WAAM™

WIRE ARC ADDITIVE MANUFACTURING

Wire Arc Additive Manufacturing: a case for sustainability

The world is slowly – many would say too slowly – transitioning towards net zero carbon emissions, as the international community struggles to limit the rapidly growing impact of global heating and climate change.

For manufacturing organisations this presents a new set of challenges, at a time when many businesses are already beset with multiple pressures, ranging from global supply chain disruption to the difficulty of recruiting skilled labour.

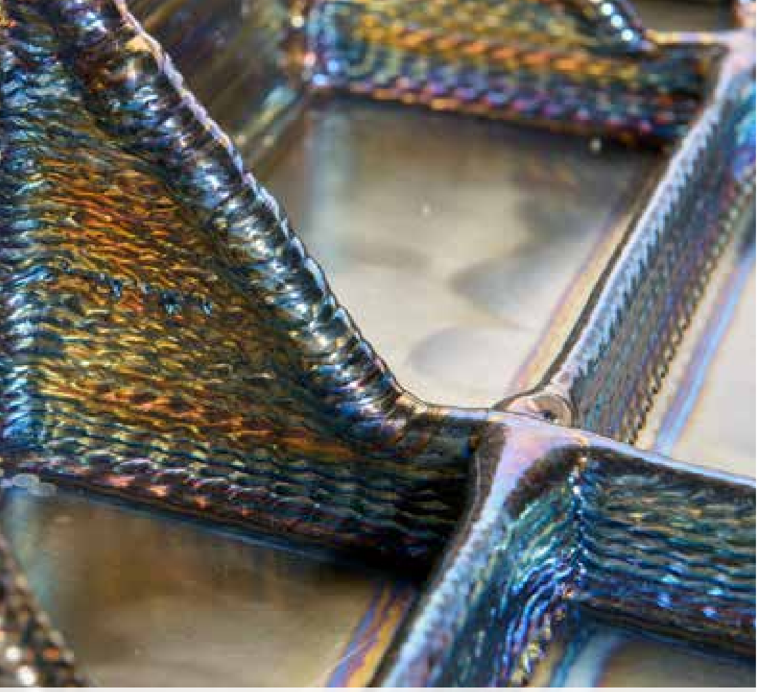
Ignoring the risk of climate change is not an option. Taking action is both a moral responsibility and a commercial necessity.

Governments are creating ever tougher regulatory environments that control carbon emissions and protect the environment, while stakeholders increasingly expect businesses to have strong environmental policies and to actively take specific actions that are seen to make a difference.

Shareholders, employees and customers are all prepared to take their support and custom elsewhere if a business fails to deliver on its environmental commitments. For many manufacturers, adopting sensible strategies to reduce carbon emissions and waste by-products makes sense at many different levels.

They can, for example, improve production efficiency and minimise waste disposal costs, while also driving innovations that lead to improvements in manufacturing processes or the design of products that can command higher profit margins.

There comes a point, however, where once the easy steps have been taken, it becomes increasingly difficult to make more than marginal gains. It's at this stage where it can pay to take a step back and reassess existing manufacturing processes or systems.



The WAAM process keeps material usage to a minimum, eradicating waste

The growth of additive manufacturing

The use of additive manufacturing technologies has risen dramatically in recent years, as an alternative to traditional subtractive processes, such as CNC milling and grinding. AM is being adopted across industry, for prototyping, the development of tooling, low volume product customisation and medium volume part production, where numbers of small, identical components can be fitted into a confined product area. Powder bed Additive Manufacturing (AM) is the most commonly used form of this technology. It offers several benefits, especially freedom of design and the ability to build complex part geometries. The process does, however, involve relatively large volumes of powder, much of which can end up being wasted, as the entire build space has to be filled with powder, even for small parts. Additionally, the printed part will require post processing: stress relief, heat treatment, machining etc. This adds further to the cost and complexity of manufacture.

Material and energy costs

It is not unusual for around 70% of the feedstock material required for powder bed AM to be wasted. Although this can sometimes be recycled, energy is consumed during its manufacture, transport, processing and disposal. Similar problems are also associated with subtractive CNC machining processes, where the desired shape is milled, ground or drilled from a solid block of metal. Additionally, the low deposition rates of powder bed AM machines result in long build times. Combined with the use of high-powered lasers this can significantly increase overall energy consumption.

