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Research on Loss Reduction in Internal Combustion Engines for Effective Use of Future Synthetic Fuels -Trends in Tribology Research for Reducing Friction Losses-

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1. Introduction

In order to realize a carbon-neutral society, the use of synthetic fuels, hydrogen and ammonia will be considered. To effectively use these fuels, it is important to improve the thermal efficiency of internal combustion engines (ICE). The improvement of thermal efficiency requires reduction of heat loss, exhaust loss and friction loss, and from the perspective of engine tribology, it is also important to study the reduction of seizure risk and oil consumption (LOC), which are contradictory phenomena. This study introduces the consortium research on internal combustion engines currently being promoted in Japan, and reports on the research being conducted and examples of research results.

2. Research Background

Consortium research on improving the thermal efficiency of internal combustion engines has accelerated significantly since 2014. The reason for this is that research on innovative combustion technologies was adopted as a SIP national project, and more than 100 universities conducted research on improving thermal efficiency in gasoline and diesel combustion engines, while loss reduction research was also promoted to improve thermal efficiency. In addition to heat loss and exhaust loss, friction loss was also considered an important research issue, and 17 universities proceeded on friction reduction, seizure risk reduction, its modeling, and oil consumption reduction. From 2022, as shown in Figure 1, research on internal combustion engines to achieve a thermal efficiency of 56% is underway as research to effectively use synthetic fuels that can contribute to carbon neutrality. (see Fig.1)

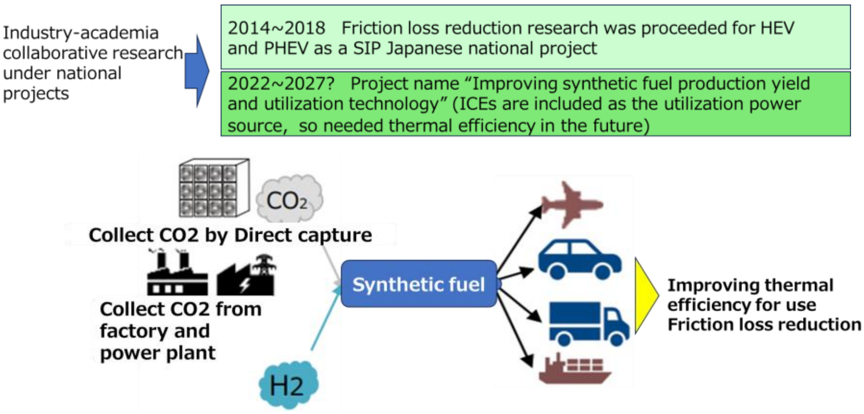

Fig.1 Overview of the joint industry-academia research on internal combustion engines

3. Aim of engine friction reduction research

The specific friction reduction studies are simply represented using the Stribeck diagram as shown in Fig. 2: boundary lubrication area (Focus 1), mixed lubrication area (Focus 2), fluid lubrication area (Focus 3), and reduction of seizure risk (Focus 4). The friction reduction research in each of these areas is mainly focused on the piston-cylinder and crank bearing systems of the engine as shown in Fig.3.

4. Example of engine friction reduction research

Fig 4 shows an example of research on friction loss reduction mainly in the fluid lubrication area. In Fig.4①, the profile of the piston and rings are changed to explore the effect of friction reduction while paying attention to noise and LOC. Fig. 4② is a study of optimizing the texture of sliding surfaces. The friction reduction effect is studied by CFD flow calculations, and the results are then processed into the actual sliding surfaces of bearings and demonstrated in an engine bearing test machine. Fig. 4③ shows research on friction reduction by micro/nano bubbles. In the area of micro bubbles, the mechanism of friction reduction is being analyzed by visualization of oil film and CFD.

5. Specific effects of lubricating oil containing nanobubbles on piston friction

Fig. 5 shows an example of piston friction force measured with a floating liner engine, using engine oil without nanobubbles (STD) and engine oil with different amounts of nanobubbles (NB200 mm < NB400 mm < NB600 mm in the figure). The friction reduction effect of the nanobubble engine oil was confirmed at the crank angle in the dotted line region in the figure. The results of this experiment were organized by friction mean effective pressure (FMEP) as shown in Fig.6. In case of NB200 mm, the friction reduction was about 7% in the low and medium load range and 10% in the high load range. In case of NB400 mm, the reduction was also 8% in the low and medium load side and 13% in the high load. In NB600 mm, the reduction was further improved to 15% at the high load side. In other words, at 1500 rpm, the friction reduction effect tended to increase at the high load side.

