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IMPLEMENTATION OF REGENERATIVE BRAKE TESTING ON DYNAMOMETER

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INTRODUCTION

The main objective of this project is the development of a control module to simulate hybrid braking on a brake dynamometer. This control module must provide the core functionalities that allow performing brake applications containing regenerative component.

To achieve the main objective of this project, several specific objectives need to be accomplished:

- Regenerative Braking Capabilities Development: adapt the Inertia Simulation module to si mulate hybrid braking on brake dynamometer.
- Vehicle Testing: obtain relevant regenerative braking data from vehicle testing.
- Validation Tests: validate the developed modules throughout the usage of the data obtained from vehicle testing.

All the stated developments are to be integrated into Applus+ IDIADA's dbDyno brake dynamometer control system.

DB DYNO INTRODUCTION

dbDyno consists of a suite of software which integrates all the necessary functions to run a Brake NVH Dynamometer test. That involves the test programming, the test execution, the data logging the data processing and the results exporting.

The above mentioned suite contains the following tools:

- dbDyno – Control System, which consists in a series of tools for programming and executing a brake dynamometer test.
- dbDyno – Export Tool, which provides tools for exporting the logged data as desired by the engineering team, as well as performing calculations.
- dbDyno – Noise Tool, which allows analysing and exporting the NVH data depending on the criterion chosen by the engineering team.

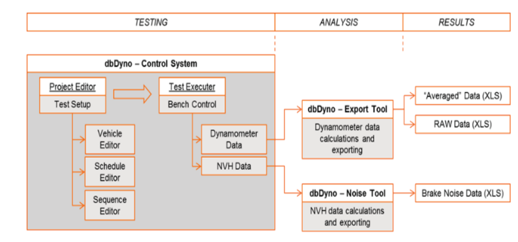


Figure 1. dbDyno Software Suite.

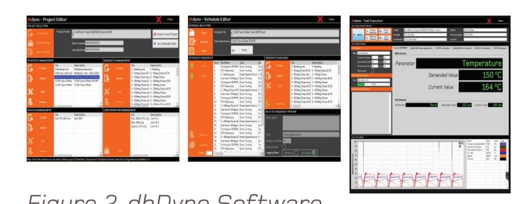


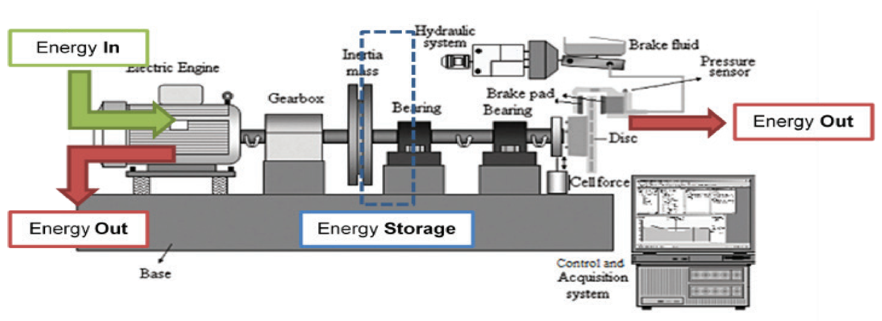
Figure 2. dbDyno Software.

INERTIA SIMULATION DEVELOPMENT

Inertia Simulation is to be used during deceleration brake applications and its principle of function is based on the regulation of the torque provided by the electric extracting or introducing energy into the dynamometer.

Conceptually when the braking system actuates on the brake dynamometer shaft which is loaded with a series of inertia flywheels, a reaction torque is generated. This reaction torque is proportional to the moment of inertia mounted on the brake dynamometer shaft. In order to compensate the difference between the values of inertia mounted on the brake dynamometer and that of the real vehicle it is required that the electric motor regulates its output torque accordingly.

It can be seen that Inertia Simulation directly depends on the control of the output torque provided by the electric motor. This statement reflects exactly what a regenerative braking system does.



Mathematical model definition

The control equation for the Inertia Simulation algorithm results in:

$$T_{mot} = \frac{I_t - I_{mec}}{I_{mec}} \cdot (T_{brk} + T_{loss})$$

Where,

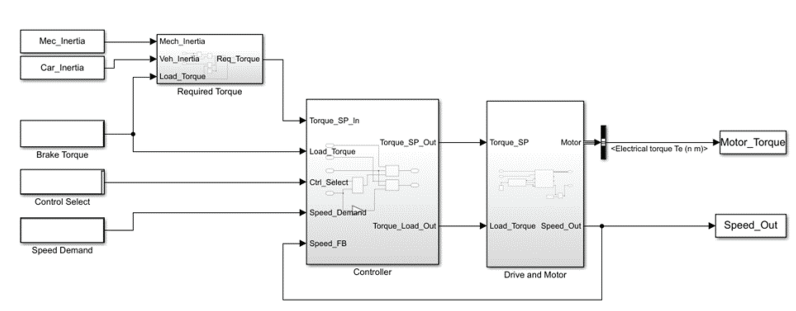
T_{brk} is the torque produced by the braking system, in [Nm],

T_{mot} is the torque provided by the electric motor of the brake dynamometer, in [Nm].

