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THE IMPACT OF MICROGEOMETRY BEARING SURFACE OF THE PISTON ON THE PARAMETERS OF OIL FILM

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Abstract

The formation of oil film is possible under certain parameters of microgeometry cooperating components the main node of the internal combustion engine, which is a piston-pin-piston rings. In addition, this node is primarily responsible for the formation of mechanical losses. It is advisable to reduce friction losses in the piston-cylinder group lead to an increase in the overall efficiency of the engine and thus reduce the fuel consumption. One way of achieving these objectives is modification of microgeometry of the piston-bearing surface, which cooperates with the cylinder wall. The geometry of the gap between the piston skirt and the cylinder liner greatly affects the friction loss inside the engine. This means that the friction loss is much more affected by the area covered by the oil film separating the mating elements than its thickness. The method to reduce the area covered by the oil film is a modification of the bearing surface of the piston by adjusting the profile. The supporting surface, which performs a reciprocating motion relative to the strokes of the cylinder liner ensure the continuity of the oil film with the smallest possible value of the friction losses at the node piston-cylinder. This paper presents the results of simulation leading which aim to determining the parameters oil film on the friction loss for the modified bearing surface of the piston.

Keywords: *combustion engine, piston, friction losses*

1. Introduction

Lubrication of internal combustion engines is the basis of their reliable operation. Constructors aspire to design units that have preserved its initial state in the longest possible time. In the case of combustion, engines can be list a few groups, which consume deteriorating engine parameters and finally, makes it impossible to operation. They are mainly components of the piston-cylinder and crankshaft bearings [8, 13, 15].

Lubrication consists in bringing the contact points cooperating surface lubricant, which creates conditions for the formation and maintenance of the oil film. A thin oil film of lubricant structure, which inside layer moving relative to each other generate hydrodynamic pressure due to the viscosity of the lubricant. The formation of the oil film is only possible under certain geometrical parameters of mating surfaces [3, 4, 6].

The geometry of the gap between the piston skirt and the cylinder liner greatly affects the friction loss inside the engine. This means that the said friction loss is much more affected by the area covered by the oil film separating the mating elements than its thickness. A way to reduce the area covered by the oil film is the application of a stepped profile of the piston skirt [10, 11]. According to theoretical considerations based on hydrodynamic theory of lubrication, the stepped shape of the gap reduces the friction loss.

The piston skirt microgeometry can be formed by the application of surface layers made from materials of good friction properties. The desired geometry of the profile can be achieved by applying thin coats on the cylindrical or conical surface of the piston skirt [7, 12, 14].

Modern coats are evenly applied on the surface of the piston skirt to modify the conditions of boundary friction. This, however, does not significantly affect the conditions of occurrence of liquid friction in the oil film. The most widespread coating technology is that based on graphite composites [1, 2, 5, 16].

This paper presents the impact of microgeometry bearing surface of the piston on the parameters of oil film. The authors also present the results of a simulation research leading to a reduction of the friction loss and the improvement of the oil film parameters for the modified profile of the piston skirt.

2. Cooperation model of the piston-cylinder pair

The calculation parameters of the oil film in the kinematic pair of the piston-cylinder group are very complex issue. That is because this type of estimate usually has to take into account the 4 groups that interact with each other by simulating the supply of lubricating oil. These groups are:

- sliding surface of the first compression ring – cylinder wall,
- sliding surface of the second compression ring – cylinder wall,
- sliding surface of the scraping ring – cylinder wall,
- the bearing surface of the piston – cylinder wall.

The adopted microgeometry of the piston skirt is a result of a continuation of former research. In order to ascertain the friction loss in the piston – cylinder pair, 6 variants of piston microgeometry have been developed as shown in Fig. 1-2.

