polyurethane materials
- 17.5.3 Explain:
  - a. where to find the mixing ratio for blade repair chemicals from the manufacturer technical data sheet (TDS)
  - b. how the TDS must be cross referenced with a blade manufacturer specific work instruction relating to mixing and curing materials
  - c. how care must be taken to ensure that the correct mixing ratio is used, as these are given in the TDS by weight and volume
  - d. how incorrect mixing ratios will affect the cured product, with a focus on the implications to health and safety of sanding in unreacted materials
  - e. why it is important to calculate the mixing ratio for each batch of chemicals that is being mixed



17.5.4 Ask the participants relevant questions about:

- a. the term 'mixing ratio'
- b. how the incorrect mixing ratio of a multi-component material will affect the properties of the cured material
- c. where to find the mixing ratio for a given material
- d. the chemical reaction between the base resin and hardener in epoxy, polyester, and polyurethane materials

17.5.5 Give constructive feedback on the participants' explanations about the term 'mixing ratio', how the incorrect mixing ratio of a multi-component material will affect the properties of the cured material and where to find the mixing ratio for a given material



The participants shall:

17.5.6 Share their understanding of:

- a. the term 'mixing ratio'
- b. how the incorrect mixing ratio of a multi-component material will affect the properties of the cured material
- c. where to find the mixing ratio for a given material
- d. the chemical reaction between the base resin and hardener in epoxy, polyester, and polyurethane materials

## ELEMENT 17.6 - CALCULATION OF MATRIX MATERIAL

Learning objective:

- 150) The participants can **perform** calculations of the amount of matrix material and the ratio of resin to hardener required for a given weight of reinforcement material (Skills, intermediate level)



The instructor shall:

17.6.1 Define the variables required for calculating the amount of matrix material required for a given weight of reinforcement material

17.6.2 Explain and demonstrate how to calculate the amount of matrix material required for a repair



- 17.6.3 Define the variables required for calculating the correct amounts of each component of a multi-component material given the mixing ratio
- 17.6.4 Explain and demonstrate how to calculate the amount of each component material given a mixing ratio
- 17.6.5 Facilitate practice to improve the participants' abilities to correctly calculate the total amount of matrix required for a given weight of reinforcement material and the amount of each component in a multi-component material given the mixing ratio for that material
- 17.6.6 Give constructive feedback on the participants' abilities to correctly calculate the total amount of matrix required for a given weight of reinforcement material and the amount of each component in a multicomponent material given the mixing ratio for that material



The participants shall:

- 17.6.7 Practise the ability to correctly calculate:
  - a. the total amount of matrix required for a given weight of reinforcement material
  - b. the amount of each component in a multi-component material given the mixing ratio for that material

## ELEMENT 17.7 - CURING AT ELEVATED TEMPERATURES

Learning objective:

- 151) The participants can **explain** how curing at elevated temperature affects the glass transition temperature (TG) and strength of a composite material (Knowledge, intermediate level)



The instructor shall:

- 17.7.1 Define the term 'glass transition temperature'
- 17.7.2 Explain:
  - a. how curing at an elevated temperature will affect the glass transition temperature of the cured material
  - b. how to find the correct curing temperature for a material from the manufacturer technical data sheet (TDS)
  - c. that the TDS curing temperature must be cross-checked with the blade manufacturer mixing and curing work instructions



- 17.7.3 Ask the participants relevant questions about how curing at elevated temperature will affect the glass transition temperature (TG) and how the TG will affect the strength of the cured material and explain where to find the correct curing temperatures for a given material
- 17.7.4 Give constructive feedback on the participants' explanations about how curing at elevated temperature will affect the glass transition temperature (TG). In addition, how the TG will affect the strength of the cured material, and explain where to find the correct curing temperatures for a given material



The participants shall:

- 17.7.5 Share their understanding of:
- how curing at elevated temperature will affect the glass transition temperature (TG)
  - how the TG will affect the strength of the cured material, and explain where to find the correct curing temperatures for a given material

#### ELEMENT 17.8 - ASCERTAINING CORRECT CURING

##### Learning objectives:

- 152) The participants can **apply** a Barcol and / or a Shore D hardness tester (Skills, Intermediate level)
- 153) The participants can **recognise** that curing control methods can vary between resin systems (Knowledge, basic level)
- 154) The participants can **act independently** in applying a Barcol/ Shore D hardness tester to ascertain that the matrix material has correctly cured in accordance with the material technical data sheet or the blade manufacturer's work instruction (Ability, intermediate level)



The instructor shall:

- 17.8.1 Demonstrate how to find the correct cured hardness values for a laminate from the material technical data sheet and from the blade manufacturer work instruction
- 17.8.2 Demonstrate how to use a Barcol and/or a Shore D hardness tester to test the hardness of a cured laminate
- 17.8.3 Highlight that curing control methods can vary between resin systems
- 17.8.4 Explain how to collect a sample of laminate for testing in a laboratory
- 17.8.5 Facilitate practice to improve the participants' ability to use a Barcol and/or a Shore D hardness tester to ascertain whether a laminate has cured correctly in accordance with the material technical data sheet or the blade manufacturer's work instruction



- 17.8.6 Give constructive feedback on the participants' ability to use a Barcol and/or a Shore D hardness tester to ascertain whether a laminate has cured correctly in accordance with the material technical data sheet or the blade manufacturer's work instruction



The participants shall:

- 17.8.7 Practise the ability to use a Barcol and/or a Shore D hardness tester to ascertain whether a laminate has cured correctly in accordance with the material technical data sheet or the blade manufacturer's work instruction

#### ELEMENT 17.9 - AMBIENT TEMPERATURE AND HUMIDITY

Learning objective:

- 155) The participants can **explain** how ambient temperature and humidity affect the lamination process (Knowledge, intermediate level)



The instructor shall:

- 17.9.1 Define the terms 'pot life' and 'gel time' and explain how the pot life and gel time are affected by the ambient temperature
- 17.9.2 Explain how the ambient humidity can affect lamination resins
- 17.9.3 Ask the participants relevant questions about how the ambient temperature and humidity will affect the lamination process and the materials used for lamination
- 17.9.4 Give constructive feedback on the participants' explanations about how the ambient temperature and humidity will affect the lamination process and the materials used for lamination



The participants shall:

- 17.9.5 Explain in their own words and share their understanding of how the ambient temperature and humidity will affect the lamination process and the materials used for lamination

#### ELEMENT 17.10 - RECORDING AMBIENT TEMPERATURE AND HUMIDITY

Learning objective:

- 156) The participants can **recognise** the importance of recording the ambient temperature and humidity (Knowledge, basic level)



- 157) The participants can **perform** the recording of ambient temperature and humidity during the process using a data logger (Skills, intermediate level)
- 158) The participants can **act independently** in recording ambient temperature and humidity during the process using a data logger (Ability, intermediate level)



#### The instructor shall:

- 17.10.1 Explain the importance of recording the ambient temperature and humidity by considering the need to demonstrate to the customer that the levels of humidity and temperature were not exceeded during the repair
- 17.10.2 Demonstrate how to use a data logger to record and document the ambient temperature and humidity throughout all the repair processes
- 17.10.3 Explain how the ambient humidity can affect lamination resins
- 17.10.4 Facilitate practice to improve the participants' ability to use a data logger to record and document the ambient temperature and humidity throughout all the repair processes
- 17.10.5 Give constructive feedback on the participants' ability to use a data logger to record and document the ambient temperature and humidity throughout all the repair processes



#### The participants shall:

- 17.10.6 Practise the ability to use a data logger to record and document the ambient temperature and humidity throughout all the repair processes

**Note** *Where the participants must practise the ability to perform a skill, these skills will be continually assessed during the subsequent practical exercises.*

## LESSON 18 - BASIC LAMINATION

290 min.

The aim of the lesson is to enable the participants to produce two, 2–3-layer flat laminate panels safely and in accordance with a work instruction.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 159) **Take responsibility** for producing two, 2–3-layer flat laminate panels safely and in accordance with a work instruction (Ability, intermediate level)





## ELEMENT 18.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

### Learning objective:

- 160) The participants can **act independently** in applying the knowledge gained during the general safety topic to the working environment to minimise the risks associated with composite repair work (Ability, intermediate level)



### The instructor shall:

- 18.1.1 Explain the safety precautions and personal protective equipment requirements for working in the workshop area (Recap from general safety)
- 18.1.2 Continually assess and give feedback on the participants' ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work



### The participants shall:

- 18.1.3 Practise the ability to apply the knowledge gained during the general safety and chemical safety lessons to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

## ELEMENT 18.2 - FIBREGLASS MATS

### Learning objective:

- 161) The participants can **describe** the different types of fibreglass mats used in blades (Knowledge, basic level)



### The instructor shall:

- 18.2.1 Define the terms 'chopped strand' (CS), 'unidirectional' (UD), 'biaxial' (biax), 'triaxial' (triax), 'areal weight' and 'zero direction' in relation to fibreglass mats used in composite laminate structures
- 18.2.2 Describe the terms 'woven mat' and 'stitched mat'
- 18.2.3 Explain why stitched mats are used in wind turbine blades
- 18.2.4 Ask the participants relevant questions about the different terms used for describing fibreglass mats used in blade repair



### The participants shall:

- 18.2.5 Describe in their own words and share their understanding of the different terms used for describing fibreglass mats used in blade repair

## ELEMENT 18.3 - FIBRE ORIENTATION AND MOULDING THEORY

### Learning objectives:

- 162) The participants can **explain** the importance of fibre orientation in a laminate structure (Knowledge, intermediate level)
- 163) The participants can **act independently** in safely producing two, 2-3-layer flat laminate panels covered on one side with gelcoat in accordance with a work instruction and drawing, creating one with epoxy and one with polyester resin systems and in accordance with a work instruction (Ability, intermediate level)



### The instructor shall:

- 18.3.1 Explain the exercise and show the participants where the required materials and tools are stored
- 18.3.2 Using a flat aluminium mould, demonstrate how to prepare the mould surface with release agent and explain the purpose of the release agent and the drying time required before adding materials
- 18.3.3 Demonstrate:
- a. how to mark out the 400mm by 300mm rectangle on the surface using flash tape
  - b. how to calculate the required amount of gelcoat for the marked-out mould area at a layer thickness of 0.8mm
  - c. how to correctly calculate, measure out and mix the separate components of the gelcoat and mention that there might be incompatible combinations of gelcoat and matrix systems.
  - d. how to apply the gelcoat to the mould surface and how to distribute the gelcoat evenly on the mould
  - e. how to use a wet film gauge to determine the layer thickness
- 18.3.4 Explain the requirement to allow the gelcoat to tack off, and demonstrate how to determine that the gelcoat is ready for the next layer of materials
- 18.3.5 Demonstrate:
- a. how to measure and cut two pieces of biax fibreglass reinforcement material and how to mark the zero direction of the roll on the cut pieces



- b. how to correctly calculate the required amount of matrix material required for the given amounts of reinforcement material
- c. how to correctly calculate, measure out and mix the separate components of the matrix material
- d. how to apply the first layer of fibreglass and matrix material focusing on the fibre straightness, wetting out the fibres and removing air from the matrix using a bolt roller. Repeat with the second layer of fibreglass
- e. how to apply peel ply to the laminate and place the thermocouple, and how to cover the laminate with vacuum film to protect the heating blanket from resin
- f. how to place the heating blanket without folds, and how to adjust the temperature of the heating blanket in accordance with the temperature reading from the thermocouple to the required curing temperature in accordance with an approved work instruction or the matrix technical data sheet
- g. how to determine the required curing time

18.3.6 Explain that the curing time starts when the matrix material has reached the required curing temperature

18.3.7 After the curing time, demonstrate how to safely remove the heating blanket and, place it to cool down

18.3.8 Demonstrate how to safely remove the vacuum film and peel ply, and measure the hardness of the cured laminate with a Barcol/Shore D tester

18.3.9 Give constructive feedback on the participants' above practice and explanations



The participants shall:

18.3.10 Practise the ability to:

- a. prepare a flat aluminium mould surface with release agent, allow sufficient time for the release agent to dry, and mark out the required area with flash tape
- b. accurately measure out and mix the required quantities of each component of gelcoat. Apply the gelcoat evenly and at the correct layer thickness in accordance with a work instruction
- c. accurately measure and cut the required pieces of glass fibre. Mark the zero direction of the roll on the cut pieces
- d. accurately measure out and correctly mix the required quantities of each component of the matrix material in accordance with an approved work instruction
- e. consolidate and remove air using a bolt roller and to keep the fibres as straight as possible
- f. apply the peel ply, thermocouple, and vacuum foil in the correct order
- g. safely handle and apply a heating blanket to the laminate



- h. adjust the temperature of the heating blanket with reference to thermocouple temperature in accordance with an approved work instruction

18.3.11 After the curing time, practise how to safely remove the heating blanket, vacuum foil, thermocouple, and peel ply

18.3.12 Practise the ability to measure the hardness of the cured laminate with a Barcol/Shore D tester

18.3.13 Share their understanding of the importance of aligning the repair fibres in the direction of the fibres in each layer of the existing fibres in the context of tensile load transfer through the repair

## LESSON 19 - SANDWICH PANEL

420 min.

The aim of this lesson is to give the participants the ability to produce a trailing edge section from two sandwich panels, which they will then use to carry out the following repairs as described in later lessons:

1. sandwich repairs with damage extending through both the inner and outer laminates
2. laminate repairs, which do not affect the core material
3. surface repairs to gelcoat and paint layers
4. open trailing edge repairs to both laminates
5. bond line repairs by adhesive injection.

The dimensions of the trailing edge section must be sufficient to allow the participants to carry out the repairs, mentioned above, while challenging them to carry out the repairs with minimal areal limits in order to achieve a sufficient skill level. It is recommended that the trailing edge section measures 500mm along the trailing edge and 600mm parallel to the trailing edge.

The final thickness of the trailing edge, including laminates and bond line, must be no more than 2mm.

