7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

Model for Optimization of Transmission Efficiency in Electric Vehicles

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Transmission power losses represent a major contribution to the overall EV power loss. Consequently, reducing these losses offers an important way of improving the overall efficiency of EVs and hence extending their range. This paper presents a new tribology-based model for prediction of EV transmission efficiency. The model accounts for gear friction, churning, bearing and seal losses, incorporates thermally coupled lubrication model and uses measured oil rheology. The model is designed to enable optimization of oil properties and gearbox design with respect to overall EV power losses.

Keywords: electric vehicles, transmissions, efficiency, power loss, optimization

1. Introduction

Transmission losses in an electric vehicle (EV) represent a much larger proportion of overall vehicle energy loss than is the case for conventional internal combustion engine powered vehicles. Depending on vehicle operating conditions, this can be over 20% of the overall energy loss. This means that reducing transmission losses offers a major opportunity for improving energy efficiency of EVs and hence extending their range. The torque-speed characteristics of EV motors present several challenges for the design of EV transmissions and formulation of transmission lubricants, the most important of which are:

- Transmission architecture needs to provide the suitable 'matching' of E-motor characteristics to vehicle demands while minimizing overall energy losses, including allowing the motor to operate as near its maximum efficiency point. This calls for adequate choice of gear ratios. Availability of high torque over a wide range of speeds allows most commercial EVs to utilize just single-speed transmissions. However, depending on the vehicle type, significant efficiency advantages may be gained by introducing 2 or more gear ratios.
- EV transmission lubricants must protect the gear and bearing surfaces at low speed – high torque input conditions but minimise churning losses at high input speeds. These are competing requirements and call for custom oil formulations.

To help address these challenges, this work presents a tribology based EV transmission efficiency model that can be used to optimize both the transmission architecture and lubricant properties in order to minimise the overall EV losses.

2. Transmission Efficiency Model

The main characteristics of the devised model include:

- It considers all sources of transmission power losses including gear friction, churning, bearing and seal losses.
- It includes a thermally coupled lubrication model which predicts gearbox temperature evolution for a given vehicle duty cycle and the effect of this on lubricant properties and hence the individual power losses.
- It includes real rheology of tested oils derived from measurements on a ball-on-disc tribometer (PCS ETM rig) and an optical interferometry film thickness rig in a manner similar to that in [1] and [2] but under more realistic conditions. A key advantage of this is that it allows the model to discriminate between very similar oils in terms of their impact on EV efficiency.
- An iterative scheme is used to account for coupling between friction, gear tooth temperature, oil viscosity and film thickness.

3. Results and Discussion

Example results based on a two stage, single-speed (9:1) transmission used on a currently available EV and a specific transmission oil are shown in Figures 1 and 2. Figure 1 illustrates the relative contribution of different losses at a constant input power demonstrating the significance of churning and bearing losses. Figure 2 shows the predicted losses for an WLTP cycle and the importance of the associated temperature evolution. Additional results are presented to illustrate the application of the model to optimization of oil properties and transmission design to minimise of EV power losses.

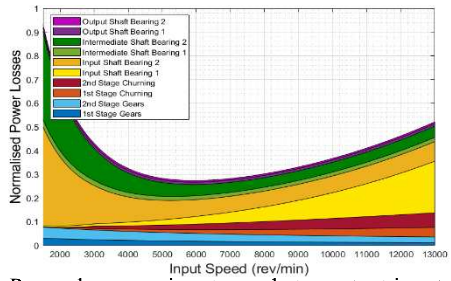

Figure 1: Power losses vs input speed at constant input power

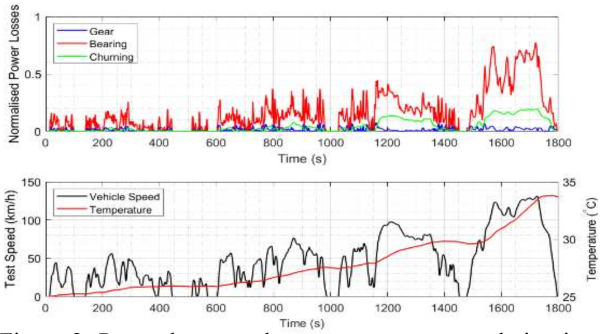

Figure 2: Power losses and sump temperature evolution in a commercially available EV gearbox across WLTP class 3 cycle

4. References

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