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Investigation of temperature influence on diesel engine friction forces with a floating-liner testing bench

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ABSTRACT – Friction reduction in optimized cylinder liner of combustion engines is of significant importance. With sophisticated measurement approaches, detailed measurements of temperature influences on friction forces under motored and fired conditions will be presented. All investigations have been done on the floating liner test engine at University of Hannover.

1. INTRODUCTION

Following the legislation, the focus of developers of combustion engines is on fuel economy and low emissions. Compliance with the guidelines requires a wide range of optimizations. Friction reduction in the piston group, consisting of cylinder liner, piston and piston rings offers great potential due its high proportion on the total engine friction of up to 50 % [1]. To reach improvements on this topic, it is necessary to measure the piston group friction accurately and building up an understanding of the friction mechanisms in detail. For this purpose, the ITV Hannover developed a Floating-Liner testing bench based on a 2-litre single cylinder diesel engine. This tool allows crank-angle resolved friction forces investigation under fired engine conditions. Preceeding projects showed that the Floating-Liner is successfully able to compare series cylinder liner with locally structured liner [2]. To expand the knowledge to design a tribological optimized cylinder liner, ITV started an extensive investigation to classify major influences on friction force in the piston group. This paper shows investigations of the influence of oil and coolant temperature on the friction forces.

2. FLOATING-LINER MEASUREMENT SETUP

The Floating-Liner measurement system is a development based on earlier work of Furuhama and Takiguchi [3], and Kessen [4]. With two piezo electric force transducers between liner and cylinder housing, the system allows the direct crank-angle resolved measurement of the piston group friction force (see Figure 1). In axial direction, the cylinder liner is mounted flexible. To center and support the cylinder liner against radial forces, a hydrostatic bearing is used. A gas balancing system, consisting of two surface areas, being located opposite to each other, compensate forces resulting from the combustion gas pressure. Elastomer elements seal the combustion chamber against the coolant areas. The test bench is fully conditioned to ensure precise operation with load points up to 180 bar cylinder pressure and 1300 $^{1}/_{min}$.

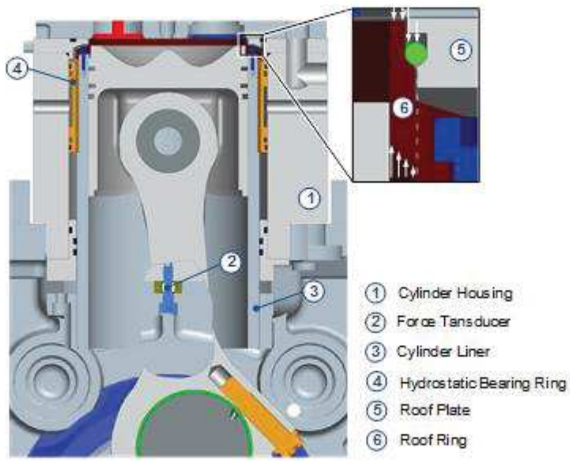

Figure 1 Floating-liner measurement system.

For this investigation, a series cylinder liner with series honing was used. The coolant and oil temperatures were varied from 40 °C to 100 °C. All other operating media have been set to defined values.

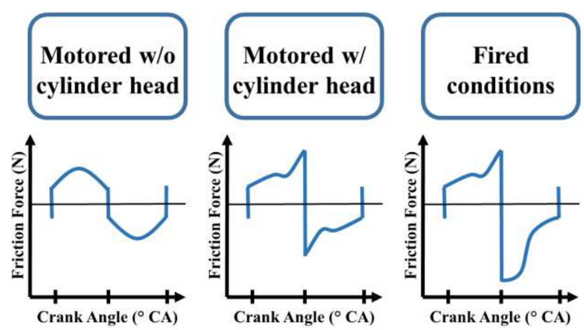

Figure 2 Operating modes for friction analysis.

For friction measurement, three operation modes were used: motored without cylinder head, motored with cylinder head and operation under fired condition with the expected friction force curves (Figure 2).

3. RESULTS AND DISCUSSION

Friction investigations without the influence of compression and combustion show the main tribological character of the tested liner piston and ring combination. Here the main friction is from the piston ring tension, without gas force. Figure 3 shows the crank-angle resolved friction force recordings of the piston group and liner combination for 40 °C and for 100 °C coolant and oil temperature. The operating points is motored at 600 $1/_{min}$ without cylinder head mounted.

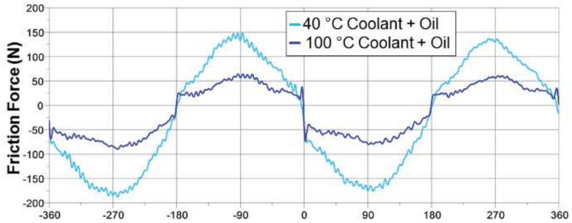

Figure 3 Motored crank-angle resolved friction forces w/o cylinder head.