The sandwich panels should include an outer laminate consisting of one layer each of triax and biax and an inner laminate consisting of one layer of biax with 10mm core material (e.g. pvc foam or balsa) tapered towards the trailing edge to produce a bond line no wider than 50mm.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 164) **Act independently** in producing a trailing edge section from two sandwich panels (Ability, intermediate level)



## ELEMENT 19.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

### Learning objective:

- 165) The participants can **act independently** in applying the knowledge gained during the general safety lessons to the working environment to minimise the risks associated with composite repair work (Ability, intermediate level)



### The instructor shall:

- 19.1.1 Continually assess and give feedback on the participants' ability to apply the knowledge gained during the general safety lessons to the working environment to mitigate the risks associated with composite repair work



### The participants shall:

- 19.1.2 Practise the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

## ELEMENT 19.2 - SANDWICH CONSTRUCTION

### Learning objectives:

- 166) The participants can **describe** common materials used for core material (Knowledge, basic level)
- 167) The participants can **explain** the reasons for using a sandwich construction (Knowledge, intermediate level)
- 168) The participants can **explain** the function of the inner and outer laminates and the core material in a sandwich construction (Knowledge, intermediate level)



### The instructor shall:

- 19.2.1 Explain the function of the inner and outer laminates and the core material in a sandwich construction
- 19.2.2 Describe common materials used for core material in wind turbine blades
- 19.2.3 Explain how a sandwich construction produces a lightweight and stiff structure



- 19.2.4 Explain why this is important in terms of wind turbine blades by considering the loads on a blade, the structural requirements of the blade, and the implications for transport and lifting operations
- 19.2.5 Ask the participants relevant questions about common materials used for core material, and the function of the inner and outer laminates and the core material in a sandwich construction, and the reasons for using a sandwich construction in wind turbine blades
- 19.2.6 Give constructive feedback on the participants' explanations about the function of the inner and outer laminates and the core material in a sandwich construction, and the reasons for using a sandwich construction in wind turbine blades



The participants shall:

- 19.2.7 Describe in their own words and share their understanding of common materials used for core material
- 19.2.8 Share their understanding of:
  - a. the function of the inner and outer laminates and the core material in a sandwich construction
  - b. the reasons for using a sandwich construction in wind turbine blades

### ELEMENT 19.3 - CURING OF FIBRE REINFORCED COMPOSITE LAMINATE

Learning objectives:

- 169) The participants can **explain** the functions of the tools, instruments and vacuum consumables used during the curing process (Knowledge, intermediate level)
- 170) The participants can **perform** the curing of a fibre-reinforced composite laminate using heat and vacuum and record the vacuum level and temperature (Skills, intermediate level)
- 171) The participants can **act independently** in performing curing of a fibre reinforced composite laminate using heat and vacuum, and record the vacuum level and temperature (Ability, intermediate level)



The instructor shall:

- 19.3.1 Explain the function of the tools required to cure a laminate with heat and vacuum, and the instruments required to record the vacuum level and curing temperature
- 19.3.2 Explain the health and safety risks associated with using heating blankets and vacuum pumps by considering the risk of burns, the risk of fire and electrical hazards
- 19.3.3 Demonstrate how to mitigate the above described risks using PPE, pre-use inspections, correct handling of the blankets, and the use of electrical safety devices such as residual current devices



- 19.3.4 Explain how a vacuum is used to remove air and to consolidate the laminate during the curing process
- 19.3.5 Explain how an absolute pressure gauge (vacuum gauge) is used to record the vacuum level during the entire curing process
- 19.3.6 Explain how to find the blade manufacturer specific vacuum levels for curing a laminate
- 19.3.7 Explain the function of the vacuum consumable materials:
- peel ply
  - release film
  - breather fabric
  - tacky tape
  - vacuum foil
  - vacuum tube
  - resin trap
- 19.3.8 Demonstrate how to create a vacuum bag over a laminate repair, where to place the thermocouple to get the most accurate temperature reading, and how to use a resin trap to protect the vacuum pump from excess resin
- 19.3.9 Explain the limitations with the temperature settings on the heating blankets
- 19.3.10 Demonstrate how to use the reading from the temperature gauge to adjust the heating blanket to the correct curing temperature
- 19.3.11 Explain:
- how to record and document the vacuum level and curing temperature at regular intervals during the curing process
  - the health and safety implications of removing the vacuum bagging materials after curing the repair by considering sharp edges and the possibility of uncured material. Demonstrate how to mitigate those risks using PPE
  - how the peel ply should not be removed until immediately before the application of the next repair layer
  - how the peel ply makes the surface of the laminate rough for the application of the next layer, and it also protects the surface of the laminate from external contamination
  - that the blade manufacturer's work instructions will detail the exact surface finish for the application of repair layers
- 19.3.12 Ask the participants relevant questions about the functions of the tools, instruments and vacuum consumables used during the curing process



19.3.13 Facilitate practice to improve the participants' ability to:

- a. mitigate the risks posed during the curing process and subsequent removal of vacuum bagging materials
- b. apply vacuum consumables in the correct order with the correct placement of a thermocouple, and to achieve, record and document the correct vacuum levels in accordance with a work instruction
- c. adjust a heating blanket to the correct temperature according to the temperature displayed on a temperature gauge. Record and document that temperature in accordance with a work instruction

19.3.14 Give constructive feedback on participants' above explanations and practice



The participants shall:

19.3.15 Share their understanding of the functions of the tools, instruments and vacuum consumables used during the curing process

19.3.16 Practise the ability to:

- a. mitigate the risks posed during the curing process and subsequent removal of vacuum bagging materials
- b. apply vacuum consumables in the correct order with the correct placement of a thermocouple, and to achieve, record and document the correct vacuum levels in accordance with a work instruction
- c. adjust a heating blanket to the correct temperature according to the temperature displayed on a temperature gauge. Record and document that temperature in accordance with a work instruction

#### ELEMENT 19.4 - PRODUCING A COMPOSITE SANDWICH PANEL

Learning objectives:

- 172) The participants can **perform** the production of a composite sandwich panel covered on one side with gelcoat in accordance with a work instruction and drawing (Skills, intermediate level)
- 173) The participants can **act independently** in producing a composite sandwich panel covered on one side with gelcoat in accordance with a work instruction and drawing (Ability, intermediate level)



The instructor shall:

19.4.1 Introduce the exercise. Hand out a work instruction and drawing with details on how to build the sandwich panel





- 19.4.2 The work instruction and drawing must contain sufficient detail about the dimensions and areal weight of each layer of fibreglass and the core material to enable the participants to build the panel (the dimensions stated in the following participants' actions are the recommended sizes)
- 19.4.3 The work instruction must contain details of the curing temperature, and the mix ratios of the gelcoat and matrix, but shall not contain details of the amount of gelcoat and matrix required as these must be calculated by the participants
- 19.4.4 Demonstrate how to correctly cut and shape core material to the dimensions required in a blade drawing or work instruction
- 19.4.5 Give constructive feedback on the participants' above practice



**The participants shall:**

- 19.4.6 Practise the ability to prepare a flat mould (aluminium is preferred) with release agent and to apply flash tape to the correct dimensions in accordance with a work instruction
- 19.4.7 Practise the ability to calculate the correct amount of gelcoat required for a given area and layer thickness, and to calculate, accurately measure and mix the required quantity of each component given the mixing ratio of the gelcoat
- 19.4.8 Practise the ability to measure and cut fibreglass mats to the correct dimensions required, and to mark the roll zero direction on the cut mats
- 19.4.9 Practise the ability to lay up the fibreglass mats on the gelcoat in the correct order and orientation referenced to zero direction with straight fibres and, where applicable, the correct overlaps between the layers
- 19.4.10 Practise the ability to lay up the fibreglass mats on the gelcoat in the correct order and orientation referenced to zero direction with straight fibres and where applicable the correct overlaps between the layers
- 19.4.11 Practise the ability to accurately cut and shape the required core material for the sandwich panel in accordance with a blade drawing
- 19.4.12 Practise the ability to correctly calculate the total amount of matrix material required for the sandwich panel from the weight of the reinforcement material
- 19.4.13 Practise the ability to correctly calculate, measure and mix the required quantities of each component of the matrix material
- 19.4.14 Practise the ability to apply the matrix material to the glass fibre mats within the pot life and gel time of the matrix
- 19.4.15 Practise the ability to select and use the correct tools to wet out all the fibres in each layer of fibreglass while keeping the fibres in each layer straight
- 19.4.16 Practise the ability to apply vacuum consumables to the mould in the correct order with the correct placement of a thermocouple, and the ability to apply, measure and record the vacuum levels required and achieved



- 19.4.17 Practise the ability to adjust the temperature of a heating blanket according to the readings from the thermocouple to the correct curing temperature for the matrix material used, and to control and record the curing temperature throughout the entire curing process
- 19.4.18 Practise the ability to record the ambient temperature and humidity throughout the entire process of building and curing a sandwich panel
- 19.4.19 After the curing time, practise the ability to safely remove and dispose of the vacuum consumables except for the peel ply

## ELEMENT 19.5 - TRAILING EDGE SECTION

### Learning objectives:

- 174) The participants can **explain** the differences between a structural and non-structural adhesive (Knowledge, intermediate level)
- 175) The participants can **perform** the bonding of two surfaces together to create a trailing edge section (Skills, intermediate level)
- 176) The participants can **act independently** in the bonding of two surfaces together to create a trailing edge section (Ability, intermediate level)



### The instructor shall:

- 19.5.1 Explain the differences between a structural and non-structural adhesive and give some examples of products in each category
- 19.5.2 Explain how surface finish and cleanliness will affect the ability of an adhesive to bond to a surface. Explain that the peel ply on a laminate can leave the correct surface finish for adhesive and that the peel ply must only be removed immediately before applying the adhesive
- 19.5.3 Explain that the blade manufacturer's work instructions detail the surface finish requirements for adhesives
- 19.5.4 Explain and demonstrate where to find the mixing and curing requirements for different adhesive products
- 19.5.5 Demonstrate how to safely cut the sandwich panel in half, and prepare the materials and tools required to bond the pieces together into a trailing edge section
- 19.5.6 Demonstrate how to apply the adhesive to the bond line to ensure the correct dimension, and how to correctly apply clamps to the bond line to ensure that the adhesive wets out the two surfaces
- 19.5.7 Explain and demonstrate how to correctly cure adhesive
- 19.5.8 Ask the participants relevant questions about the differences between structural and non-structural adhesives



- 19.5.9 Facilitate practice to improve the participants' ability to cut the sandwich panel in half and to bond the two halves together to create a trailing edge section
- 19.5.10 Give constructive feedback on the participants' explanations about the differences between structural and non-structural adhesives, and their ability to cut the sandwich panel in half and to bond the two halves together to create a trailing edge section



The participants shall:

- 19.5.11 Share their understanding of the differences between structural and non-structural adhesives
- 19.5.12 Practise the ability to cut the sandwich panel in half and to bond the two halves together to create a trailing edge section

## LESSON 20 - PAINTING

120 min.

The aim of the lesson is to enable the participants to paint a blade to a specific layer of thickness safely and in accordance with a work instruction.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 177) **Take responsibility** for painting a blade to a specific layer of thickness, safely and in accordance with a work instruction (Ability, intermediate level)

### ELEMENT 20.1 - COMPLETION OF BLADE

Learning objectives:

- 178) The participants can **apply** the described paint layers and complete the blade build (Skills, intermediate level)
- 179) The participants can **act independently** in painting a blade to a specific layer of thickness in a safe manner (Ability, intermediate level)



The instructor shall:

- 20.1.1 Explain:



- a. the function of the paint layers on a wind turbine blade and describe the materials from which paint products can be made
  - b. the health and safety risks associated with paint products by considering the base and hardener materials and the solvents used to thin the paint
  - c. the precautions to be adopted to mitigate the health and safety risks posed from paint products by considering the use of PPE and the type of filters required for a mask
  - d. the term 'flash-off time' in the context of paint products
  - e. why it is important to follow a blade manufacturer's work instruction for painting a blade by considering the correct surface finish for paint adhesion, whether the paint requires one or two coats, the curing time for the paint, and the ambient humidity and temperature limits
- 20.1.2 Demonstrate how to calculate the amount of paint required for a given surface area and layer thickness
- 20.1.3 Demonstrate how to mask off an area of blade repair for painting
- 20.1.4 Demonstrate how to apply paint to a repair using a foam roller, and how to measure the layer thickness using a wet film gauge
- 20.1.5 Continually assess and give feedback on the participants' ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work
- 20.1.6 Facilitate practice to improve the participants' ability to select the correct mask and filter for working with paint products
- 20.1.7 Facilitate practice to improve the participants' ability to safely apply paint to a blade surface to a specified layer thickness and to be able to measure the layer thickness with a wet film gauge. The trailing edge section built in Lesson 19 can be used for this
- 20.1.8 Give constructive feedback on the participants' ability to select the correct mask and filter for working with paint products, to safely apply paint to a blade surface to a specified layer thickness, and to measure the layer thickness with a wet film gauge.



The participants shall:

- 20.1.9 Practise the ability to:
- a. select the correct mask and filter for working with paint products
  - b. safely apply paint to a blade surface to a specified layer thickness, and to be able to measure the layer thickness with a wet film gauge. The trailing edge section built in Lesson 19 can be used for this



## LESSON 21 - BLADE INSPECTION

230 min.

The aim of the lesson is to enable the participants to conduct an inspection using the appropriate methodology in accordance with a work instruction.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

180) **Show** an **interest** in conducting an inspection using the appropriate methodology in accordance with a work instruction (Ability, basic level)

### ELEMENT 21.1 - TYPICAL FAILURES

#### Learning objectives:

- 181) The participants can **recognise** and categorise typical failures found in wind turbine blades (Knowledge, basic level)
- 182) The participants can **recognise** the importance of consulting the blade manufacturer's documentation to obtain the manufacturer specific damage categories for the accurate reporting of blade damage (Knowledge, basic level)



#### The instructor shall:

- 21.1.1 Show examples of and describe typical failures and defects in wind turbine blades covering:
  - a. erosion
  - b. impact damage
  - c. holes
  - d. cracks and delamination in the leading edge
  - e. blade surface and trailing edge
  - f. trailing edge bond line failures
  - g. lightning damage
- 21.1.2 Explain how to categorise those defects and failures on a scale from 1 to 5, with 1 being minor damage and 5 being serious structural failure. Show examples of typical failures in each category



- 21.1.3 Emphasise the importance of consulting blade manufacturer documentation to obtain the manufacturer specific damage categories for the accurate reporting of blade damage
- 21.1.4 Demonstrate the ability to recognise typical defects and failures found in wind turbine blades, and correctly identify which damage category each failure or defect falls under



The participants shall:

- 21.1.5 Share their own understandings about how to recognise typical defects and failures found in wind turbine blades and which damage category each failure or defect falls under

## ELEMENT 21.2 - REACTIONS TO DAMAGE CATEGORIES

### Learning objectives:

- 183) The participants can **recognise** the importance of consulting blade manufacturer specific documentation (Knowledge, basic level)
- 184) The participants can **describe** typical reactions to the different damage categories (Knowledge, basic level)



The instructor shall:

- 21.2.1 Highlight the importance of consulting blade manufacturer-specific documentation. This is for guidance on how to react to the various categories of blade damage and to highlight that damage categorisations can vary between companies, so participants should always adhere to company-specific damage categorisations
- 21.2.2 Outline the following typical reactions to damage categories:
- a. no action required - turbine can run
  - b. follow-up inspection required - turbine can run
  - c. repair required within a time frame - turbine can run
  - d. repair required within a short time frame - turbine can run
  - e. repair required immediately - stop the turbine
- 21.2.3 Describe the lost production implications of stopping a turbine
- 21.2.4 Ask the participants relevant questions about the typical reactions to the different damage categories, and to recall where manufacturer-specific information about reactions to blade damage can be found