An alternative form of AM, wire arc additive manufacturing (WAAM) – see side bar – can reduce waste feedstock considerably; often to less than 10% of the total used. Just as importantly, the process is ideal for the production of large metal parts and offers an extremely cost-effective and energy-efficient alternative to traditional casting and forging processes; it is also far faster to produce a part, from design to delivery, reducing typical lead times from a year or more, to a few weeks or less.

One of the key areas of application – and one where it can make a significant contribution to the reduction in energy consumption and the carbon footprint for each manufactured part – is for the repair or refurbishment of industrial products.

Product repair and reuse

Unlike other forms of subtractive or additive manufacturing, WAAM (being a directed energy deposition AM process) is ideal for the repair or reconstruction of metal parts, from gear wheels to large support structures. WAAM is unique in its ability to repair parts that would otherwise be scrapped and to do this in a way that retains or enhances the original mechanical characteristics of the part in a resource-efficient manner.

First WAAM full-scale prototype of a titanium pressure vessel to be used in future manned missions for space exploration

What is Wire Arc Additive Manufacture (WAAM)?

Wire and Arc Additive Manufacturing (WAAM) is a fusion and wire-based additive Manufacturing (AM) technology that uses a robotic arm to build, layer upon layer, a desired shape in a range of metals.

It is characterised by relatively high material deposition rates, which make it ideal for the production of medium to large sized components.

WAAM is an innovative process that has gained considerable industrial attention due to its potential to reduce cost and environmental impact, especially by comparison with traditional subtractive approaches.

Many of these advantages arise from lower material utilisation, making the process significantly more efficient.

Other important business drivers for the adoption of WAAM include freedom of design, customisation and faster time to market.

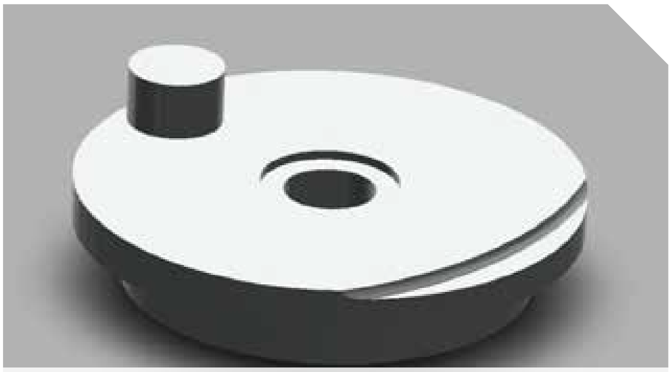


Fig.1 - Driver disk

Perhaps the best method of demonstrating these advantages is to consider a product Life Cycle Assessment (LCA) of a typical part. In our example, we've selected a steel disk, which drives a crank via a protruding pin weighing 36.5kg (see fig 1). Our comparison is between a part where the disk has been machined conventionally and the pin additively printed, and an identical part that has been forged, followed by rough and then final machining (see fig 2 for a simple comparison of production processes).

Our scenario is based on a real-world application where the original part is used in heavy industry and is produced by an OEM in Spain for an installation in Norway. If the part fails or begins to wear outside of its safe operating parameters it would normally be replaced. This would require a new forging to be produced and finished, a process that is potentially expensive and lengthy; as noted above, this could take many months. The part would also have to be shipped across Europe, with carbon emissions from whichever method of transport is used.