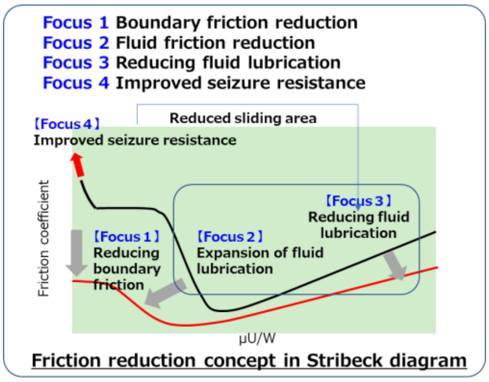

Fig.2 Each university's specialty research is applied to friction reduction in all lubrication areas.

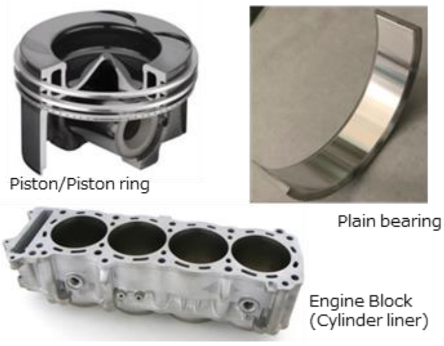

Fig.3 Each university's specialty research is applied to friction reduction in all lubrication areas.

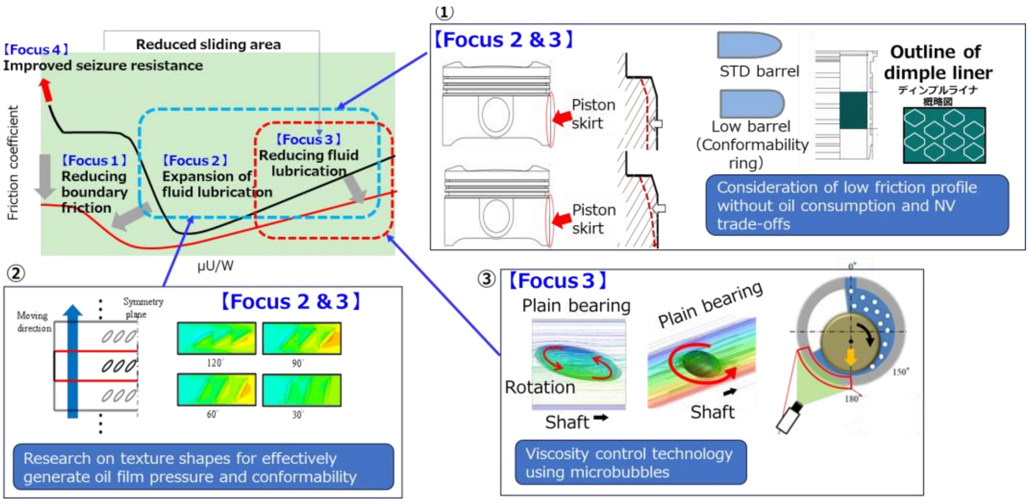

Fig.4 Specific examples of research mainly targeting fluid lubrication

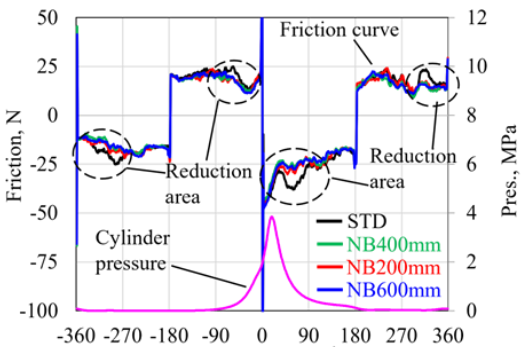

Fig.5 Specific examples of research mainly targeting fluid lubrication

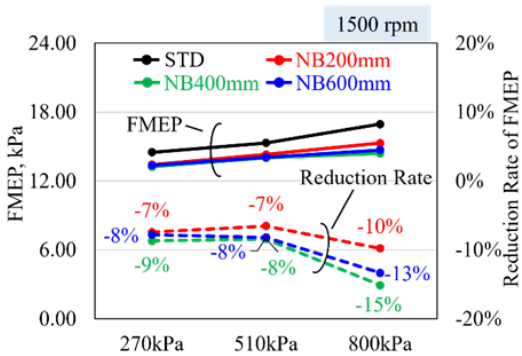

Fig.6 Effect of carbon sludge in lubrication oil (Collected from TCU engine)

Summary

Although the fluid lubrication area is introduced here, research on boundary friction reduction, such as the use of fullerenes and the promotion of running-in by laser processing, as well as the development of models for seizure, are also being promoted. New basic research is being actively promoted, and the demonstration of the friction reduction effect on internal combustion engines will be continued in the project.