#### The participants shall:

- 21.2.5 Share their understanding of typical reactions to the different damage categories, and recall where manufacturer-specific information about reactions to blade damage can be found

### ELEMENT 21.3 - FOCUSED AND SCALED PHOTOGRAPHS

#### Learning objectives:

- 185) The participants can **recognise** the reasons for including photographs in a blade inspection or repair report (Knowledge, basic level)
- 186) The participants can **recognise** the advantages of well-focused photographs and the inclusion of scale in the photograph when identifying the size of the damage (Knowledge, basic level)
- 187) The participants can **copy** how to take focused photographs of damage with a scale to indicate size (Skills, basic level)



#### The instructor shall:

- 21.3.1 Explain the reasons for including photographs in a blade inspection or repair report. Give examples of photographs that are required in a blade inspection or repair report, e.g. blade data plate
- 21.3.2 Compare examples of poorly focused and well focused photographs of blade damage. Explain the advantages of well focused photographs
- 21.3.3 Show examples of photographs with no indication of scale and photographs with an indication of scale. Explain the advantages of including scale in the photograph when identifying the size of the damage
- 21.3.4 Demonstrate how to adjust a camera focus setting to 'spot focus', and explain why this setting is preferred for long distance photographs
- 21.3.5 Demonstrate the ability to take focused photographs of blade damage from long and short distances, including a scale to indicate the size of the damage on short distance photographs



#### The participants shall:

- 21.3.6 Practise the ability to take focused photographs of blade damage from long and short distances, including a scale to indicate the size of the damage on short distance photographs



## ELEMENT 21.4 - TAP TEST

### Learning objectives:

- 188) The participants can **describe** possible causes of delamination in a blade (Knowledge, basic level)
- 189) The participants can **perform** a tap test to locate areas of delamination (Skills, intermediate level)
- 190) The participants can **take responsibility** for performing a tap test to identify the extent of areas of delamination in a fibre-reinforced composite structure (Ability, intermediate level)



### The instructor shall:

- 21.4.1 Show examples of a delaminated fibre reinforced composite material and explain possible causes of delamination, such as impact damage
- 21.4.2 Demonstrate how to locate the outer edges of an area of delamination by performing a tap test with an appropriate tool
- 21.4.3 Ask the participants relevant questions about the possible causes of delamination in a blade
- 21.4.4 Facilitate practice to improve the participants' ability to perform a tap test to identify the extent of areas of delamination in a fibre-reinforced composite structure
- 21.4.5 Give constructive feedback on the participants' ability to perform a tap test to identify the extent of areas of delamination in a fibre-reinforced composite structure



### The participants shall:

- 21.4.6 Share their understanding of the possible causes of delamination in a blade
- 21.4.7 Practise the ability to perform a tap test to identify the extent of areas of delamination in a fibre reinforced composite structure

## ELEMENT 21.5 - LIGHTING

### Learning objectives:

- 191) The participants can **recognise** the importance of lighting (intensity & angle) in terms of inspecting composite materials (Knowledge, basic level)





- 192) The participants can **perform** adjustments of the light intensity and angle to correctly identify difficult-to-see damage in a laminate structure (Skills, intermediate level)
- 193) The participants can **act independently** in adjusting the light intensity and angle to correctly identify difficult-to-see damage in a laminate structure (Ability, intermediate level)



#### The instructor shall:

- 21.5.1 Explain how the intensity and the angle of the light source used for inspecting a laminate structure can affect the visibility of defects within the laminate
- 21.5.2 Explain how incorrect lighting can hide defects
- 21.5.3 Facilitate practice to improve the participants' ability to adjust the light intensity and angle to correctly identify difficult-to-see damage in a laminate structure
- 21.5.4 Give constructive feedback on the participants' ability to adjust the light intensity and angle to correctly identify difficult-to-see damage in a laminate structure



#### The participants shall:

- 21.5.5 Practise the ability to adjust the light intensity and angle to correctly identify difficult-to-see damage in a laminate structure

### ELEMENT 21.6 - INSPECTION TOOLS AND METHODS

#### Learning objectives:

- 194) The participants can **recognise** the situations when blade inspections are required (Knowledge, basic level)
- 195) The participants can **recognise** the conditions for accessing a blade for inspection or repair (Knowledge, basic level)
- 196) The participants can **recognise** the different inspection tools and methods (Knowledge, basic level)
- 197) The participants can **act independently** in locating, identifying, categorising, and documenting damage on a wind turbine blade (Ability, intermediate level)



#### The instructor shall:



- 21.6.1 Describe situations when blade inspections are required by considering installation, periodic maintenance, end-of-warranty inspections, and when damage is suspected following an incident, such as a bird strike
- 21.6.2 Explain the conditions for accessing a blade for inspection or repair (such as, platforms, rope access) if the blade is on the ground; inspecting a blade from a distance and the inspection methods that can be used in each situation
- 21.6.3 Explain which tools can be used for inspecting a blade from a distance by considering telescopes, cameras and drones, and the limitations and advantages of each tool
- 21.6.4 Facilitate practice to improve the participants' ability to locate, identify, categorise, and document damage on a wind turbine blade (both on the blade itself and from a distance) using visual inspection, tap testing, a telescope and a camera with a zoom lens
- 21.6.5 Give constructive feedback on the participants' ability to locate, identify, categorise, and document damage on a wind turbine blade



The participants shall:

- 21.6.6 Practise the ability to locate, identify, categorise, and document damage on a wind turbine blade (both on the blade itself and from a distance) using visual inspection, tap testing, a telescope and a camera with a zoom lens

#### ELEMENT 21.7 - TYPES OF DAMAGE

##### Learning objectives:

- 198) The participants can **describe** situations when a blade inspection might be required, the methods that can be utilised to access a blade and the methods that can be used to perform a blade inspection (Knowledge, basic level)
- 199) The participants can **act independently** in locating, identifying, categorising and documenting damage on a wind turbine blade (Ability, intermediate level)



The instructor shall:

- 21.7.1 Create an exercise where the participants must locate, identify, and categorise the damage to a wind turbine blade. The damage must include the following: an area of delamination, cracks in the surface layers of gelcoat and paint, cracks in the laminate and holes through to the core material
- 21.7.2 The areas of damage must cover different categories of damage and must include damage that can only be found by using a specific angle of lighting



- 21.7.3 Create an exercise where the participants must inspect and identify damage on a wind turbine blade from a distance using a telescope and a camera with a zoom lens. Demonstrate the use of these tools to perform a blade inspection
- 21.7.4 Ask the participants relevant questions about situations when a blade inspection might be required, the methods that can be utilised to access a blade, and the methods that can be used to perform a blade inspection
- 21.7.5 Give constructive feedback on the participants' ability to locate, identify, categorise, and document damage on a wind turbine blade (both on the blade itself, and from a distance) using visual inspection, tap testing, a telescope, and a camera with a zoom lens



The participants shall:

- 21.7.6 Describe situations when a blade inspection might be required, the methods that can be utilised to access a blade, and the methods that can be used to perform a blade inspection
- 21.7.7 Practise the ability to locate, identify, categorise and document damage on a wind turbine blade (both on the blade itself and from a distance) using visual inspection, tap testing, a telescope, and a camera with a zoom lens

## LESSON 22 - INSPECTION LIGHTNING PROTECTION SYSTEM

50 min.

The aim of the lesson is to enable the participants to measure lightning receptors and to identify damage to lightning protection system components.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 200) **Take responsibility** for measuring lightning receptors and identifying damage to lightning protection system components (Ability, intermediate level)

### ELEMENT 22.1 - SURFACE COMPONENTS

Learning objective:

- 201) The participants can **explain** the function of typical surface components of a lightning protection system (Knowledge, intermediate level)



#### The instructor shall:

- 22.1.1 Explain the reasons for having a lightning protection system in a blade by considering the effects of lightning current on fibre-reinforced composites and by showing examples of damage caused to a blade by lightning current
- 22.1.2 Describe typical components in a lightning protection system, such as lightning receptors, lightning cable, and the connection to the hub
- 22.1.3 Explain how the lightning receptors connect to the lightning cable, and how they conduct lightning current from the surface of the receptor to the lightning cable and out of the blade
- 22.1.4 Ask the participants relevant questions about the function of the lightning receptors in a wind turbine blade, and how lightning current is conducted from the surface of the receptor through the lightning cable and out of the blade
- 22.1.5 Give constructive feedback on the participants' above explanations



#### The participants shall:

- 22.1.6 Share their understanding of the function of the lightning receptors in a wind turbine blade, and how lightning current is conducted from the surface of the receptor through the lightning cable and out of the blade

## ELEMENT 22.2 - VISUAL AND CONDUCTIVITY INSPECTION

### Learning objectives:

- 202) The participants can **copy** how to carry out a visual inspection of the lightning protection system (Skills, basic level)
- 203) The participants can **act independently** in identifying damaged components of the lightning protection system by conducting a visual inspection (Ability, intermediate level)



#### The instructor shall:

- 22.2.1 Show examples of damaged lightning protection system components
- 22.2.2 Demonstrate how to carry out a visual inspection of the lightning protection system
- 22.2.3 Facilitate practice to improve the participants' ability to identify damaged components of the lightning protection system by conducting a visual inspection



- 22.2.4 Give feedback on the participants' abilities to identify damaged components of the lightning protection system by conducting a visual inspection



The participants shall:

- 22.2.5 Practise the ability to identify damaged components of the lightning protection system by conducting a visual inspection

### ELEMENT 22.3 - MEASURE RESISTANCE

Learning objectives:

- 204) The participants can **perform** safe measurements of the conductivity and resistance of a typical lightning protection system using a low-resistance ohmmeter (Skills, intermediate level)
- 205) The participants can **take responsibility** for safely using a low-resistance ohmmeter to measure the resistance of the lightning protection system and to identify a defective lightning receptor (Ability, intermediate level)



The instructor shall:

- 22.3.1 Describe the tools required for measuring the resistance of the lightning protection system
- 22.3.2 Explain the safety precautions to be adopted for using a low-resistance ohmmeter
- 22.3.3 Explain common procedures to ensure correct reading and direct contact between receptor surface and low-resistance ohmmeter (e.g. cleaning the receptor)
- 22.3.4 Demonstrate how to safely use a low-resistance ohmmeter to measure the resistance in the entire lightning protection system
- 22.3.5 Demonstrate how to safely use the low-resistance ohmmeter to identify which lightning receptor or section of cable is defective
- 22.3.6 Facilitate practice to improve the participants' ability to:
- a. safely use a low-resistance ohmmeter to measure the resistance of the lightning protection system
  - b. safely use a low-resistance ohmmeter to identify a defective lightning receptor
- 22.3.7 Give feedback on the participants' ability to safely use a low-resistance ohmmeter to measure the resistance of the lightning protection system and identify a defective lightning receptor



The participants shall:

22.3.8 Practise the ability to:

- a. safely use a low-resistance ohmmeter to measure the resistance of the lightning protection system
- b. safely use a low-resistance ohmmeter to identify a defective lightning receptor

## LESSON 23 - SANDING SKILLS

45 min.

The aim of the lesson is to enable the participants to choose the correct PPE, equipment, and method to sand safely and effectively.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 206) **Act independently** in selecting the correct PPE, equipment, and method to sand safely and effectively (Ability, intermediate level)

### ELEMENT 23.1 - SANDING

Learning objectives:

- 207) The participants can **describe** health and safety risks associated with working with a sander and how to mitigate those risks (Knowledge, basic level)
- 208) The participants can **describe** how the surface profile affects the aerodynamic performance of the blade, and how blade repair work can change the surface profile leading to reduced performance and loss of production (Knowledge, basic level)
- 209) The participants can **act independently** in sanding filler material to match the surrounding aerodynamic profile following a repair, and achieve the correct surface finish for paint adhesion (Ability, intermediate level)



The instructor shall:

- 23.1.1 Lead a discussion about the health and safety risks associated with working with a sander by considering the ergonomic implications, including vibration, the dust produced, the electrical hazard, flying debris, noise and the risks posed by high-speed rotating tools



- 23.1.2 Demonstrate how to mitigate those risks by means of body positioning, adequate breaks, correct PPE, pre-use tool inspection, and electrical safety devices such as RCDs
- 23.1.3 Outline how the surface profile affects the aerodynamic performance of the blade. Explain how blade repair work can change the surface profile, leading to reduced performance and loss of production
- 23.1.4 Explain how the surface finish affects the adhesion of subsequent repair layers such as filler and paint. Indicate that the surface finish varies for different products, and that the required finish is detailed in the manufacturer's work instructions and the technical data sheet for the product
- 23.1.5 Explain the different grades of sanding disc available
- 23.1.6 Demonstrate how to recognise and replace a worn sanding disc
- 23.1.7 Demonstrate how to safely use a sander and select an appropriate sanding disc first; to remove excess filler to match the surrounding aerodynamic profile of the blade; and secondly, to create the correct surface finish for adhesion of subsequent repair layers
- 23.1.8 Ask the participants relevant questions about how the surface profile of a repair affects the aerodynamic performance of the blade, and explain how the surface finish affects the adhesion of subsequent repair layers



The participants shall:

- 23.1.9 Engage in a discussion and share their understanding of the health and safety risks associated with working with a sander
- 23.1.10 Share their understanding about how the surface profile of a repair affects the aerodynamic performance of the blade, and explain how the surface finish affects the adhesion of subsequent repair layers
- 23.1.11 Practise the ability to:
  - a. recognise and replace a worn sanding disc
  - b. safely operate a sander to remove excess filler to match the surrounding aerodynamic profile and to create the correct surface finish for adhesion of subsequent repair layers

**Note** *These abilities shall be assessed in each of the following repair exercises.*

## LESSON 24 - GRINDING SKILLS

100 min.

The aim of the lesson is to enable the participants to choose the correct PPE, equipment, and method to grind safely and effectively.