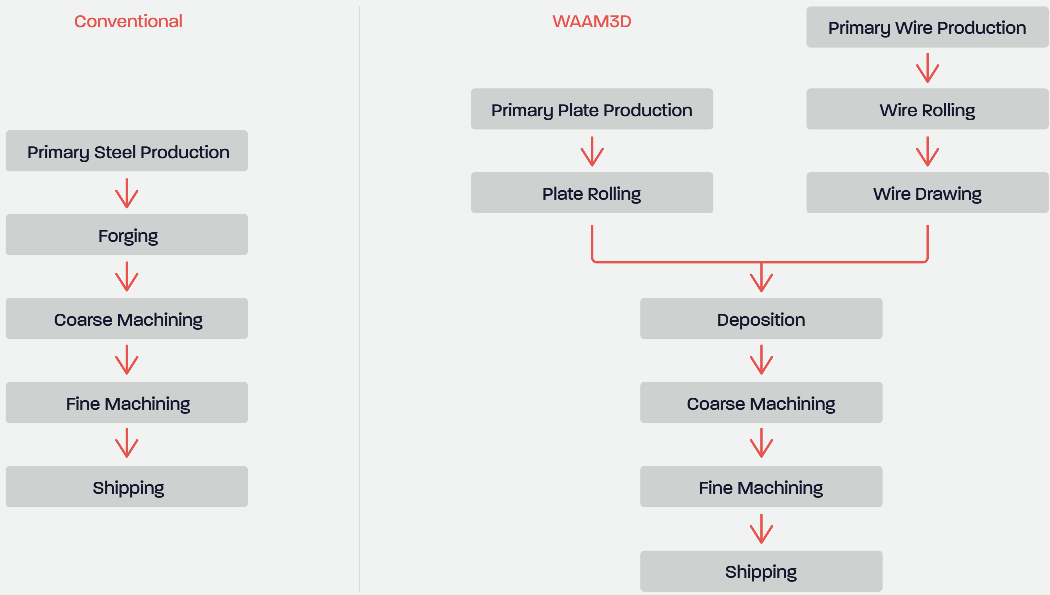


Fig.2 - Conventional (left) and WAAM (right) manufacturing routes to assess the environmental impact of the driver disk

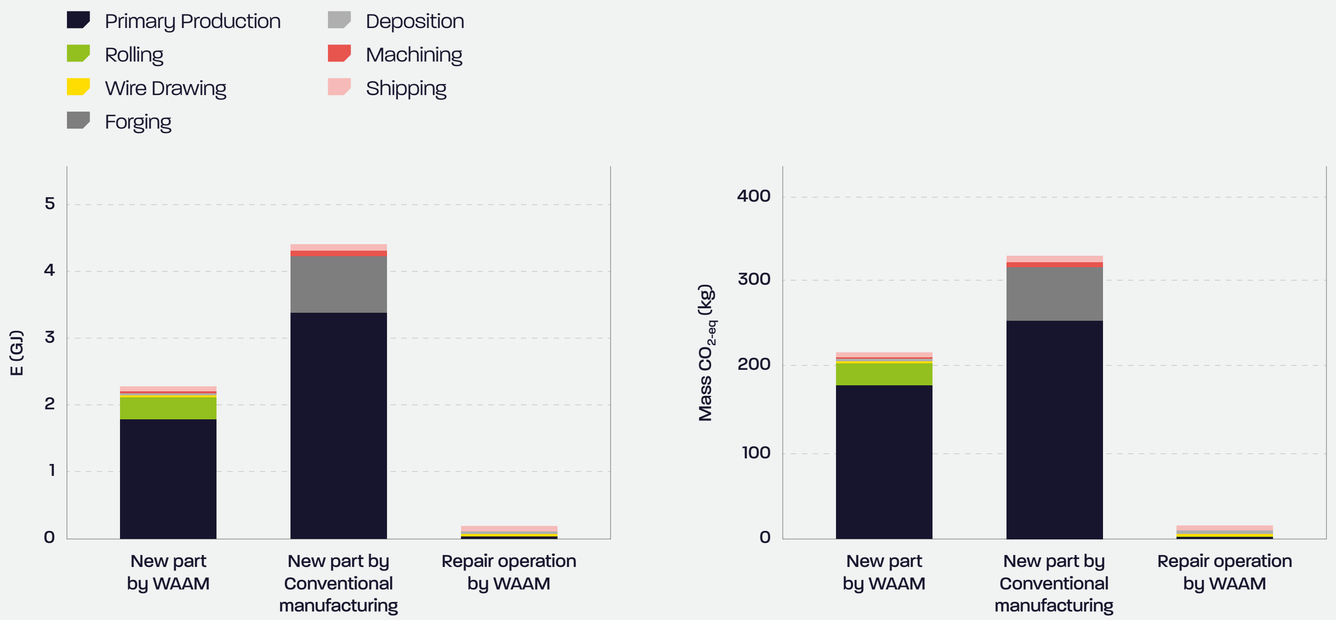


Fig.3 - Cumulative Energy Consumption (left) and cumulative carbon dioxide equivalent emissions (right) associated with the Conventional and the WAAM routes to manufacture the driver disk, as well as a repair operation using the WAAM process

As can be seen in fig 3 our LCA figures show cumulative energy consumption and carbon emissions. Energy consumption is estimated at between 3.0 and 4.4. GJ, allowing for a wide margin of error. CO_2 emissions are estimated at between 225 and 340 Kg. In each case, we have taken account of the energy required for the various manufacturing stages, including initial production of all raw materials used, plus shipping.