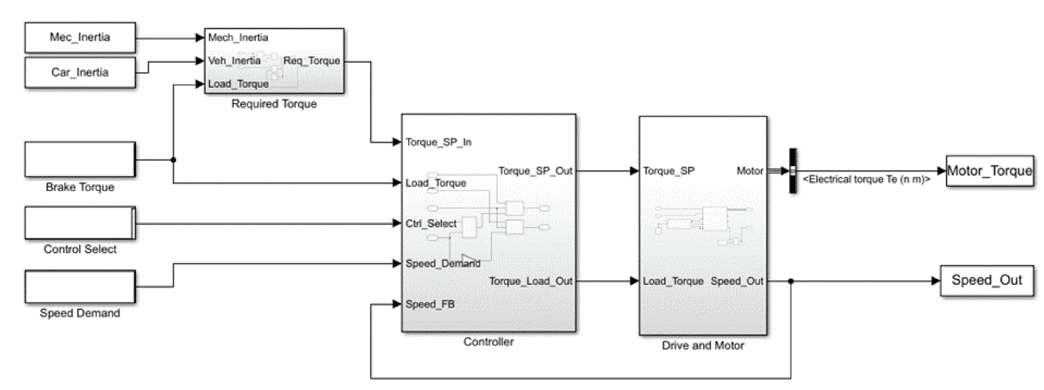
T_{loss} is summation of torque produced by all the road losses, in [Nm]

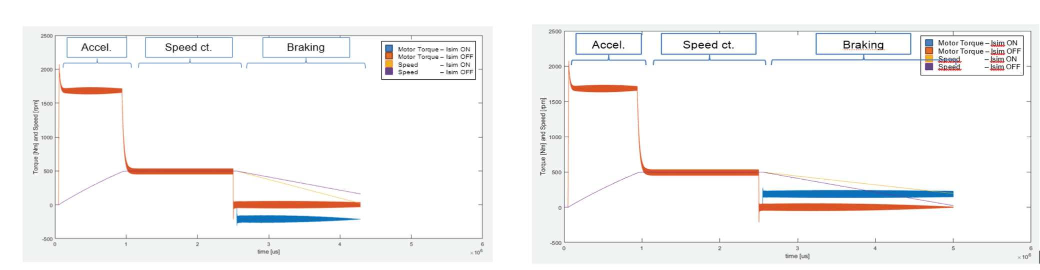
I_t is the moment of inertia of the brake dynamometer, in [kgm2]

I_{mec} is the moment of inertia of the flywheels mounted in the brake dynamometer, in [kgm2]



In order to virtually validate the control equation presented in the previous section, a model has been created in Matlab Simulink.





Case studies: increasing and decrasing inertia.

REGENERATIVE BRAKING INTEGRATION ON DYNAMOMETER

It is important to note that the current project is about providing the regenerative capabilities, not about completely emulating a hybrid braking system from the point of logics and other variables. That is why the chosen approach for this project relates with vehicle testing profiles. There are many reasons for using it: in one hand, with proper instrumentation it is possible to obtain directly the required variables for using the dynamometers regenerative capabilities; on the other hand it can be used for validating the developed functionalities.

Having previously developed the Inertia Simulation module eases a lot the task of implementing the regenerative capabilities concept.

The amount of torque required for the electric motor, T_mot in [Nm], taking into consideration regenerative braking results in:

$$T_{mot} = \left(\frac{I_t - I_{mec}}{I_{mec}} \cdot (T_{brk} + T_{loss}) \right) + T_{regen}$$