After having successfully completed this lesson of the Blade Repair Module, the participants can:



- 210) **Take responsibility** for selecting the correct PPE, equipment and method to grind safely and effectively (Ability, intermediate level)

#### ELEMENT 24.1 - GRINDING

##### Learning objectives:

- 211) The participants can **describe** the health and safety risks associated with working with a grinder and how to mitigate those risks (Knowledge, basic level)
- 212) The participants can **act independently** in safely performing the accurate grinding of composite materials to reveal the fibre orientation, and create overlaps and/or scarf joints to existing material prior to applying repair layers (Ability, intermediate level)



##### The instructor shall:

- 24.1.1 Lead a discussion about the health and safety risks associated with working with a grinder by considering the ergonomic implications, including vibration, the dust produced, the electrical hazard, flying debris, noise and the risks posed by high-speed rotating tools
- 24.1.2 Demonstrate how to mitigate those risks by means of body positioning, adequate breaks, correct PPE, pre-use tool inspection, and electrical safety devices such as residual current devices
- 24.1.3 Explain the different grades of grinding disc available
- 24.1.4 Demonstrate how to recognise and replace a worn grinding disc
- 24.1.5 Demonstrate how to safely use a grinder to accurately grind a composite structure to reveal the fibre orientation, and create overlaps and/or scarf joints of the correct dimensions in each layer of laminate
- 24.1.6 Facilitate practice to improve the participants' ability to:
- a. select and correctly use the appropriate PPE for the task and perform a pre-use tool inspection before working with a grinder
  - b. recognise and replace a worn-out grinding disc
  - c. safely use a grinder to accurately grind composite materials to reveal the fibre orientation, and create overlaps and/or scarf joints of the correct dimensions in each layer of laminate
- 24.1.7 Give constructive feedback on the participants' above practice





The participants shall:

- 24.1.8 Engage in a discussion and share their understanding of the health and safety risks associated with working with a grinder
- 24.1.9 Practise the ability to:
- a. select and correctly use the appropriate PPE for the task and perform a pre-use tool inspection before working with a grinder
  - b. recognise and replace a worn-out grinding disc
  - c. safely use a grinder to accurately grind composite materials to reveal the fibre orientation, and create overlaps and/or scarf joints of the correct dimensions in each layer of laminate

**Note** *These skills and abilities shall be assessed in each of the following repair exercises.*

## LESSON 25 - SURFACE REPAIRS

180 min.

The aim of the lesson is to enable the participants to repair minor damage to the surface of the wind turbine blade safely and effectively.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 213) **Take responsibility** for repairing minor damage to the surface of the wind turbine blade safely and effectively (Ability, intermediate level)

### ELEMENT 25.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Learning objectives:

- 214) The participants can **act independently** in applying the knowledge gained during the general safety lessons to the working environment to minimise the risks associated with composite repair work (Ability, intermediate level)
- 215) The participants can **act independently** in applying the knowledge gained during Lesson 18 (basic lamination) (Ability, intermediate level)



#### The instructor shall:

- 25.1.1 Continually assess and give constructive feedback on the participants' ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work



#### The participants shall:

- 25.1.2 Practise the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

### ELEMENT 25.2 - FILLER ADHESION

#### Learning objectives:

- 216) The participants can **perform** the preparation of the repair area in terms of filler adhesion (Skills, intermediate level)
- 217) The participants can **take responsibility** for safely using a small grinder and a sander to remove small areas of surface damage like pin holes, scratches, and cracks, and know how to create the correct surface finish for the adhesion of subsequent repair layers (Ability, intermediate level)



#### The instructor shall:

- 25.2.1 Demonstrate how to safely use a small grinder and a sander to remove surface damage such as pin holes, scratches, and cracks, and how to create the correct surface finish for the adhesion of subsequent repair layers
- 25.2.2 Facilitate practice to improve the participants' ability to safely use a small grinder and a sander to remove small areas of surface damage like pin holes, scratches, and cracks, and to create the correct surface finish for the adhesion of subsequent repair layers
- 25.2.3 Give constructive feedback on the participants' ability to safely use a small grinder and a sander to remove small areas of surface damage like pin holes, scratches, and cracks, and to create the correct surface finish for the adhesion of subsequent repair layers



#### The participants shall:

- 25.2.4 Practise the ability to safely use a small grinder and a sander to remove small areas of surface damage like pin holes, scratches, and cracks, and to create the correct surface finish for the adhesion of subsequent repair layers



### ELEMENT 25.3 - REPRODUCE SURFACE PROFILE

#### Learning objectives:

- 218) The participants can **perform** the reproduction of the surface profile shape using filler (Skills, intermediate level)
- 219) The participants can **act independently** in applying thin layers of filler to match the surrounding profile shape of the blade (Ability, intermediate level)



#### The instructor shall:

- 25.3.1 Demonstrate how to apply thin layers of filler to a surface repair to match the surrounding profile shape of the blade
- 25.3.2 Facilitate practice to improve the participants' ability to apply thin layers of filler to match the surrounding profile shape of the blade
- 25.3.3 Give constructive feedback on the participants' ability to apply thin layers of filler to match the surrounding profile shape of the blade



#### The participants shall:

- 25.3.4 Practise the ability to apply thin layers of filler to match the surrounding profile shape of the blade

### ELEMENT 25.4 - PAINT ADHESION

#### Learning objective:

- 220) The participants can **act independently** in applying the knowledge gained in Lesson 23 (Sanding Skills) by demonstrating the ability to create the correct surface finish for the adhesion of the paint layer (Ability, intermediate level)



#### The instructor shall:

- 25.4.1 Facilitate practice for the participants to apply the knowledge gained in Lesson 23 (Sanding Skills) by practising the ability to create the correct surface finish for the adhesion of the paint layer
- 25.4.2 Give constructive feedback on the participants' application of the knowledge gained in Lesson 23 (Sanding Skills) by practising the ability to create the correct surface finish for the adhesion of the paint layer



The participants shall:

- 25.4.3 Apply the knowledge gained in Lesson 23 (Sanding Skills) by practising the ability to create the correct surface finish for the adhesion of the paint layer

#### ELEMENT 25.5 - LAYER THICKNESS

Learning objective:

- 221) The participants can **act independently** in applying the knowledge gained in Lesson 20 (Painting) by demonstrating the ability to determine the correct layer thickness for paint using a work instruction (Ability, intermediate level)



The instructor shall:

- 25.5.1 Facilitate practice for the participants to apply the knowledge gained in Lesson 20 (Painting) by practising the ability to determine the correct layer thickness for paint using a work instruction
- 25.5.2 Give constructive feedback on the participants' application of the knowledge gained in Lesson 20 (Painting) by practising the ability to determine the correct layer thickness for paint using a work instruction



The participants shall:

- 25.5.3 Apply the knowledge gained in Lesson 20 (Painting) by practising the ability to determine the correct layer thickness for paint using a work instruction

#### ELEMENT 25.6 - APPLY PAINT WITH A ROLLER

Learning objective:

- 222) The participants can **apply** paint to surface repairs using a roller (Skills, intermediate level)



The instructor shall:

- 25.6.1 Facilitate practice for the participants to apply the knowledge gained in Lesson 20 (Painting) by applying paint to surface repairs using a roller
- 25.6.2 Give constructive feedback on the participants' application of the knowledge gained in Lesson 20 (Painting) by practising the application of paint to surface repairs using a roller



The participants shall:

- 25.6.3 Apply the knowledge gained in Lesson 20 (Painting) by practising how to apply paint to surface repairs using a roller

#### ELEMENT 25.7 - LAYER THICKNESS WITH WET FILM

Learning objectives:

- 223) The participants can **perform** measurements of the layer thickness of the paint using a wet film gauge (Skills, intermediate level)
- 224) The participants can **act independently** in applying the knowledge gained in Lesson 20 (Painting) by measuring the layer thickness of paint using a wet film gauge (Ability, intermediate level)



The instructor shall:

- 25.7.1 Facilitate practice for the participants to apply the knowledge gained in Lesson 20 (Painting) by practising the ability to measure the layer thickness of paint using a wet film gauge
- 25.7.2 Give constructive feedback on the participants' application of the knowledge gained in Lesson 20 (Painting) by practising the ability to measure the layer thickness of paint using a wet film gauge



The participants shall:

- 25.7.3 Apply the knowledge gained in Lesson 20 (painting) by practising the ability to measure the layer thickness of paint using a wet film gauge

#### ELEMENT 25.8 - RECORD AMBIENT TEMPERATURE AND HUMIDITY

Learning objectives:

- 225) The participants can **perform** the recording of the ambient temperature and humidity throughout the process using a data logger (Skills, intermediate level)
- 226) The participants can **act independently** in applying the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to record and document the ambient temperature and humidity throughout the entire repair process (Ability, intermediate level)



#### The instructor shall:

- 25.8.1 Facilitate practice for the participants to apply the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to record and document the ambient temperature and humidity throughout the entire repair process
- 25.8.2 Give constructive feedback on the participants' application of the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to record and document the ambient temperature and humidity throughout the entire repair process



#### The participants shall:

- 25.8.3 Apply the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to record and document the ambient temperature and humidity throughout the entire repair process

### ELEMENT 25.9 - INSPECTION AND DOCUMENTATION

#### Learning objective:

- 227) The participants can **act independently** in applying the knowledge gained in Lesson 21 (Blade Inspection) by practising the ability to inspect a blade surface and identify typical surface defects such as pinholes, scratches, and cracks (Ability, intermediate level)



#### The instructor shall:

- 25.9.1 Facilitate practice for the participants to apply the knowledge gained in Lesson 21 (Blade Inspection) by practising the ability to inspect a blade surface and identify typical surface defects such as pinholes, scratches and cracks
- 25.9.2 Give constructive feedback on the participants' application of the knowledge gained in Lesson 21 (Blade Inspection) by practising the ability to inspect a blade surface and identify typical surface defects such as pinholes, scratches and cracks



#### The participants shall:

- 25.9.3 Apply the knowledge gained in Lesson 21 (Blade Inspection) by practising the ability to inspect a blade surface and identify typical surface defects such as pinholes, scratches and cracks



## LESSON 26 - LAMINATE REPAIRS

600 min.

The aim of the lesson is to enable the participants to actively remove damaged laminate, prepare for the repair and perform the repair safely and effectively.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 228) **Take responsibility** for actively removing damaged laminate, preparing for the repair and performing the repair safely and effectively (Ability, intermediate level)

### ELEMENT 26.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Learning objective:

- 229) The participants can **act independently** in applying the knowledge gained during the general safety module to the working environment to minimise the risks associated with composite repair work (Ability, intermediate level)



The instructor shall:

- 26.1.1 Continually assess and give feedback on the participants' ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work



The participants shall:

- 26.1.2 Practise the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

### ELEMENT 26.2 - SAFE REMOVAL OF DAMAGED MATERIAL

Learning objectives:

- 230) The participants can **safely** perform the removal of damaged material and properly clean a composite laminate prior to repair activities (Skills, intermediate level)
- 231) The participants can **explain** methods that can be used to protect the cleaned surface if the lamination cannot be performed immediately (Knowledge, intermediate level)



- 232) The participants can **act independently** in assessing and safely removing damaged laminate with a grinder without damaging the underlying core material (Ability, intermediate level)
- 233) The participants can **act independently** in documenting each stage of the repair (Ability, intermediate level)



#### The instructor shall:

- 26.2.1 Create a small area of damage in the trailing edge section produced in Lesson 18 (Basic Lamination), with the damage limited to the laminate structure
- 26.2.2 Demonstrate:
- how to correctly document the initial damage with photographs
  - how to use a grinder to remove all the damaged laminate material without damaging the underlying core material, and how to evaluate the extent of the damage
  - how to clean the surface in preparation for lamination using a vacuum cleaner, tacky rags, and isopropyl alcohol
  - how to protect the cleaned surface if the lamination cannot be performed immediately
- 26.2.3 Facilitate practice to improve the participants' ability to safely remove damaged laminate with a grinder without damaging the underlying core material. Assess the extent of the damage and how to properly clean the surface in preparation for lamination, and how to document each stage of the repair
- 26.2.4 Ask the participants relevant questions about methods that can be used to protect the cleaned surface if the lamination cannot be performed immediately
- 26.2.5 Give constructive feedback on the participants' above practice and explanations



#### The participants shall:

- 26.2.6 Practise the ability to safely remove damaged laminate with a grinder without damaging the underlying core material. Assess the extent of the damage and how to properly clean the surface in preparation for lamination, and how to document each stage of the repair
- 26.2.7 Share their understanding of methods that can be used to protect the cleaned surface if the lamination cannot be performed immediately





## ELEMENT 26.3 - IDENTIFYING FIBRE DIRECTION

### Learning objectives:

- 234) The participants can **copy** how to safely use a grinder to remove existing layers of laminate to reveal the fibre orientation in each layer of damaged fibre after having removed damaged material (Skills, basic level)
- 235) The participants can **take responsibility** for safely using a grinder to remove existing layers of laminate to reveal the fibre orientation in each layer of damaged fibre (Ability, Intermediate level)



### The instructor shall:

- 26.3.1 After removing damaged material, demonstrate how to safely use a grinder to remove existing layers of laminate to reveal the fibre orientation in each layer of damaged fibre
- 26.3.2 Facilitate practice to improve the participants' ability to safely use a grinder to remove existing layers of laminate to reveal the fibre orientation in each layer of damaged fibre
- 26.3.3 Give constructive feedback on the participants' ability to safely use a grinder to remove existing layers of laminate to reveal the fibre orientation in each layer of damaged fibre



### The participants shall:

- 26.3.4 Practise the ability to safely use a grinder to remove existing layers of laminate to reveal the fibre orientation in each layer of damaged fibre

## ELEMENT 26.4 - REINFORCEMENT OVERLAPS AND MATRIX ADHESION

### Learning objectives:

- 236) The participants can **perform** measurements of and mark the overlaps and/or scarf joints for each repair layer (Skills, intermediate level)
- 237) The participants can **apply** a grinder safely to create overlaps and/or scarf joints of the correct dimension in each layer of existing fibre (Skills, intermediate level)
- 238) The participants can **perform** measurements of the created overlaps and/or scarf joints and cut repair glass fibre mats of the correct size and areal weight for each repair layer (Skills, intermediate level)
- 239) The participants can **act independently** in correctly measuring and marking the overlaps and/or scarf joints for each repair layer (Ability, intermediate level)



- 240) The participants can **take responsibility** for grinding the existing laminate to create overlaps and/or scarf joints of the correct dimension for each repair layer, so that they have the correct surface finish for adhesion of the repair laminates (Ability, intermediate level)
- 241) The participants can **act independently** in measuring the created overlaps and/or scarf joints and cutting repair glass fibre mats of the correct size and areal weight for each repair layer (Ability, intermediate level)



#### The instructor shall:

- 26.4.1 Explain the importance of repairing each layer of laminate that is damaged with the same type and weight of glass as the original
- 26.4.2 Demonstrate:
- a. how to measure out and mark the overlaps and/or scarf joints for each repair layer
  - b. how to safely use a grinder to create overlaps and/or scarf joints of the correct dimension in each layer of existing fibre
  - c. how to use the created overlaps and/or scarf joints to measure and cut the required glass fibre mats for each repair layer
- 26.4.3 Facilitate practice to improve the participants' ability to:
- a. correctly measure and mark the overlaps and/or scarf joints for each repair layer
  - b. grind the existing laminate to create overlaps and/or scarf joints of the correct dimension for each repair layer, so that they have the correct surface finish for adhesion of the repair laminates
  - c. measure the created overlaps and/or scarf joints and cut repair glass fibre mats of the correct size and areal weight for each repair layer
- 26.4.4 Give constructive feedback on the participants' above practice



