Tribology in Automotive Engine Applications

Hongwook Lee*#, Juyeong An* and Sungbaek Joo**

*Engine Tribology Research Lab, Hyundai Motor Group
**Powertrain Center1, Hyundai Motor Group
Corresponding author: hongwook@hyundai.com

1. Introduction

In the 21th century, great efforts have been undertaken to minimize carbon dioxide emissions which are the major contributor to global warming. The governments of many countries regulate the amount of carbon dioxide emissions and OEMs that do not follow the regulation have to pay high penalty fees. In the automotive industry, the market trend has also been changing from best performance cars to cleanest and most fuel-efficient cars. Eco-friendly cars, such as hybrid and full electric vehicles have been rapidly developing. However, most vehicles are still driven by internal combustion engines (ICE) and because of hybrid vehicles, ICE's very long presence in the market is expected. [1]

2. Friction Reduction

Fig.1 shows energy losses in the internal combustion engine. Almost 65% of the total fuel energy is lost in the engine, whereof 10% are mechanical losses. Crankshaft, oil pump, and piston group together account for 70% of the engine's mechanical losses. Minimizing friction of such engine parts still has a big potential to reduce the mechanical losses in the ICE. The methods to reduce friction are varied. Developing low friction coatings or lubricants and improving the parts design are among them. These measures have to be cost effective, which is very challenging.

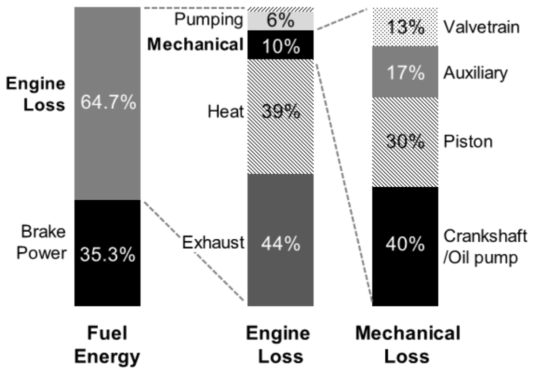

Fig. 1 Mechanical losses of engine

Also, friction has to be reduced while not compromising the engine's reliability. In order to predict friction in the engine, e.g. in the crankshaft bearing system, numerical methods are commonly used. Implementing boundary conditions is a very important task to carry out such simulations. They are mainly gathered from experimental results.

3. Advanced Simulation Methodology

Low viscosity oils are popular for reducing engine friction but at the same time can increase the risk of seizure, particularly at high rotational speeds due to direct metal-to-metal contact.

TEHL (Thermo-Elasto-Hydrodynamic Lubrication) simulations[2] of the connecting rod bearing have been performed at max speed condition; investigating effects of bearing material type, oil viscosity, clearance, oil temperature and oil feed pressure. As expected, results show increased oil film severity for lower viscosity oil, increased lubricant temperature and reduced oil feed pressure. However, the severity factors remained within the safe margin for aluminum bimetal material.

Limitations within THEL model arise due to oil feed pressure assumptions, therefore CFD simulations are needed to determine realistic oil pressures feeding the connecting rod bearing and to ensure a minimum required oil flow level is maintained. CFD simulations capture pressure variations at the big-end journal oil hole due to grooved and un-grooved regions on main bearings and also "air bubble" effects in the crank drillings as shown in Fig.2. The generation of air bubbles and thus a potential for oil starvation becomes more significant at high rotational speeds and low oil feed pressures.

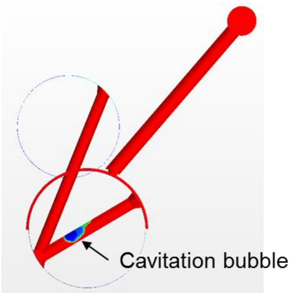

Fig. 2 CFD simulation for oil supply system

4. Real-time Measurement Techniques

Precise boundary conditions are very important to enable simulation tools to provide a more reliable output. However, due to high rotation speeds and high temperatures, it is very difficult to measure any physical data for moving parts of the engine, such as piston, bearing, and connecting rod. Advanced techniques and methodologies can make it possible to measure temperature, stress, pressure and wear-rates for engine moving parts with high accuracy and in real-time. Measured data is used for validation as well as boundary conditions for bearing simulation.

5. Conclusions

Friction reduction in the engine is still a big area to improve fuel economy of the vehicle, but in some cases such as low viscosity oil and certain friction reduction technologies conflict with the reliability of the engine. For this reason, advanced simulation tools and real-time measurement techniques have been developed and are applied to reduce friction and to ensure the engine's reliability.

References

[1] J. Dulac, Global Transport Outlook to 2050: Targets and Scenarios for a Low-carbon Transport Sector, IEA (2012)

[2] D. Wang and D. D. Parker, Effects of Crank-Pin Surface Circumferential Waviness on the EHL of a Big-End Bearing in a Diesel Engine, SAE 2003-01-3120 (2003).