Both graphs show the general expected friction trends (see Figure 2). Differences can be found in the bottom and top dead centers (-360 °CA, 0 °CA and 360 °CA), where the piston change directions. At those points, the lower temperature graph shows a slightly lower friction peak. In the areas around the dead centers, the friction level is higher than in the graph with higher temperature. In the hydrodynamic areas (around ±270 °CA and around ±90 °CA) the lower temperature case shows a significant higher friction level. The overall friction decrease with the higher temperature is 44 %.

Figure 4 shows the crank-angle resolved friction force recordings at 600 $1/_{min}$ with cylinder head mounted together with the pressure history.

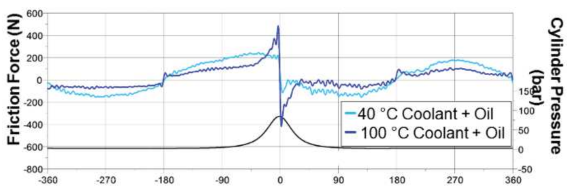

Figure 4 Motored crank-angle resolved friction forces w/ cylinder head.

Here, the previous trend continues. The lower temperature graph shows smaller friction peaks in the dead centers; in all other areas, the friction level is higher. The compression stroke of the higher temperature graph (-180 °CA – 0 °CA) shows a significant increase of friction. The overall decrease of friction with higher temperature is 45 %.

Figure 5 shows the crank-angle resolved friction force recordings with fired conditions at 600 $^{1}/_{min}$ with 2 bar IMEP load. Here a similar trend is found in comparison with the non-fired friction investigations. The lower temperature graph shows smaller friction peaks in the dead centers; in all other areas, the friction is higher than the friction level of the 100 °C temperature graph. Around the compression and combustion areas (-45 °CA – 45 °CA), the friction of the lower temperature graph increases in comparison to the motored investigation. Overall, the friction difference is 44 %.

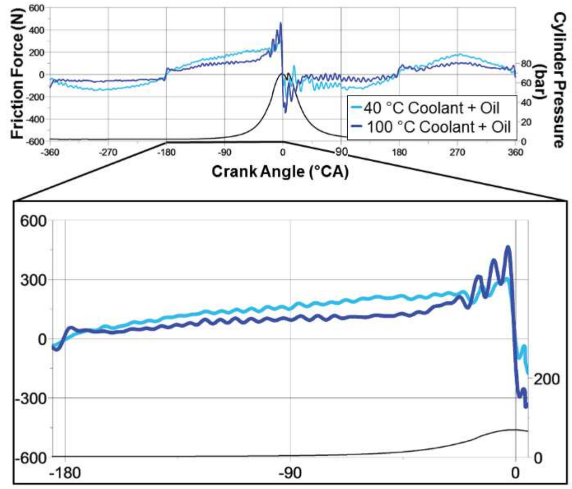

Figure 5 Fired crank-angle resolved friction forces.

The main influence for this behavior can be explained with the temperature-dependent viscosity of the oil. The oil film thickness varies with its temperature. If the film thickness is low in the dead centers, the friction increases because liner and piston rings get in contact. In the hydrodynamic areas, a low film thickness lowers the friction level because the fluid friction is reduced. With the resulting higher temperatures, the combustion also lowers the oil film thickness. Other operation modes and points showed that these effects are not proportional to load and rounds per minutes.

4. CONCLUSION

At ITV Hannover extensive friction force investigation are done based on a Floating-Liner measuring system. An exemplary friction analysis showed reverse dependencies from the conditioning and combustion temperatures. They can, however, be understood if the influences the oil viscosity on the oil film thickness and the hydrodynamic friction are analyzed. Optimized liner layouts should regard these effects.

REFERENCES

[1] Golloch, R., Kessen, U., & Merker, G. P. (2002). Tribologische Untersuchungen an der Kolbengruppe eines NFZ-Dieselmotors. *MTZ-Motortechnische Zeitschrift*, *63*(6), 494-501.

[2] Ulmer, H. C. (2015). *Einfluss mikrostrukturierter Zylinderlaufbahnen auf die Tribologie der Kolbengruppe bei Nutzfahrzeug Dieselmotoren*. PZH Verlag, TEWISS-Technik und Wissen GmbH.

[3] Furuhama, S., & Takiguchi, M. (1979). *Measurement of piston frictional force in actual operating diesel engine* (No. 790855). SAE Technical Paper.

[4] Kessen, U. *Tribologische Untersuchungen an der Kolbengruppe eines Dieselmotors bei hohen Mitteldrücken.-1999. Hannover, Universität* (Doctoral dissertation).