#### The participants shall:

- 26.4.5 Practise the ability to:
- a. correctly measure and mark the overlaps and/or scarf joints for each repair layer
  - b. grind the existing laminate to create overlaps and/or scarf joints of the correct dimension for each repair layer, so that they have the correct surface finish for adhesion of the repair laminates



- c. measure the created overlaps and/or scarf joints and cut repair glass fibre mats of the correct size and areal weight for each repair layer

#### ELEMENT 26.5 - MIXING

##### Learning objectives:

- 242) The participants can **perform** calculations, weigh out and mix matrix material for a given repair using both epoxy and polyester resin systems (Skills, intermediate level)
- 243) The participants can **act independently** in correctly calculating the total amount of matrix required and the quantities of each component of the matrix (Ability, intermediate level)
- 244) The participants can **act independently** in correctly mixing the matrix material (Ability, intermediate level)



##### The instructor shall:

- 26.5.1 Assess and give constructive feedback on the participants' ability to calculate the amount of matrix material and the quantities of each component required for the repair



##### The participants shall:

- 26.5.2 Practise the ability to:
  - a. correctly calculate the total amount of matrix required and the quantities of each component of the matrix
  - b. correctly mix the matrix material

#### ELEMENT 26.6 - REPAIR LAYERS

##### Learning objectives:

- 245) Participants can **copy** how to apply the repair layers in the correct order and orientation while maintaining the specified overlaps and fibre straightness (Skills, basic level)
- 246) Participants can **take responsibility** for correctly calculating the total amount of matrix required and the quantities of each component of the matrix, and for correctly mixing the matrix material (Ability, intermediate level)



#### The instructor shall:

- 26.6.1 Demonstrate how to apply the repair layers, focusing on the correct order, maintaining the required overlaps and fibre orientation to the existing layers, and ensuring that the fibres are straight
- 26.6.2 Facilitate practice to improve the participants' ability to correctly calculate the total amount of matrix required and the quantities of each component of the matrix, and to correctly mix the matrix material
- 26.6.3 Give constructive feedback on the participants' ability to correctly calculate the total amount of matrix required and the quantities of each component of the matrix, and to correctly mix the matrix material



#### The participants shall:

- 26.6.4 Practise the ability to correctly calculate the total amount of matrix required and the quantities of each component of the matrix, and to correctly mix the matrix material

### ELEMENT 26.7 - WETTING OUT FIBRES USING APPROPRIATE TOOLS

#### Learning objectives:

- 247) Participants can **apply** appropriate tools to consolidate and remove air from the laminate (Skills, intermediate level)
- 248) Participants can **act independently** in using a bolt roller to consolidate and remove air from the laminate (Ability, intermediate level)



#### The instructor shall:

- 26.7.1 Demonstrate how to use a bolt roller to consolidate and remove air from the laminate
- 26.7.2 Facilitate practice to improve the participants' ability to use a bolt roller to consolidate and remove air from the laminate
- 26.7.3 Give constructive feedback on the participants' ability to use a bolt roller to consolidate and remove air from the laminate



#### The participants shall:

- 26.7.4 Practise the ability to use a bolt roller to consolidate and remove air from the laminate



## ELEMENT 26.8 - WETTING OUT FIBRES WITH MATRIX MATERIAL

### Learning objective:

- 249) Participants can **act independently** in using appropriate tools to apply the matrix material to the repair and consolidate and remove air from the laminate while maintaining the correct overlaps and keeping the fibres straight in each layer of the repair (Ability, intermediate level)



### The instructor shall:

- 26.8.1 Demonstrate how to, and facilitate practice for the participants to, use a brush to apply the matrix material to the repair and how to use a bolt roller to consolidate and remove air from the laminate while maintaining the correct overlaps and/or scarf dimensions and keeping the fibres straight in each layer
- 26.8.2 Give constructive feedback on the participants' practice mentioned above



### The participants shall:

- 26.8.3 Practise the ability to use appropriate tools to apply the matrix material to the repair and to consolidate and remove air from the laminate while maintaining the correct overlaps and keeping the fibres straight in each layer of the repair

## ELEMENT 26.9 - VACUUM CONSOLIDATION

### Learning objectives:

- 250) Participants can **recognise** the challenges that can arise from creating a vacuum in a repair setting and ways to mitigate against these challenges (Knowledge, basic level)
- 251) Participants can **act independently** in documenting and applying vacuum consumables to the repair in the correct order, and achieve the correct vacuum levels in accordance with a work instruction (Ability, intermediate level)
- 252) Participants can **act independently** in reading a vacuum gauge to verify and to be able to document the vacuum level applied to the repair (Ability, intermediate level)



### The instructor shall:



- 26.9.1 Explain the challenges that can arise from creating a vacuum in a repair setting by considering the surface finish of the blade, the porosity of the laminate, the core material in the blade and the distance from the repair to the vacuum pump. Discuss ways in which to mitigate against these challenges
- 26.9.2 Demonstrate:
- a. how to apply vacuum consumables to a repair to achieve the specified vacuum levels as stated in a work instruction
  - b. the application of flash tape and tacky tape prior to applying resin to ensure that the flash tape and tacky tape will adhere to the surface. Demonstrate how to prevent contamination of the tape by using masking tape
  - c. how to record and document the vacuum level using a vacuum gauge
- 26.9.3 Facilitate practice to improve the participants abilities to:
- a. apply vacuum consumables to the repair in the correct order and achieve the correct vacuum levels in accordance with a work instruction
  - b. read a vacuum gauge to verify and to be able to document the vacuum level applied to the repair
- 26.9.4 Give constructive feedback on the participants' above practice



The participants shall:

- 26.9.5 Practise the ability to:
- a. apply vacuum consumables to the repair in the correct order and achieve the correct vacuum levels in accordance with a work instruction
  - b. read a vacuum gauge to verify and to be able to document the vacuum level applied to the repair

## ELEMENT 26.10 - CURING THE REPAIR USING HEATING BLANKETS

### Learning objectives:

- 253) Participants can **correctly** perform curing of the repair using heating blankets and record the curing temperature (Skills, intermediate level)
- 254) Participants can **act independently** in finding the correct curing temperature and duration for the lamination resin being used for the repair (Ability, intermediate level)
- 255) Participants can **act independently** in adjusting and controlling the heating blanket to the correct curing temperature as displayed on the temperature gauge (Ability, intermediate level)



- 256) Participants can **act independently** in documenting the correct curing temperature throughout the curing process (Ability, intermediate level)



The instructor shall:

- 26.10.1 Explain how to safely use a heating blanket, how to adjust and control the heating blanket to the correct curing temperature as displayed on the temperature gauge, and how to document the curing temperature
- 26.10.2 Facilitate practice to improve the participants' ability to:
- find the correct curing temperature and duration for the lamination resin being used for the repair
  - adjust and control the heating blanket to the correct curing temperature as displayed on the temperature gauge
  - document the curing temperature throughout the curing process
- 26.10.3 Give constructive feedback on the participants' above practice



The participants shall:

- 26.10.4 Practise the ability to:
- find the correct curing temperature and duration for the lamination resin being used for the repair
  - adjust and control the heating blanket to the correct curing temperature as displayed on the temperature gauge
  - document the curing temperature throughout the curing process

## ELEMENT 26.11 - VERIFYING THE CURING

Learning objectives:

- 257) Participants can **recognise** the requirement to record and document the hardness of the cured laminate (Knowledge, basic level)
- 258) Participants can **act independently** in using use a Barcol/Shore D hardness tester to verify that the laminate has cured to the correct hardness level, and know how to document this reading (Ability, intermediate level)



#### The instructor shall:

- 26.11.1 Explain the requirement to record and document the hardness of the cured laminate
- 26.11.2 Facilitate practice to enable the participants to apply the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to use a Barcol/Shore D hardness tester to verify that the laminate has cured to the correct hardness level, and explain how to document this reading
- 26.11.3 Give constructive feedback on the participants' application of the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to use a Barcol/Shore D hardness tester to verify that the laminate has cured to the correct hardness level, and explain how to document this reading



#### The participants shall:

- 26.11.4 Apply the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to use a Barcol/Shore D hardness tester to verify that the laminate has cured to the correct hardness level, and know how to document this reading

## ELEMENT 26.12 - RECORDING THE AMBIENT TEMPERATURE AND HUMIDITY

### Learning objective:

- 259) Participants can **take responsibility** for using a data logger to record and document the ambient temperature and humidity throughout the entire repair process (Ability, intermediate level)



#### The instructor shall:

- 26.12.1 Remind the participants of the requirement to record and document the ambient temperature and humidity throughout the entire repair process
- 26.12.2 Remind the participants to comply with the requirement of minimum and maximum temperature and humidity while mixing of chemicals
- 26.12.3 Facilitate practice to enable the participants to apply the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to use a data logger to record and document the ambient temperature and humidity throughout the entire repair process
- 26.12.4 Give constructive feedback on the participants' application of the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to use a data logger to record and document the ambient temperature and humidity throughout the entire repair process





The participants shall:

- 26.12.5 Apply the knowledge gained in Lesson 17 (Lamination Skills) by practising the ability to use a data logger to record and document the ambient temperature and humidity throughout the entire repair process

## LESSON 27 - FILLING AND SHAPING

180 min.

The aim of the lesson is to enable the participants to apply filling safely and effectively.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 260) **Take responsibility** for applying filling safely and effectively (Ability, intermediate level)

### ELEMENT 27.1 - FILLER

Learning objectives:

- 261) The participants can locate areas in need of filling and **apply** filler material to gaps/pinholes (Skills, intermediate level)
- 262) The participants can **explain** the limitations of using filler in terms of short pot life and layer thickness (Knowledge, intermediate level)
- 263) The participants can **act independently** in applying filler with the correct tools to fill pinholes and small defects in the surface of a wind turbine blade (Ability, intermediate level)



The instructor shall:

- 27.1.1 Describe how pinholes and surface defects degrade the aerodynamic performance of the blade
- 27.1.2 Explain the limitations of using filler by considering the short pot life of some fillers, and how ambient temperature and humidity can affect the pot life and limitations layer thickness
- 27.1.3 Demonstrate which tools to use and how to apply filler to fill small gaps and pinholes in the surface of a blade while maintaining the correct profile shape of the blade
- 27.1.4 Ask the participants relevant questions about the limitations of using filler in terms of short pot life and layer thickness



- 27.1.5 Facilitate practice to improve the participants' ability to apply filler with the correct tools to fill pinholes and small defects in the surface of a wind turbine blade
- 27.1.6 Give constructive feedback on the participants' above explanations and ability to apply filler with the correct tools to fill pinholes and small defects in the surface of a wind turbine blade



The participants shall:

- 27.1.7 Share their understanding of the limitations of using filler in terms of short pot life and layer thickness
- 27.1.8 Practise the ability to apply filler with the correct tools to fill pinholes and small defects in the surface of a wind turbine blade

## LESSON 28 - TRAILING EDGE REPAIRS

380 min.

The aim of the lesson is to enable the participants to conduct a laminate repair on the trailing edge area of a wind turbine blade safely and in accordance with a work instruction.

**Note** *Trailing edge repairs must be carried out in accordance with a blade manufacturer's work instruction. Where these are not impossible to obtain, then the training provider shall create a work instruction.*

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 264) **Take responsibility** for conducting a laminate repair on the trailing edge area of a wind turbine blade safely and in accordance with a work instruction (Ability, intermediate level)

### ELEMENT 28.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Learning objective:

- 265) The participants can **act independently** in applying the knowledge gained during the general safety lessons to the working environment to minimise the risks associated with composite repair work (Ability, intermediate level)



The instructor shall:

- 28.1.1 Continually assess and give feedback on the participants' ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work



The participants shall:

- 28.1.2 Practise the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

#### ELEMENT 28.2 - REPAIR TASK

Learning objective:

- 266) The participants can **act independently** in applying the knowledge gained during Lesson 26 (laminare repairs) to the repair task (Ability, intermediate level)



The instructor shall:

- 28.2.1 Assess and give feedback on the participants' ability to apply the lamination and curing skills gained in Lesson 26 (Laminare Repairs) to laminate repairs on the trailing edge



The participants shall:

- 28.2.2 Apply the lamination and curing skills gained in Lesson 26 (Laminare Repairs) by practising the ability to carry out laminate repairs on the trailing edge (with minimal help from the instructor)

#### ELEMENT 28.3 - CRACK REPAIRS

Learning objectives:

- 267) The participants can **perform** the repairing of cracks running parallel to the trailing edge in accordance with a work instruction (Skills, intermediate level)
- 268) The participants can **act independently** in repairing cracks running parallel to the trailing edge by using a temporary hardback repair to support the laminate repair on one side of the trailing edge and then removing the temporary hardback and completing the repair by laminating the remaining side of the trailing edge (Ability, intermediate level)



The instructor shall:



- 28.3.1 Explain the requirement to perform repairs in accordance with an approved work instruction by considering the safety and quality implications of repair work on the trailing edge
- 28.3.2 Using the trailing edge section created in the sandwich panel topic create a crack running parallel to the trailing edge that extends through both sides of the trailing edge section but allows sufficient undamaged material at either end of the crack to allow the correct overlaps for the laminate repair
- 28.3.3 Demonstrate:
- a. how to remove the damaged material from the trailing edge
  - b. how to create a temporary hardback repair on one side of the trailing edge and explain that this is temporary and to support the lamination of the other side of the trailing edge
  - c. how to laminate and cure one side of the trailing edge using the temporary hardback repair as a support for the lamination
  - d. how to remove the temporary hardback repair, and laminate and cure the remaining side of the trailing edge
- 28.3.4 Facilitate practice to improve the participants' ability to repair cracks running parallel to the trailing edge by using a temporary hardback repair to support the laminate repair on one side of the trailing edge, and then removing the temporary hardback and completing the repair by laminating the remaining side of the trailing edge
- 28.3.5 Give constructive feedback on the participants' ability to repair cracks running parallel to the trailing edge



The participants shall:

- 28.3.6 Practise the ability to repair cracks running parallel to the trailing edge by using a temporary hardback repair to support the laminate repair on one side of the trailing edge and then removing the temporary hardback and completing the repair by laminating the remaining side of the trailing edge

#### ELEMENT 28.4 - RECREATING BLADE PROFILE

##### Learning objectives:

- 269) The participants can **perform** the recreation of the trailing edge profile using filler (Skills, intermediate level)
- 270) The participants can **act independently** in recreating the trailing edge profile using filler (Ability, intermediate level)



#### The instructor shall:

- 28.4.1 Explain the importance of recreating the aerodynamic profile of the blade
- 28.4.2 Demonstrate:
  - a. how to apply filler to the repair to cover the repair and to approximately match the surrounding aerodynamic profile of the trailing edge
  - b. how to use a sander to shape the filler to match the surrounding aerodynamic profile and create the correct surface finish for the adhesion of the paint layer
- 28.4.3 Facilitate practice to improve participants' abilities to:
  - a. use filler to cover the repair and to match the surrounding aerodynamic profile of the blade
  - b. use a sander to shape the filler to match the surrounding aerodynamic profile, and create the correct surface finish for the adhesion of the paint layer
- 28.4.4 Give constructive feedback on the participants' above practice



#### The participants shall:

- 28.4.5 Practise the ability to:
  - a. use filler to cover the repair and to match the surrounding aerodynamic profile of the blade
  - b. use a sander to shape the filler to match the surrounding aerodynamic profile, and create the correct surface finish for the adhesion of the paint layer

### ELEMENT 28.5 - RECORD AMBIENT TEMPERATURE AND HUMIDITY

#### Learning objectives:

- 271) The participants can **perform** the recording of the ambient temperature and humidity throughout the process using a data logger (Skills, intermediate level)
- 272) The participants can **act independently** in recording and documenting the ambient temperature and humidity throughout the entire trailing edge repair process (Ability, intermediate level)



#### The participants shall:



- 28.5.1 Without help from the instructor, act independently in recording and documenting the ambient temperature and humidity throughout the entire trailing edge repair process

## LESSON 29 - LEADING EDGE REPAIRS

440 min.

