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Predictive Engine Friction Modeling in GT-SUITE – WTC 2021, Lyon

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A multibody dynamics model of a 4-cylinder passenger car engine has been set up to predictively determine its frictional power losses. The validated model can be used, standalone, to investigate measures to reduce these losses. It can furthermore be integrated with the engine performance model and the lubrication circuit to run transient scenarios like start-stop or priming. This presentation will focus on the modeling technique and validation of the model with measurements. The multi-physics simulation platform GT-SUITE provides extensive capabilities in system level modeling as it provides connectivity between different sub-systems and components in order to capture their interaction.

Keywords: friction, engine, simulation, mixed lubrication, optimization

1. Introduction

Today's short development cycles in the automotive industry and stricter requirements on emissions require a simulation-based solution. The integrated multi-physics simulation platform GT-SUITE fulfills these needs to set up a representative model of the engine and optimize it with respect to these needs. The model setup with its underlying theory and the obtained results compared with measurement data will be shown.

2. Methods

The engine model consists of the following detailed sub-systems that have been set up and correlated with strip down measurement data:

- Cranktrain system including piston group with rings, skirt and cylinder
- Valvetrain and camshafts
- Timing chain drive connecting the camshaft with the crankshaft
- Accessory belt drive system.

2.1. Model setup

The main focus of this model is to represent the frictional power loss inside the engine. The CAD-driven process allows one to set up the multibody dynamic system based on individual part properties. The resulting, calculated forces are then used as inputs for the tribology models.

2.2. Numerical Scheme and Tribology Models

The implicit Hilber-Hughes-Taylor integration scheme, 2nd order accurate, is used to solve the stiff equations in the multibody dynamics system [1]. The applied modeling technique combines advanced mathematical tribology models based on established theories of hydrodynamic and elasto-hydrodynamic lubrication (EHL), Hertzian contact, asperity contact of rough surfaces, lubricant rheology including temperature, pressure and shear-thinning defined by detailed measurements of lubricant properties and surface finish [2].

2.3. Results

The simulation results for the friction torque in the cranktrain system including the piston group can be seen in Figure 1. A comparison with the measured strip test data (dashed line) has been performed. It shows a good correlation for all operating engine speeds at 90°C oil temperature.

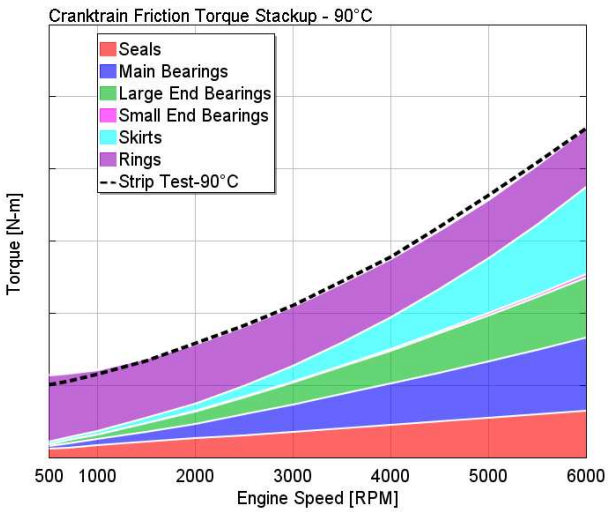

Figure 1: Overall cranktrain system friction torque (stacked) compared with measured strip down data.

3. Discussion

Similar to the results shown above, the remaining submodels have been constructed, calibrated and validated. The integrated predictive friction model can be run with imposed boundary conditions like structure and feed oil temperatures, different oil types, surface finishes, geometry, etc. A reduction in frictional losses can also be achieved by using the built-in design optimizer for design parameter variations. Other enhanced simulations like blow-by estimation, component validation, lubrication circuit integration or running transient start-stop scenarios will support the engineers in the overall development process.

4. References

[1] Gamma Technologies, GT-SUITE: Mechanics Theory Manual, Gamma Tech. LLC, 2019, 22.
[2] Okarmus, M., et al., "Methodology for Predictive Friction Modeling in Direct-Acting Mechanical Bucket Valvetrain System," SAE Int. J. Fuels Lubr. 8(1):1-15, 2015.