Where,

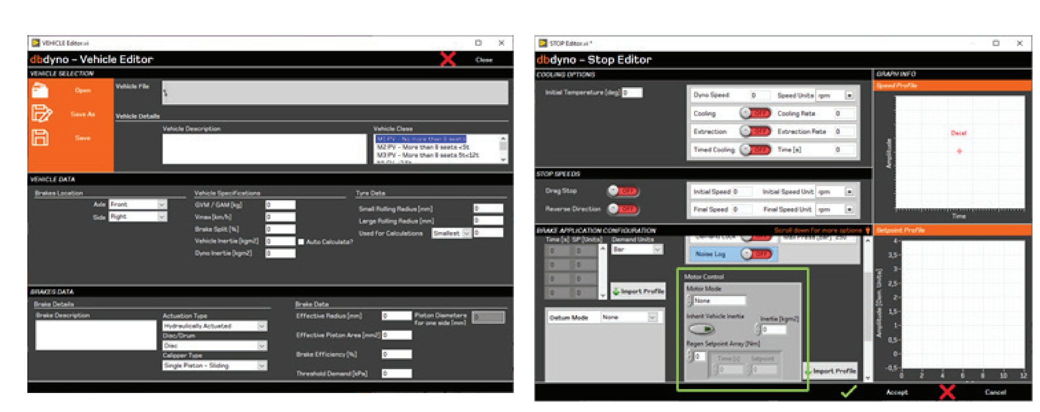
T_{regen} is the torque of the regenerative braking system.

In order to implement these modules into dbDyno – Control System it has been necessary to perform the following steps:

Step 1: Create a LabVIEW API containing Inertia Simulation and Regenerative Braking functionalities.

Step 2: Integrate the developed functionalities into dbDyno's control tasks, more specifically in the brake control phase. This function is in charge of generating a control demand in volts.

Step 3: Modify dbDyno's user interface to incorporate the set of parameters to configure the Inertia Simulation and Regenerative Braking behaviour.



Step 4: Add the necessary modifications in the physical layer in order to allow communicating dbDyno and the drive units of the electric motors regarding torque control.

VALIDATION

In order to characterize the hybrid braking systems of both vehicles and to obtain data to be used as a reference during the validation tests to be conducted in dbDyno, two tests have been performed on both vehicles. From the tests conducted in vehicle it has been decided to use the blending characterization results as a reference to be reproduced in the brake dynamometers, as it is the test were the contribution of the regenerative braking can be quantified easier.

In the next figure, the left side graphs show the obtained results using Regenerative Braking Capabilities in vehicle 1, whereas the right side ones show the results without any regenerative contribution, equivalent to the vehicle's neutral gear. The same level of deceleration is obtained in each figure but with notoriously lower pressure and friction braking torque when Regenerative Braking Capabilities are active. Note that this vehicle had parallel regenerative system and torque blending cannot be appreciated.

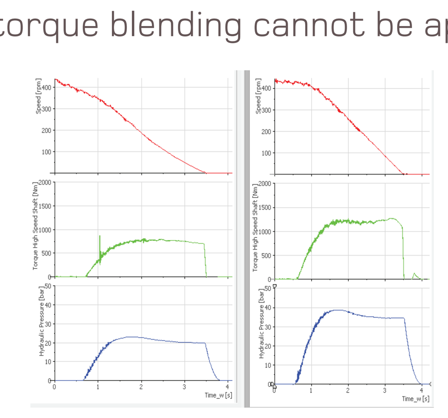


Figure A: Vehicle 1, brake dynamometer data, blending characterization @50km/h, 0.4g, D and N modes (left to right).

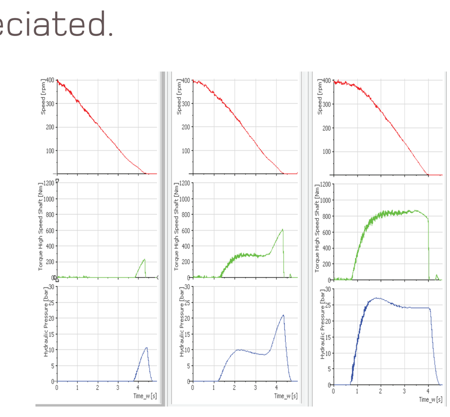


Figure B: Vehicle 2, brake dynamometer data, blending simulation @50km/h, 0.4g, D3, D0 and N modes (left to right).

In the previous figure B, the left side graphs show the obtained results using Regenerative Braking Capabilities whereas the right side ones show the results without any regenerative contribution, equivalent to the vehicle's neutral gear. The same level of deceleration is obtained in each figure but with notoriously lower pressure and friction braking torque when Regenerative Braking Capabilities are active. In this vehicle it is possible to observe the torque blending when the regenerative system is actuating.

CONCLUSIONS

- The project has been successfully concluded, validating brake dynamometer regenerative testing capabilities, using vehicle data testing on proving ground.
- It is important to note that this objective does not include the simulation of regenerative brake logics, as this is not the primary goal for brake dynamometer testing at this stage.
- Together with that, dynamics of the electric motor must be evaluated in a passenger car brake dynamometer to confirm that the torque profiles obtained from the motor fully match with vehicle profiles. Further tests must be performed but the solutions obtained up to date look promising for current and future applications.