The aim of the lesson is to enable the participants to conduct laminate repairs on a leading edge safely and effectively.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 273) **Take responsibility** for conducting laminate repairs on a leading edge safely and effectively (Ability, intermediate level)

### ELEMENT 29.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Learning objective:

- 274) The participants can **act independently** in applying the knowledge gained during the general safety lessons to the working environment to minimise the risks associated with composite repair work (Ability, intermediate level)



The instructor shall:

- 29.1.1 Continually assess and give feedback on the participants' ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work



The participants shall:

- 29.1.2 Practise the ability to apply the knowledge gained during the general safety and chemical safety lessons to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process

### ELEMENT 29.2 - REPAIR TASK

Learning objective:



- 275) The participants can **act independently** in applying the lamination and curing skills gained during Lesson 26 (Laminate Repairs) to carry out laminate repairs to repairs on the leading edge (Ability, intermediate level)



The instructor shall:

- 29.2.1 Create an exercise where the participants must repair damage equivalent to cracks in the leading edge of a blade
- 29.2.2 Give constructive feedback to the participants' ability to carry out laminate repairs, with minimal help from the instructor, on the leading edge



The participants shall:

- 29.2.3 Apply the lamination and curing skills gained in Lesson 26 (Laminate Repairs) by practising the ability to carry out laminate repairs, with minimal help from the instructor, on the leading edge

### ELEMENT 29.3 - LEADING EDGE REPAIR

Learning objectives:

- 276) The participants can **perform** the repairing of delamination, holes and cracks running parallel to the leading edge in accordance with a work instruction (Skills, intermediate level)
- 277) The participants can **act independently** in safely removing damaged material from the leading edge of a blade, while creating overlaps and/or scarf joints and the correct surface finish for subsequent repair layers (Ability, intermediate level)
- 278) The participants can **act independently** in laying up, and correctly using a vacuum and heat to cure a laminate repair on the leading edge with at least two layers of biax (Ability, intermediate level)



The instructor shall:

- 29.3.1 Demonstrate how to use a grinder to safely remove damaged material from the leading edge of a blade
- 29.3.2 Facilitate practice to improve the participants' ability to:
- a. safely remove damaged material from the leading edge of a blade, while creating overlaps and/or scarf joints and the correct surface finish for subsequent repair layers



- b. lay up and correctly cure with a vacuum and heat a laminate repair on the leading edge with at least two layers of biax

29.3.3 Give constructive feedback on the participants' above practice



The participants shall:

29.3.4 Practise the ability to:

- a. safely remove damaged material from the leading edge of a blade, while creating overlaps and/or scarf joints and the correct surface finish for subsequent repair layers
- b. lay up and correctly cure with a vacuum and heat a laminate repair on the leading edge with at least two layers of biax

#### ELEMENT 29.4 - RELOCATE LEADING EDGE

Learning objectives:

- 279) The participants can **perform** the recreation of the leading-edge profile using filler (Skills, intermediate level)
- 280) The participants can **act independently** in recreating the leading-edge profile using filler (Ability, intermediate level)



The instructor shall:

- 29.4.1 Demonstrate the tools and techniques that can be used to shape the filler to the approximate profile shape of the leading edge, and explain that the final profile shape will be obtained by sanding
- 29.4.2 Facilitate practice to improve the participants' ability to:
  - a. apply filler to a laminate repair on the leading edge, and to shape the filler to approximately match the surrounding aerodynamic profile of the leading edge
  - b. shape the cured filler with a sander so that it accurately matches the surrounding aerodynamic profile of the leading edge and has the correct surface finish for the adhesion of paint
- 29.4.3 Give constructive feedback on the participants' above practice



The participants shall:

29.4.4 Practise the ability to:





- a. apply filler to a laminate repair on the leading edge and to shape the filler to approximately match the surrounding aerodynamic profile of the leading edge
- b. shape the cured filler with a sander so that it accurately matches the surrounding aerodynamic profile of the leading edge and has the correct surface finish for the adhesion of paint

## LESSON 30 - SANDWICH PANEL REPAIR

180 min.

The aim of the lesson is to enable the participants to carry out laminate repairs on the inner and outer laminate of a sandwich panel safely and effectively.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 281) **Take responsibility** for carrying out laminate repairs on the inner and outer laminate of a sandwich panel safely and effectively (Ability, intermediate level)

### ELEMENT 30.1 - MINIMISE RISKS ASSOCIATED WITH COMPOSITE FIBRE WORK

Learning objective:

- 282) The participants can **act independently** in applying the knowledge gained during the general safety module to the working environment to minimise the risks associated with composite repair work (Ability, intermediate level)



The instructor shall:

- 30.1.1 Continually assess and give feedback on the participants' ability to apply the knowledge gained during the general safety module to the working environment to mitigate the risks associated with composite repair work



The participants shall:

- 30.1.2 Practise the ability to apply the knowledge gained during the general safety and chemical safety modules to their working environment by correctly selecting and using PPE appropriate to the task in hand and to work in a safe manner with the materials and tools required for each process without help from the instructor



## ELEMENT 30.2 - REPAIR TASK

### Learning objective:

- 283) The participants can **act independently** in applying the knowledge gained during Lesson 26 (laminare repair) to the repair task (Ability, intermediate level)



### The instructor shall:

- 30.2.1 Assess and give feedback to the participants on their ability to apply the lamination and curing skills gained in Lesson 26 (Laminare Repair) to laminate repairs



### The participants shall:

- 30.2.2 Without help from the instructor, apply the lamination and curing skills gained in Lesson 26 (Laminare Repair) by practising the ability to carry out laminate repairs, with minimal help from the instructor, on the trailing edge

## ELEMENT 30.3 - REPAIR INNER AND OUTER LAMINATE

### Learning objectives:

- 284) The participants can **perform** repair of the inner and outer laminate of a sandwich panel in accordance with a work instruction (Skills, intermediate level)
- 285) The participants can **act independently** in performing repair of the inner and outer laminate of a sandwich panel in accordance with a work instruction (Ability, Intermediate level)



### The instructor shall:

- 30.3.1 Using the sandwich panel created in the sandwich panel topic, create a small hole, approximately ten millimetres in diameter, that extends through both the outer and inner laminates
- 30.3.2 Demonstrate:
- how to remove the outer laminate and the core material to reveal the inner laminate
  - how to remove damaged material from the inner laminate



- c. how to use hardback and non-structural adhesive to create a support upon which to repair the inner laminate

30.3.3 Facilitate practice to improve the participants' ability to:

- a. in accordance with a work instruction, create a support using hardback and to perform a laminate repair with the correct overlaps and fibre orientation on the inner laminate
- b. repair the outer laminate with the correct overlaps and fibre orientation, after replacing the core material

30.3.4 Give constructive feedback on the participants' above practice



The participants shall:

30.3.5 Practise the ability to:

- a. create a support using hardback and to perform a laminate repair with the correct overlaps and fibre orientation on the inner laminate (in accordance with a work instruction)
- b. repair the outer laminate with the correct overlaps and fibre orientation, after replacing the core material

## ELEMENT 30.4 - REPLACEMENT CORE

Learning objectives:

- 286) The participants can **act independently** in correctly sizing and shaping the replacement core material in a sandwich panel repair (Ability, intermediate level)
- 287) The participants can **act independently** in correctly measuring, cutting and shaping replacement core material so that it matches the profile shape of the surrounding core material with a gap of less than two millimetres on all sides in accordance with a work instruction (Ability, intermediate level)
- 288) The participants can **act independently** in bonding the replacement core material, and correctly curing the chosen material with heat and a vacuum in accordance with a work instruction (Ability, intermediate level)



The instructor shall:

30.4.1 Explain the requirement for the gap between the existing and replacement core material to be less than 2 millimetres

30.4.2 Demonstrate:

- a. how to measure, cut, and shape the replacement core material to match the profile of the surrounding core material



- b. how to apply the replacement core material to the sandwich panel, how to bond it into place using lamination resin or structural adhesive, and how to cure it using a vacuum and heat
- c. how to repair the outer laminate following the replacement of the core material

30.4.3 Facilitate practice to improve the participants' ability to, in accordance with a work instruction:

- a. correctly measure, cut, and shape replacement core material so that it matches the profile shape of the surrounding core material with a gap of less than two millimetres on all sides
- b. bond the replacement core material with either lamination resin or structural adhesive, and to correctly cure the chosen material with heat and a vacuum

30.4.4 Give constructive feedback on the participants' above practice



The participants shall:

30.4.5 In accordance with a work instruction, practise the ability to:

- a. correctly measure, cut and shape replacement core material so that it matches the profile shape of the surrounding core material with a gap of less than two millimetres on all sides
- b. bond the replacement core material with either lamination resin or structural adhesive, and to correctly cure the chosen material with heat and a vacuum

## ELEMENT 30.5 - INSPECTION AND DOCUMENTATION

Learning objective:

- 289) The participants can **act independently** in documenting with photographs all stages of the sandwich panel repair including; the vacuum levels, curing temperatures, ambient temperature, humidity, and batch numbers of all materials used (Ability, intermediate level)



The instructor shall:

- 30.5.1 Facilitate practice to improve the participants' ability to document with photographs all stages of the sandwich panel repair including; the vacuum levels, curing temperatures, ambient temperature, humidity, and batch numbers of all materials used
- 30.5.2 Give feedback on the participants' ability to document, with photographs all stages of the sandwich panel repair including; the vacuum levels, curing temperatures, ambient temperature, humidity, and batch numbers of all materials used



The participants shall:

- 30.5.3 Practise the ability to document with photographs all stages of the sandwich panel repair including; the vacuum levels, curing temperatures, ambient temperature, humidity, and batch numbers of all materials used

## LESSON 31 - BOND LINE REPAIRS

180 min.

The aim of the lesson is to enable the participants to be able to drill injection and verification holes and subsequently inject appropriate adhesive according to the work instruction to repair the bond line safely and effectively.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- 290) **Take responsibility** for drilling injection and verification holes, and subsequently injecting structural adhesive to repair the bond line safely and effectively (Ability, intermediate level)

### ELEMENT 31.1 - DEBONDING

Learning objective:

- 291) The participants can **act independently** in correctly identifying and documenting areas on a blade where the bond line has failed (Ability, intermediate level)



The instructor shall:

- 31.1.1 Define the term 'bond line' and describe where bond lines are located on a blade
- 31.1.2 Explain the possible defects that can occur within a bond line on a blade
- 31.1.3 Demonstrate how to identify areas in a blade where a bond line has failed by using tap testing and visual inspection
- 31.1.4 Create an exercise where the participants must identify areas where a bond line has failed
- 31.1.5 Give constructive feedback on the participants' ability to correctly identify and document areas on a blade where the bond line has failed



The participants shall:



31.1.6 Practise the ability to correctly identify and document areas on a blade where the bond line has failed

## ELEMENT 31.2 - INJECTION OF ADHESIVE

### Learning objectives:

- 292) The participants can **recognise** the needs for caution, and follow a blade manufacturer's work instruction when repairing bond lines that are located above structural parts (Knowledge, basic level)
- 293) The participants can **describe** how to drill injection and verification holes through the laminate without damaging the underlying structural parts of the blade (Knowledge, basic level)
- 294) The participants can **describe** how to inject structural adhesive into the area of debonding and how to verify that it has flowed across the de-bonded area (Knowledge, basic level)



### The instructor shall:

- 31.2.1 Explain the need for caution and the need to follow a blade manufacturer's work instruction when repairing bond lines that are located above structural parts like the spar or webs of the blade
- 31.2.2 Demonstrate how to identify the laminate thickness from a blade drawing
- 31.2.3 Explain:
  - a. how to drill injection and verification holes through the laminate without damaging the underlying structural parts of the blade
  - b. how to position the holes so that adhesive can be injected from one side and flow across the area of debonding
  - c. how to inject structural adhesive into the area of debonding and how to verify that it has flowed across the de-bonded area
  - d. the limitations of this method in terms of size and quality
- 31.2.4 Ask the participants relevant questions about:
  - a. how to drill injection and verification holes through the laminate without damaging the underlying structural parts of the blade
  - b. how to inject structural adhesive into the area of debonding, and how to verify that it has flowed across the deboned area



The participants shall:

31.2.5 Share their understanding about:

- a. how to drill injection and verification holes through the laminate without damaging the underlying structural parts of the blade
- b. how to inject structural adhesive into the area of debonding and how to verify that it has flowed across the de-bonded area

### ELEMENT 31.3 - INJECTING MATERIAL IN THE TRAILING EDGE

Learning objectives:

- 295) The participants can **act independently** in determining the correct dimensions of the bond line in the trailing edge from a blade drawing or blade manufacturer's work instruction (Ability, intermediate level)
- 296) The participants can **act independently** in drilling injection and verification holes in the trailing edge (Ability, intermediate level)
- 297) The participants can **act independently** in injecting appropriate adhesive into the trailing edge in accordance with a work instruction (Ability, intermediate level)



The instructor shall:

31.3.1 Demonstrate:

- a. how to determine the correct dimensions of the trailing edge bond line on a blade from a blade drawing or manufacturer work instruction
- b. how to drill injection and verification holes along the trailing edge so that the spacing does not compromise the integrity of the trailing edge
- c. how to inject structural adhesive into the trailing edge

31.3.2 Facilitate practice to improve the participants' ability to:

- a. determine the correct dimensions of the bond line in the trailing edge from a blade drawing or blade manufacturer's work instruction
- b. drill injection and verification holes in the trailing edge
- c. inject adhesive into the trailing edge in accordance with a work instruction



31.3.3 Give constructive feedback on the participants' above practice



The participants shall:

31.3.4 Practise the ability to:

- a. determine the correct dimensions of the bond line in the trailing edge from a blade drawing or manufacturer's work instruction
- b. drill injection and verification holes in the trailing edge
- c. inject adhesive into the trailing edge in accordance with a work instruction

## LESSON 32 - SUMMARY AND FINAL TEST

60 min.