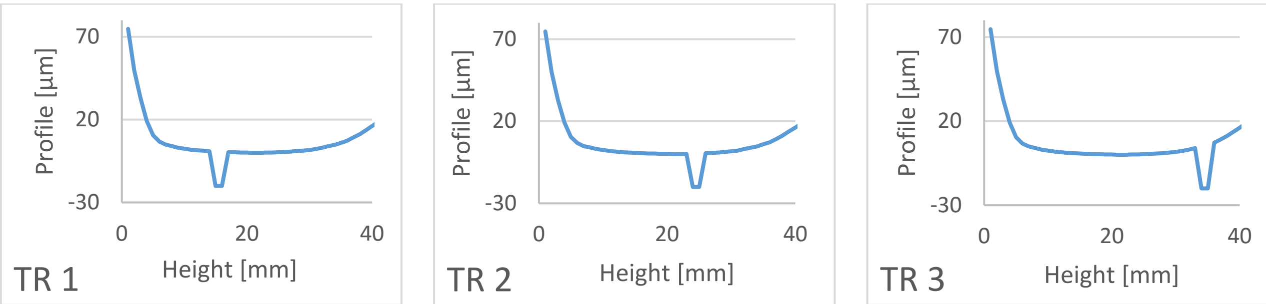

Fig. 1. TR1, TR2, TR3 variants of the piston bearing surface profile

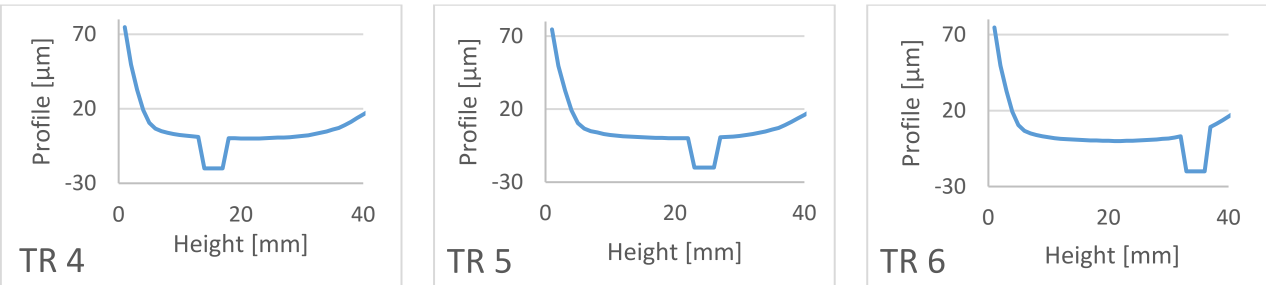

Fig. 2. TR4, TR5, TR6 variants of the piston bearing surface profile

The horizontal bar of the letter H allows extending the area of high hydrodynamic pressure at the same time obtaining the effect of reduction of the oil film internal friction forces. The problem consists in determining the thickness proportion of the H bar guaranteeing high oil film bearing capacity at a limited internal friction force. Because the correctness of the computer model was validated experimentally in earlier research [8, 11, 12], the results confirm the positive results of the modification of the piston skirt microgeometry of a specified thickness of the H bar, which proves the validity of the replacement of classic barrel-shaped profile of the piston skirt with the stepped one by the application of a layer of graphite of a specified thickness.

Simulations have been conducted on the parameters of the engine Fiat CC700, which is prelude to the research on real object. The initial phase of the research, was define the characteristic operating points of the combustion engine, during idling and full power speed. These points as shown in Fig. 3.

The next step of research was determined the friction losses and defines parameters for the selected operating points of this engine. Simulations were performed using a computer program developed by professor Iskra in the Department of Internal Combustion Engines at Poznan University of Technology [9].

Calculation of the oil film was made for the reference pistons and all variants with modified microgeometry bearing surface of the pistons.

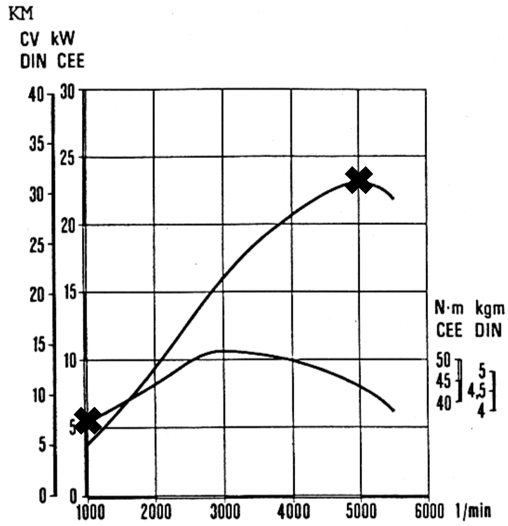

Fig. 3. Engine performance-Fiat CC700

3. Simulation research results

Simulations have been conducted at two point's combustion engine for idling and full power speed, Figs. 4-5. The calculations of the parameters of the oil film were performed for different microgeometries of the piston skirt, starting from the barrel-shaped profile of the reference pistons and ending with the stepped piston skirt profile. The thickness of the H bar is variable as well as its height in the bottom or top position against the symmetrical one.