Fig 3 also shows, that, by removing the damaged part, shipping it to one of the growing number of WAAM specialists – in this instance, a company based in Belgium – and then repairing it, considerable savings can be made. In addition, once the process parameters - WAAM head path combination has been programmed, repairs can be carried out relatively quickly; typical deposition rates are between 2.0 and 4.0 kg/hour enabling repair times of a few hours.

Note that the study excluded several aspects of the product life cycle, notably the phases for the product in use and any ongoing maintenance, as the assumption was that these would be similar, regardless of the method of production.

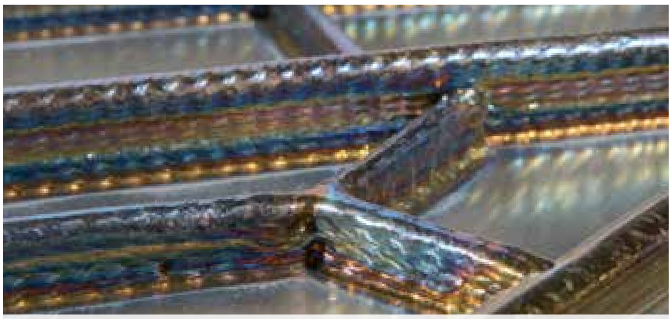
Mechanical characteristics

One of the key benefits of the WAAM process for the repair of industrial parts is the ability to maintain a high level of mechanical integrity. The precision controlled WAAM process ensures that an extremely accurate and consistent weld path and bead size is maintained across the entire area of the repair, with the wire feedstock being fully melted to become an integral part of the final structure.

WAAM can be used with a wide range of metals and can also be used to produce multi-metal repairs, using layers of different metals, such as steel and nickel. This can be achieved simply by changing the feedstock and adjusting the relevant process parameters during the deposition process.

It should be noted that with metals such as titanium alloys the solidification process of the layered deposits of weld beads can produce significant anisotropy in mechanical properties.

To overcome this, Cranfield University and WAAM3D have shown that by combining a degree of mechanical deformation (by an integrated roller or a peening tool, which forms part of the deposition head and end-effector), with the heat from the next deposition pass of the deposition head, a high level of microstructural refinement can be achieved. This normally produces a greater yield strength, with excellent retained elongation properties and a finished material that is fully isotropic.



WAAM enables a high level of metal integrity to be maintained, ensuring durable, high quality components

A versatile technology

It is important to recognise that wire arc additive manufacturing is not ideal for all applications; for example, unlike powder bed AM, it is unsuitable for small or highly complex parts.

Nonetheless, WAAM offers a range of technical and commercial benefits and, in many manufacturing applications, can play a key role in helping to reduce energy, transport and through-life costs, which in turn will help to reduce the carbon footprint of each part or component.

At a time when the future of our planet depends on the measures we take today, it is incumbent on all of us to take whatever measures we can to reduce our carbon footprint, as a means of preventing the runaway effects of global heating and climate change. Technologies such as WAAM can be at the forefront in helping us reach that goal, while delivering real savings in manufacturing costs. Commercially and ethically it's the right choice.

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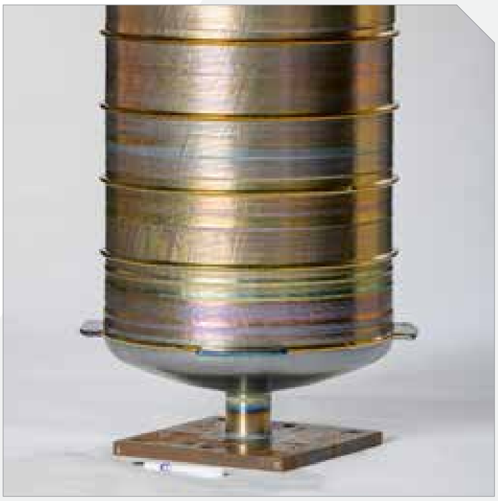
An industrial gas turbine blade built with a multi-hierarchical approach

Credit:
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