The aims of the final test are to summarise the blade repair module and to assess the participants' understanding of key theoretical and safety related elements of the module.

After having successfully completed this lesson of the Blade Repair Module, the participants can:

- a. Pass the final test

### ELEMENT 32.2 - SUMMARY



The instructor shall:

32.2.1 Summarise the blade repair module referring to the learning objectives covered

### ELEMENT 32.3 - FINAL TEST



The instructor shall:

- 32.3.1 Introduce the final test and explain the criteria for the test with reference to the participant performance assessment
- 32.3.2 Conduct the test in accordance with the participant performance assessment criteria
- 32.3.3 Upon completion of the test, check the participants' answers and give feedback to the participants about the test results
- 32.3.4 In the event that a participant does not pass the test, conduct an interview with the participant in accordance with the participant performance assessment





## LESSON 33 - TRAINING REVIEW

30 min.

The aim of this lesson is to enable the participants to reflect on and process their learning outcome and key take-aways from the module, aiming to achieve a high learning transfer from the module to their way of working.

### ELEMENT 33.1 - TRAINING REVIEW



The instructor shall:

- 33.1.1 Re-present the overall aims and learning objectives of the module for the participants' comparison of their learning outcomes and the achievement of their previously stated expectations for the module



The participants shall:

- 33.1.2 Reflect on their learning outcome and key takeaways from Blade Repair Module, aiming to achieve a high learning transfer from the module to their way of working by means of e.g.
- group discussion or walk & talk
  - questions & answers in class, or where suitable

**Note** *The instructor may additionally conduct a local evaluation of the training.*

### ELEMENT 33.2 - FEEDBACK SESSION



The instructor shall:

- 33.2.1 Give an overall feedback and feed forward on the participants' learning outcome inspired by the training as well as from the training-review-session
- 33.2.2 Encourage the participants to examine and grow awareness of how their own workplace WTG types/WTG environments differ from the training scenario environment. Promote participants discussion with their colleagues about how blade repair content, methods and techniques are similar or different to the local specific conditions identified after the module completion



GLOBAL WIND  
ORGANISATION

# Annexes

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## ANNEX 1 - EQUIPMENT LIST

Any equipment used during this GWO training module shall meet or exceed the minimum requirements of the national standards in the country where the training is taking place. When working in a country where there is no applicable national standard, the equipment shall meet or exceed the minimum requirements of the European standards.

### 1. Documentation:

1. safety data sheets for all materials used throughout the training module
2. technical data sheets (where applicable) for materials used throughout the training module
3. work instruction examples
4. photocard
5. blade inspection report
6. risk assessment templates and examples (hand out)

### 2. Measuring Tools (enough for all participants):

1. ambient temperature & humidity data logger
2. thermocouple temperature gauge and probes
3. absolute pressure gauge (vacuum gauge)
4. 0-150 mm rule
5. 0-300 mm rule
6. tape measure
7. weighing scale
8. wet film thickness gauge

### 3. Power tools (enough for all participants)

1. heating blankets
2. vacuum pump
3. electric orbital sanding machine
4. electric grinding machine



#### 4. Hand tools (enough for all participants)

1. scissors
2. retractable blade knife
3. clamps
4. flat aluminium mould 1000x600
5. caulking gun
6. straight edge
7. filling knife
8. spatula
9. glass fibre cutter
10. chisel
11. bolt roller
12. 1-ounce hammer (tap tester)

#### 5. Tools consumables

1. sufficient types and numbers of discs etc.
2. painting rollers
3. brushes
4. cleaning cloth
5. rags
6. diamond cutting wheel
7. marker pens
8. duct tape
9. mask tape
10. plastic cover
11. rubbish bag



12. surface cleaner (preferably isopropyl alcohol)

## 6. Consumable materials:

1. unidirectional fibreglass material
2. biaxial stitched mat fibreglass
3. triaxial stitched mat fibreglass
4. core material (not honeycomb)
5. epoxy gelcoat kit
6. polyester gelcoat kit
7. epoxy lamination resin kit
8. polyester lamination resin kit
9. paint
10. polyurethane glue
11. filler
12. 'Araldite 2021' (or similar non-structural adhesive)
13. mixing pots
14. mixing sticks
15. vacuum foil
16. breather fabric
17. peel ply
18. release film
19. vacuum hose
20. sealant tape (tacky tape)
21. polyurethane topcoat
22. release agent
23. vinyl ester



## 7. Personal Protective Equipment

1. air fed mask
2. filter
3. safety glasses
4. face shield
5. dust suits
6. lamination suits
7. protective sleeves
8. thin nitrile gloves
9. cotton inner gloves
10. nitrile gloves
11. handling gloves
12. boot covers
13. hearing protection
14. face mask
15. anti-vibration gloves
16. safety boots

**Note** *All equipment shall be maintained and where appropriate, inspected and tested in accordance with current national standards/ legislation and manufacturers' recommendations.*



## ANNEX 2 - PRACTICAL EXERCISE (EXAMPLE)

### 1. Introduction

This exercise will enable the participants to produce a sandwich panel that can be used for later repair exercises.

Exercise name	Sandwich Panel
PPE	Disposable coverall Gloves (type dependant on materials used) Mask (type dependant on materials used) Eye protection Hearing protection
Materials	Mould release agent Flash tape Gelcoat Vacuum consumables Matrix material (epoxy) Fibreglass (size and weight as indicated by the instructor) 10 mm core material (PVC foam or balsa wood) Vacuum consumables Thermocouple temperature probe
Tools	Non-metallic scraper for mould surface Mixing pots Mixing sticks Brushes Rollers Scissors Bolt roller Vacuum pump (or supply from workshop) Heating blanket
Documentation	SDS for materials used TDS for materials used

### 2. Exercise 1 – Mould Preparation

- Carefully remove any debris from the mould surface using non-metallic tools.
- Clean the surface of the mould using isopropyl alcohol.



3. Apply a thin layer of mould release agent to the mould surface and allow it to dry for 1 to 2 minutes.
4. Remove any excess release agent using a clean dry cloth.
5. Allow the release agent to dry for a further 15 minutes.
6. Apply flash tape to the mould surface according to the instructions given by the instructor.
7. Apply vacuum tape on top of the flash tape.

### 3. Exercise 2 - Gelcoat

1. Find the SDS for the gelcoat being used and identify the PPE required. Fill in the information in the table below:

Gloves required	
Mask required	

2. Find the TDS for the gelcoat, and use this to calculate the amount of gelcoat required to cover the mould surface at a layer thickness of 0.8mm. Enter the information in the table below:

Total amount of gelcoat	
Mixing ratio	
Amount of gelcoat base	
Amount of gelcoat hardener	
Curing time for gelcoat	

3. Carefully weigh out and thoroughly mix the gelcoat.
4. Apply the gelcoat to the mould surface and distribute evenly using a roller.
5. Allow the gelcoat to tack-off in accordance with the TDS.

### 4. Exercise 3 - Dry material preparation

1. Cut out the fibreglass mats and core material to the sizes indicated by the instructor.
2. Shape the core material as directed by the instructor.

### 5. Exercise 4 - Matrix material





1. Find the SDS for the matrix material being used and identify the PPE required for the matrix material being used. Enter this information in the table below:

Type of gloves required	
Type of mask required	
Type of mask filter required	
Other PPE required	

2. Find the TDS for the matrix material being used and use this to calculate the amount of matrix required for the panel. Enter the information in the table below:

Total amount of matrix	
Mixing ratio	
Amount of matrix base	
Amount of matrix hardener	
Curing time for matrix	
Curing temperature for matrix	

## 6. Exercise 5 - Panel assembly

1. Carefully weigh out and thoroughly mix the material.
2. Apply a thin layer of matrix material onto the gelcoat on the mould.
3. Apply the first layer(s) of glass fibre onto the gelcoat on the mould.
4. Apply matrix to the glass fibre, and thoroughly wet out the glass using a bolt roller, ensuring the fibres are straight.
5. Apply the core material to the first layer of glass and apply a thin layer of matrix on top of the core material.



6. Place the subsequent layers of glass fibre onto the matrix and thoroughly wet out the glass fibre with matrix.

## 7. Exercise 6 - Curing

1. Apply peel ply on top of the glass fibre and remove the air.
2. Apply release film onto the peel ply.
3. Place the thermocouple onto the release film.
4. Apply breather fabric onto the release film.
5. Insert a vacuum hose and cover the entire panel with vacuum foil. Ensure that the vacuum foil is sealed to the vacuum tape all the way around.
6. Apply vacuum to the panel, check for air leaks, and fix air leaks.
7. Place a heating blanket onto the panel and adjust the temperature to the curing temperature in the TDS. Note the time that the blanket reaches the curing temperature.



## ANNEX 3 - WORK INSTRUCTION (EXAMPLE)

**Note** *This annex includes a template that must be developed by the training provider into a work instruction for use during the blade repair training module. It details the required elements in a work instruction and some text as a suggestion of what should be included in each section.*

*The template is incomplete in some areas and is therefore **not** intended to be used in its current form*

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### SAFETY

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Work involving the repair of glass fibre-reinforced composite material carries risks to you and those around you. To limit these risks, read and obey the warnings below!



#### WARNING

Obey the manufacturer's instructions when you use cleaning agents, resins, sealants, fillers, and paints. These materials are hazardous to your health and, if used incorrectly, represent a fire hazard.

Wear the correct personal protective equipment as specified in the safety data sheet for the materials that you are working with. The materials used in fibre-reinforced composite repair can cause life-changing injuries or death.

Wear the correct personal protective equipment: eye protection, correct filter dust mask, hearing protection, disposable coverall, and the correct gloves for the task when you cut, abrade, or drill fibre-reinforced composite materials. The dust from these materials can cause lung injuries and skin irritation. These activities create high levels of noise, which can damage your hearing. Flying debris from these activities can damage your eyes.

### Environmental conditions

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The materials used in the repair of fibre-reinforced composite materials are sensitive to environmental conditions like ambient temperature and humidity. When these materials are used outside of their intended temperature and/or humidity range, they may not cure as intended by the manufacturer, leading to health risks from uncured material and a loss of material performance resulting in a failure of the repair. To limit these risks, read and obey the warning below!



#### WARNING

Obey the environmental conditions described in the Technical Data Sheet for all materials used.

The ambient temperature and humidity must be recorded using a suitable data logger for the entire duration of the repair process.

### Documentation of the repair

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During the repair process, it is of utmost importance to document each stage of the repair with photographs, and to include these in a repair report. The repair report must contain, as a minimum:

- Batch numbers and expiry dates of all materials used



- 
- A record of ambient temperature and humidity throughout the repair process
  - Curing temperature achieved
  - Vacuum levels achieved
  - References to documentation used during the repair
  - Photographs (including the size and location, site name, turbine ID number, blade serial number and technician) of:
    - The initial damage
    - The repair after damaged material has been removed
    - Each repair layer applied
    - Filler applied
    - Gelcoat and or paint applied

The photocard in Annex 4 can be used for this purpose.

### **Documentation**

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#### **Safety documentation**

The following safety documentation is required before commencing repair activities:

- Safety data sheet for each material
- Company specific safety instructions
- Risk assessments

#### **Reference documentation**

The following reference documentation is required before commencing repair activities:

- Technical data sheet for each material
- Company specific repair instructions
- Blade drawings, if not included in the repair instruction

#### **Personal Protection Equipment**

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The following personal protective equipment is the minimum to be expected for carrying out repair work. It must be supplemented with specifics from the safety data sheet and company specific requirements.

- Disposable coverall
- Safety footwear
- Eye protection



- 
- Hearing protection
  - Cut resistant gloves
  - Chemical resistant gloves (specific to the materials used)
  - Nitrile gloves for general work
  - Mask (with filters specific to the materials used)
  - Dust mask

### **Tools**

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The following list of tools is the minimum to be expected for carrying out repair work. It must be supplemented with additional tools specific to the repair being performed.

- Knife with a retractable blade
- Tape measure (or equivalent)
- Chisels
- Hammer
- Photocard
- Grinding machine
- Sanding machine
- Vacuum pump
- Bolt roller
- Foam paint roller
- Vacuum gauge
- Data logger (for ambient temperature and humidity)
- Thermocouple temperature probe
- Resin trap
- Weighing scales
- Hardness tester (Barcol or ShoreD)
- Wet film gauge
- Plastic scrapers

### **Materials**

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#### **Consumable materials**



The following list of consumable materials is the minimum to be expected for carrying out repair work, it must be supplemented with additional consumable materials specific to the repair being performed.

- Paint brushes
- Foam paint rollers
- 80 and 120 grit grinding discs
- 120 and 240 grit sanding discs
- 1" and 2" Masking tape
- Flash tape
- Vacuum sealant tape
- Mixing pots
- Mixing sticks
- Waste chemical bags
- General waste bags
- Vacuum hose
- Vacuum foil
- Breather fabric
- Release film
- Peel-ply
- Cleaning agent (like isopropyl alcohol)
- Cleaning rags

### **Repair materials**

The following list of repair materials is the minimum to be expected for carrying out repair work and it is very general in nature considering all repair scenarios. It must be supplemented with additional repair materials specific to the repair being performed.

- Glass-fibre mats
- Hardback material
- Core material
- Matrix material
- Non-structural adhesive (like Araldite 2021)



- Structural adhesive
- Filler
- Gelcoat
- Paint

### Repair stage 1

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#### Preparation

Gather all documentation, tools and materials that are required for the inspection and repair task.

#### Assessment and damage removal

- 1) Photograph the initial damage, making sure to include a scale in the photographs to indicate the size of the damage. Make a note of any relevant observations that might indicate the root cause of the damage
- 2) Perform a tap test around the damage to identify the extent of underlying delamination. Mark this extent on the blade surface.



Note

*If the laminate has been in prolonged contact with water, it must be dried before repair activities are commenced.*

- 3) Carefully remove all the damaged material, taking care to not damage underlying structural elements like spar caps.
- 4) Assess the size of the repair needed, taking into consideration the overlaps required for each layer of laminate and the size of the core material (if required).



