Development and validation of modelling techniques for lubricated contacts

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MOTIVATION

Due to increasing awareness of environmental concerns, the industry regulators are setting stringent targets for energy efficiency and emissions of drivetrains. Manufacturers are forced to improve their designs by balancing conflicting requirements between customers (increasing performance) and regulatory bodies (increasing efficiency). Mechanical transmissions are responsible for significant energy losses (6 to 8 percent of the total) in automotive and wind energy applications. Recent research studies document measures to significantly reduce transmission losses by 50 percent, revealing potential for saving 9.3 million tons of CO2 emissions in the automotive field, but do not consider the loss phenomena and their impact on crucial performance attributes such as durability and NVH. The solution to the riddle lies in the system-level dynamics within the transmission design engineering process.

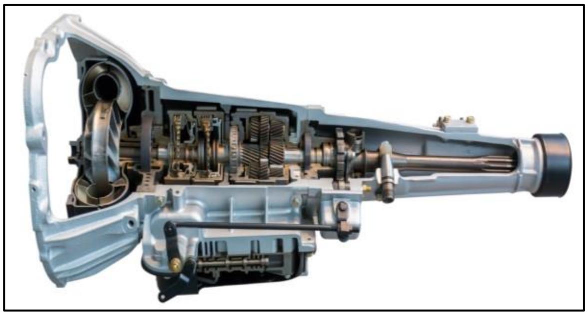

Figure 1 - Automatic Gearbox

The basic components of a transmission system are gears, bearings, shafts and the supporting structure. These are all mutually connected and the supporting structure substantially affects bearings contacts and gear meshing through several types of misalignments.

This project targets a holistic global and local dynamic simulation, intrinsically capturing the couplings between the different scales. Specific challenges lie in the necessity of an efficient yet accurate overall mechatronic simulation, requiring efficient but accurate model representations for lubricated contact, and dedicated numerical technology to embed them in the system-level model equations.

This is achieved by the development of Elastohydrodynamic lubricated (EHL) contact modeling techniques of increasing fidelity. Starting from analytical models to Computational-Fluid-Dynamics models, including the well established Reynolds based approach.

In order to further increase the computational efficiency of the developed methods, Model-Order-Reduction techniques for lubricated contacts have been developed to reduce the computing time while maintaining the same level of accuracy.

OBJECTIVES

The innovation goals of this project consist of the development of modelling techniques for EHL contacts that are suitable for system-level simulations. This translates to two separate objectives:

1. Increase the accuracy of the physics-based modelling techniques with respect to the current state of use in drivetrain simulations;
2. Increase the computational efficiency of the developed methods to be in line with the overall simulation framework.

APPROACH

In order to deliver an increasing level of fidelity of EHL contact models to cover all the simulation requirements from proof-of-concept analysis to NVH performance evaluations, three different modelling techniques have been developed.

For design exploration or proof-of-concepts simulations, analytical EHL models are the most suitable thanks to their low computational cost. These models allow for estimating the contact behavior using simple formula that are curve fitted on more complex models or experimental data. This in turns allows for fast what-if analysis of the system-level behavior of the driveline.

For applications that require a more accurate contact description or when the pressure and fluid film thickness in the contact is required for further analysis, e.g. for durability calculations, the more advanced Reynolds-Boussinesq modelling techniques can be employed.

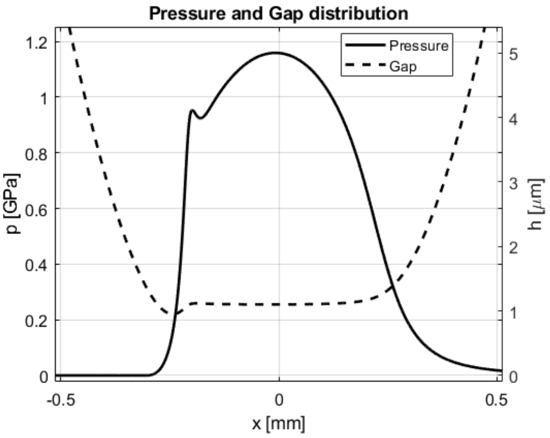

Figure 2 - Pressure and fluid film thickness computed with the Reynolds based approach

The increased model fidelity of Reynolds-Boussinesq modelling techniques comes at an increased computational cost. In order to allow for fast computations, Model Order Reduction techniques are developed. This allows to drastically reduce the computing time (speed-up factor of $O(10^3)$) without significant loss of accuracy. The low computational cost this methodology suitable to be employed in system-level simulations. This is a major improvement of the state-of-the-art since it allows to employ the Reynolds-Boussinesq model for system level analysis while before this project its use was limited to component level analysis.

In order to validate the developed Reynolds-Boussinesq method and to provide a modelling technique with highest level of accuracy, the EHL contact was modelled using a CFD software. This model allows for evaluating the accuracy and validity of the Reynolds-Boussinesq method and, if necessary, study the effects of more complex phenomena on the contact behaviour.

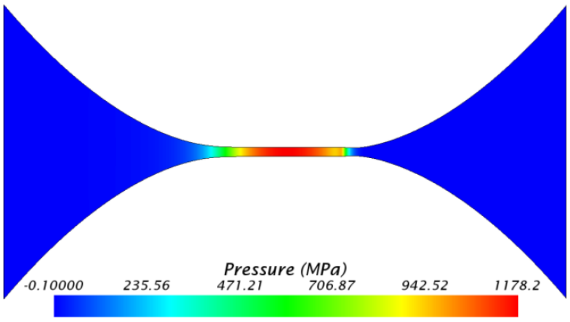

Figure 3 - Pressure distribution computed using the CFD software

The different level of accuracy developed in the framework of this project allows for different level of fidelity and involve different computational overhead. This gives a complete portfolio of modelling techniques for system level analysis of drivetrain.

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