In the form of diagrams, Figs. 6-7 show the results of the simulation of friction loss for barrel-shaped reference pistons and the pistons of a modified piston skirt.

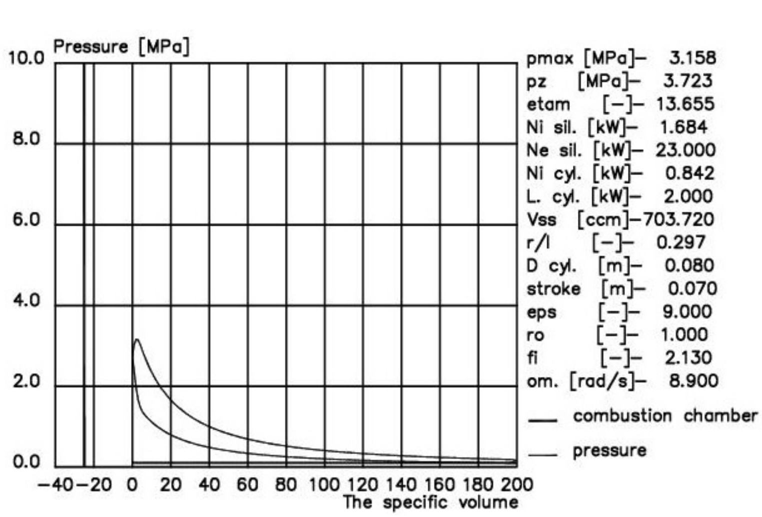

Fig. 4. Indicator diagram – idling speed

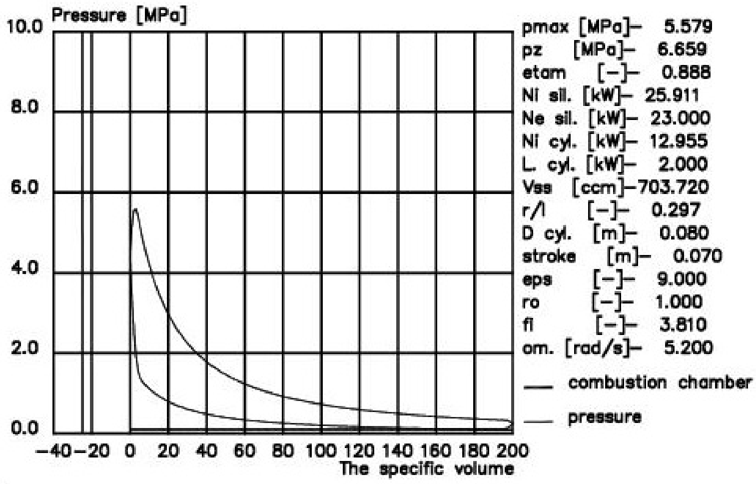

Fig. 5. Indicator diagram – full power speed

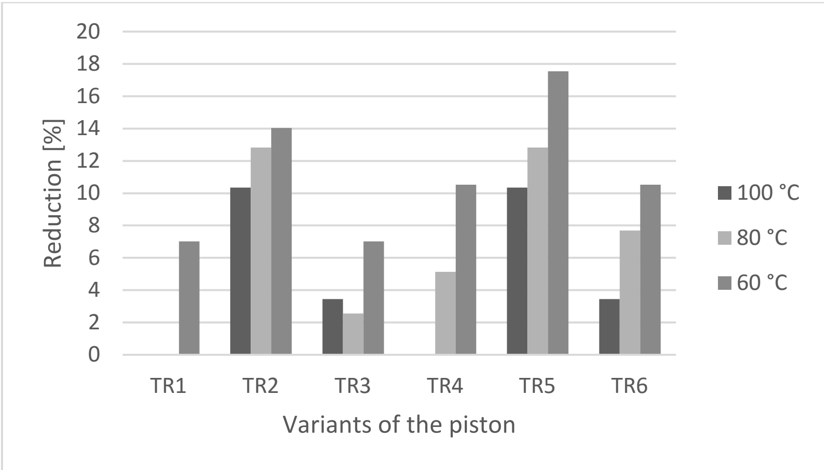

Fig. 6. The percentage reduction friction losses for all variants of the pistons to the crankshaft speed of 850 rev/min and lubricating oil temperature of 100, 80, 60°C