Note

*During removal of the damaged material, it may be found that the repair size exceeds the ability of the technician performing the repair. In this case, work should stop and the OEM contacted for advice on how to proceed.*

- 5) Carefully grind the existing laminate around the area being repaired, to create overlaps in each layer of laminate being repaired.
- 6) Clean the repair area with a cleaning agent, ensuring that you remove all dust, debris and oils

### Repair stage 2

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#### Preparation

- 1) Measure the extent of the overlaps and the removed core material created above. Use these measurements to carefully cut and shape the repair pieces as required, taking care to ensure the correct fibre orientation for each repair layer.



Note

*A fundamental principle of fibre-reinforced composite repair work is that you should replace what you take out. This applies in the case of blade repair work, but you should consult the OEM specific repair instructions and or blade drawings to identify which materials to use for the repair task.*

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- 
- 2) Calculate the amount of resin required for each repair layer based upon the weight of the glass-fibre and the size of the core material being replaced. Note down the amount for each layer.

### Applying the repair



**WARNING** Mixing large quantities of matrix materials can cause a runaway exothermic reaction and lead to a fire. Take precautions to avoid an exothermic reaction by only mixing sufficient quantities of matrix material for the repair being performed, and, where large quantities are required, by dividing this into smaller quantities.

- 3) For the first repair layer, weigh out and thoroughly mix the matrix material components.
- 4) Apply resin to the existing laminate with a paint brush, and carefully apply the first glass fibre repair layer. Apply enough resin to fully wet out the glass fibre mat. Carefully roll the mat with a bolt roller to ensure complete wet-out of the fibres with matrix and to remove any air bubbles.
- 5) For the next repair layer, weigh out and thoroughly mix the matrix material components.
- 6) Apply the next repair layer and wet-out as described in step 4.
- 7) Continue steps 5 and 6 until all repair layers are applied.



### Note

*If the repair is small and only has a small number of layers, it is possible to mix all the matrix material and apply all of the repair layers in one go. Consult the OEM specific instructions for the maximum number of layers that can be applied at a time.*

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### Vacuum bagging

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- 1) Clean the area around the repair and apply flash tape to the blade surface so that it surrounds the repair. Ensure that there are no creases or folds in the flash tape.
- 2) Apply vacuum sealant tape on top of the flash tape.
- 3) Apply peel ply on top of the last laminate repair layer and roll this to remove any air bubbles.
- 4) Apply the release film on top of the peel ply.
- 5) Apply a thermocouple probe on top of the release film, placing it to the side of the repair so that it does not cause an impression in the repair layers. Guide the wires from the thermocouple probe out from the repair, and seal with vacuum sealant tape. Connect the wires to the temperature gauge.
- 6) Apply the breather fabric on top of the release film.
- 7) Cut two lengths of vacuum hose – one for the vacuum pump and one for the vacuum gauge. The pieces should be long enough to reach the vacuum pump and gauge. Wrap the repair end of the vacuum hose pieces with breather fabric to ensure that they do not become clogged by vacuum film or resin.
- 8) Where the vacuum hoses cross the vacuum sealant tape, additional vacuum sealant tape should be applied on top of the hoses to ensure a seal.





- 
- 9) Connect the vacuum gauge to one of the vacuum hoses, and attach the other hose to the vacuum pump. Use a resin trap between the repair and the vacuum pump.
  - 10) Apply the vacuum film on top of the repair and press it down onto the vacuum sealant tape.
  - 11) Start the vacuum pump and check for air leaks around the repair. Consult the OEM-specific instruction for the vacuum level to be achieved.

### Curing

---

- 1) Consult the TDS for the matrix material, to ascertain the correct curing temperature and time.
- 2) Place a heating blanket over the repair and switch it on. Adjust the temperature of the heating blanket until the temperature gauge reaches the correct curing temperature.
- 3) Make a note of the time that the temperature gauge reaches the correct temperature – this is the time at which the curing duration starts.
- 4) Allow the repair to cure for the time specified in the TDS.



#### **WARNING**

The cured vacuum bagging consumables will have sharp edges

- 5) After the specified curing time has elapsed, carefully remove the vacuum bagging materials from the repair, leaving the peel ply in place.
- 6) Verify that the matrix material has reached the specified hardness in the TDS using a Barcol or ShoreD tester.

### Filling

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- 1) Remove the peel ply from the repair, and sand the surface to the required finish as stated in the TDS for the filler being used.
- 2) Weigh out and mix the filler (if using a two-component filler)
- 3) Apply filler to the repair and shape using a plastic scraper so that it matches the surrounding blade profile shape.
- 4) Allow the filler to cure fully in accordance with the TDS.
- 5) After the filler has cured, sand the filler using 120 grit paper so that it matches the surrounding blade profile as closely as possible.

### Paint or gelcoat

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- 1) Consult the OEM specific repair instruction to ascertain whether gelcoat or paint or both are required to finish the repair.
  - 2) Clean the filler surface using an appropriate cleaning agent and allow any residual cleaning agent to fully evaporate before proceeding.
-

**Note**

*Steps 3 to 6 below will depend on the OEM's requirements. Consult the OEM specific instructions. If the OEM demands both gelcoat and paint, proceed with steps 3 to 6. If the OEM only requires paint, omit steps 3 to 5.*

- 3) Calculate and then weigh out and mix the required amount of gelcoat, and apply this to the filler, distributing it evenly and to the specified layer thickness with a plastic scraper. Verify the layer thickness using a wet film gauge.
  - 4) Allow the gelcoat to fully cure in accordance with the TDS.
  - 5) Sand the gelcoat to the required surface finish in accordance with the TDS for the paint.
  - 6) Calculate and then weigh out and mix the required amount of paint and apply this to the sanded gelcoat, distributing it evenly and to the specified layer thickness using a foam roller. Verify the layer thickness with a wet film gauge.
-



## ANNEX 4 - PHOTOCARD

Below is an example of a photocard that can be used by the participants during the blade repair and inspection exercises. This should be printed and laminated so that it can be written on and used in each photograph taken to ensure consistency.

<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>	<b>cm</b>											
<b>2</b>												<b>17</b>											
<b>3</b>	<div style="border: 1px solid black; padding: 5px;"> <p><b>Date:</b></p> </div>											<b>16</b>											
<b>4</b>												<div style="border: 1px solid black; padding: 5px;"> <p><b>Site:</b></p> </div>											<b>15</b>
<b>5</b>																							<b>14</b>
<b>6</b>	<div style="border: 1px solid black; padding: 5px;"> <p><b>Company:</b></p> </div>											<b>13</b>											
<b>7</b>												<div style="border: 1px solid black; padding: 5px;"> <p><b>Technician:</b></p> </div>											<b>12</b>
<b>8</b>																							<b>11</b>
<b>9</b>	<div style="border: 1px solid black; padding: 5px;"> <p><b>Turbine ID:</b></p> </div>											<b>10</b>											
<b>10</b>												<div style="border: 1px solid black; padding: 5px;"> <p><b>Blade Serial number:</b></p> </div>											<b>9</b>
<b>11</b>																							<b>8</b>
<b>12</b>	<div style="border: 1px solid black; padding: 5px;"> <p><b>Radius:</b></p> </div>					<div style="border: 1px solid black; padding: 5px;"> <p><b>Blade Side:</b></p> </div>					<b>7</b>												
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<b>14</b>	<div style="border: 1px solid black; padding: 5px;"> <p><b>Photo No.:</b></p> </div>					<div style="border: 1px solid black; padding: 5px;"> <p><b>Dist. From LE/TE:</b></p> </div>					<b>5</b>												
<b>15</b>											<b>4</b>												
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<b>cm</b>	<b>12</b>	<b>11</b>	<b>10</b>	<b>9</b>	<b>8</b>	<b>7</b>	<b>6</b>	<b>5</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>											



## ANNEX 5 - VERSION HISTORY

Amendment date	Version	Approved by & date	Description of changes
April 2022	3	GWO TC APRIL 2022	<p><u>Taxonomy alignment throughout</u></p> <p>The section Understanding GWO learning objectives has been updated to reflect the reviewed GWO Taxonomy Framework.</p> <p>All learning objectives have been updated with action verbs that reflect the taxonomic levels (basic, intermediate, and advanced level) and the domain (knowledge, skills, and ability) without changing the content of the element.</p> <p>Action verb ‘demonstrate’ in learning objectives is changed to relevant action verb level/domain.</p> <p>Learning activity “demonstrate” was changed to ‘practise’ because during training activities, the participants are in a learning process and abilities should be trained, not evaluated.</p> <p>Learning activities have been aligned to match the updated learning objectives with a focus on participant engagement.</p> <p>Delegates have been changed to Participants, as participant is the proper designation for a person participating in an activity.</p> <p>Training staff has been changed to Instructors.</p> <p>The instructor’s perspective has been changed to a generic perspective accommodating different types of training.</p> <p>All instructor guidelines have been compiled in one section under the individual elements.</p> <p>More guidelines on the use of feedback have been added to emphasize its importance and ensure its effective use by involving the participants.</p> <p>All learning objectives have been numbered throughout the standard.</p> <p>New learning objectives have been created for all lessons that describe the overall ability the participants should acquire during the specific lesson. This focuses the attention on how knowledge and skills support the responsible performance of the employee in the context of the job and the deeper involvement enables participants to learn and remember more deeply.</p> <p>Learning objectives previously positioned at the beginning of a training lesson have been moved to the relevant lesson elements and updated with new taxonomic levels (basic, intermediate, and advanced) and action verbs that reflect these levels. This makes more evident the connection between the learning objectives, the instructor actions, and the participants actions.</p> <p>The Introduction lesson for all standards has been updated to ensure alignment between all GWO training standards for generic lessons.</p>



The Training Review lesson for all standards has been updated to ensure alignment between all GWO training standards for generic lessons.

For all modules, the title of lesson Learning outcomes of the XXX Module changed to Detailed description of the XXX Module.

There are no changes to the technical content and the time duration of the standard.

Amendment date	Version	Approved by & date	Description of changes
April 2021	2		

#### Taxonomy alignment throughout

- To be aligned with the reviewed GWO Taxonomy, all learning objectives have been updated with action verbs that reflect the new taxonomic levels (basic, intermediate and advanced level).
- Additionally, learning activities have been added to the standard to match the updated learning objectives e.g., learning activities that focus on participant engagement have been added for all intermediate level learning objectives to reflect the reviewed GWO Taxonomy.
- The learning domain Attitude has been changed to Ability, as ability covers both attitude issues as well as personal and professional experiences and skills and knowledge.

#### Updates to the dimensions of the Blade Repair Standard in section 9.1

Dimensions changed to:

- Laminate repairs including leading edge and trailing edge repairs affecting a maximum amount of 5 layers and a maximum repair area size of 500 cm<sup>2</sup>
- Core material replacement up to 200 cm<sup>2</sup>
- Surface repair to paint and gelcoat

#### Changes to section “Understanding GWO learning objectives”

- The section Understanding GWO learning objectives has been updated to reflect the reviewed GWO Taxonomy

#### Delegates to participants

- The Delegates have been changed to The Participants, as participant is the proper designation for a person participating in an activity.

#### Human factors

- Added as an introductory element in all the standard to initiate the participants’ focus on how human behaviour and taking responsibility influences a safe work environment. Furthermore, this focus on the human factors is also expressed in the learning objectives within the ability domain with the focus on responsibility and initiative.



#### Activity change for the introduction lesson

- To align with the other GWO standards, the activities in the introduction lesson has been changed to enable the participants in engaging in the training safely and motivated while recognizing what is expected of them during the training

#### Name change for the Evaluation lesson to Training review

- The naming of the Evaluation lesson has been changed to Training review to align with the other GWO standards

#### Content changes

- Element 2.2.1 change in focus to the importance of obtaining the most up-to-date company specific safety information
- Element 2.2.2 included MSDS as an additional source of information
- Element 3.2.1 change in focus to the importance of obtaining the most up-to-date company specific WI
- Element 4.2.1 change in focus to the importance of obtaining the most up-to-date company specific Risk Assessment
- Elements 4.4 & 4.5 removed
- Element 14.3 added “Explain the function and hazards of Stall strips, Gurney flaps, Anti- icing system”
- Element 14.3 - Adhesives: Non-structural and structural adhesives renamed as adhesives for Blade Construction and adhesives for Blade Enhancement
- Elements 14.5 moved to lesson 13 (Composites and blade construction)
- Elements 15.1.9 and 22.3 – Megohmmeter renamed as a low resistance ohmmeter
- Element 15.8.2 – removed “Explain the importance of grounding a generator”
- Element 17.3.1 - “scarfing” added and the difference between scarfing and overlap added as instructor explanation
- Element 18.3.5 added “and mention that there might be incompatible combinations of gelcoat and matrix systems.”
- Element 19.3.14 reworded to “Explain how the peel ply makes the surface of the laminate rough for the application of the next layer and it also protects the surface of the laminate from external contamination”
- Element 21.2.1 added” ...to highlight that damage categorisations can vary between companies, so participants should always adhere to company specific damage categorisations”
- Element 23.3.3 added “Explain common procedures to ensure correct reading and direct contact between receptor surface and low resistance ohmmeter (e.g., cleaning the receptor)”
- Element 26.7.1 and throughout the standard with bolt roller reworded “...to consolidate and remove air from the laminate”



- Element 28.3 – Trailing edge repair removed, and its time allocation moved to the Grinding skills lesson
- Lesson sequence changes: Sanding skills moved to be lesson 23, Grinding skills moved to be lesson 24, Surface repairs moved to be lesson 25
- Lesson 27 name change – (Filling) and shaping

Amendment date	Version	Approved by & date	Description of changes
Oct. 2020	1.1	GWO TC OCT 2020	

- GWO Standard updated to match the Corporate Visual identity of GWO (CVI)
- Each module now contains a cover page and the module name listed in the header as reference.
- New ISO Code added to standard
- All previous versions of the Change log have now been moved to Annex 5. The current change log remains at the start of the standard.
- Duplicate information removed from Section 4. Scope

The following sections have been removed due to this information now included in the new Requirements for Training and Requirements for Certification Bodies (released May 2020)

#### Section 5

- 5.3 Conformity with other training – section removed
- 5.4 Legal Requirements – Section Removed

#### Section 6

- 6.2 Facilities and Equipment – section removed
- 6.3 Theory training facilities – section removed

#### Section 8

- 8.1 Administrative arrangements – section removed
- 8.3 Requirement to upload training record in WINDA – section removed (course Codes have now been moved to section 5.6)



- 8.4 Training Providers own Records and Certificates issue – section removed

**Annex 1**

- participants Performance Assessment Form – Section removed

**Annex 2**

- Medical Assessment Form – Section removed

**All section reference numbers have now been updated**

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Amendment date	Version	Approved by & date	Description of changes
05/02/2019	1	GWO SC 05/02/2019	

**Minor corrections since launch**

**October 2019**

- Section 9.2 duration updated to clarify meaning of contact time

**First Edition**

New Training Module created

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