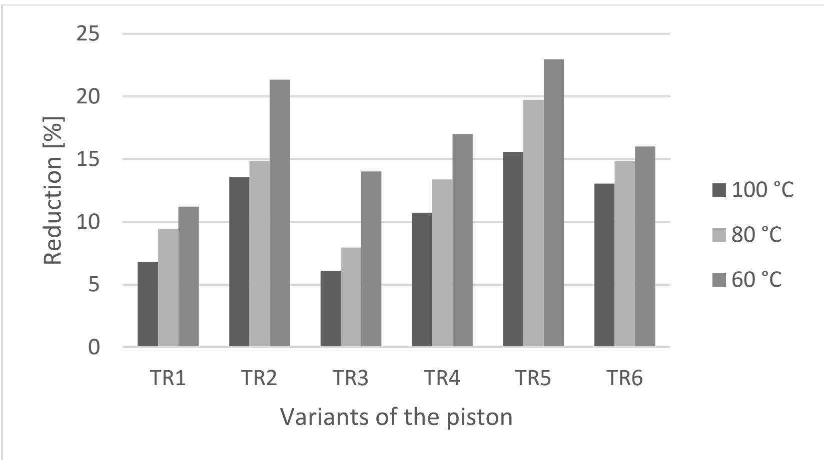

Fig. 7. The percentage reduction friction losses for all variants of the pistons to the crankshaft speed of 5000 rev/min and lubricating oil temperature of 100, 80, 60°C

The slot between piston and bore is filled with oil to great extent, which increases the friction force value drastically. Research shows that not all variants have brought the expected reduction in friction losses for the piston-cylinder system in relation to reference pistons. In most cases, however, friction losses reduction can be obtained. For further analysis, there were two H-shapes chosen with different crossbar thicknesses between the slats.

As a result of the simulation, TR2 and TR5 variants showed the greatest friction losses reduction in the piston-cylinder system. It can be also observed that reduction in friction loss is more intense for higher crankshaft revolution speed. The importance of this observation should not be undervalued as increasing of the revolution speed results in faster heating of engine components and lubricating oil hence reducing its viscosity that may lead to the occurrence of boundary friction conditions. This may also have a positive effect on reducing friction losses under the assumption that the boundary friction will not occur at the bearing surface and the cylinder liner.

As the recently carried out simulation show the profile of piston skirt considerably affect the friction losses within piston assembly. The obtained results can be explained with the diagrams showing piston skirt covered with oil film. Such diagrams are seen in successive figures:

- Fig. 7 for the reference piston,
- Fig. 8 for the piston TR2,
- Fig. 9 for the piston TR5.

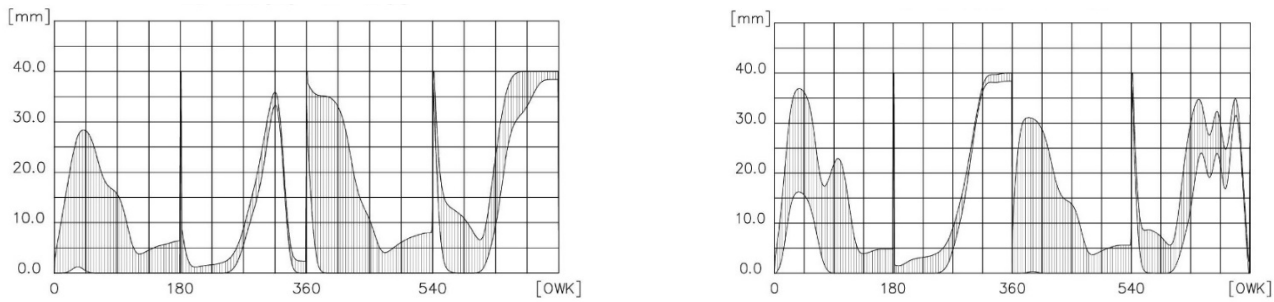

Fig. 8. Oil film height on the reference piston skirt for 850 rev/min (left) and 5000 rev / min (right)

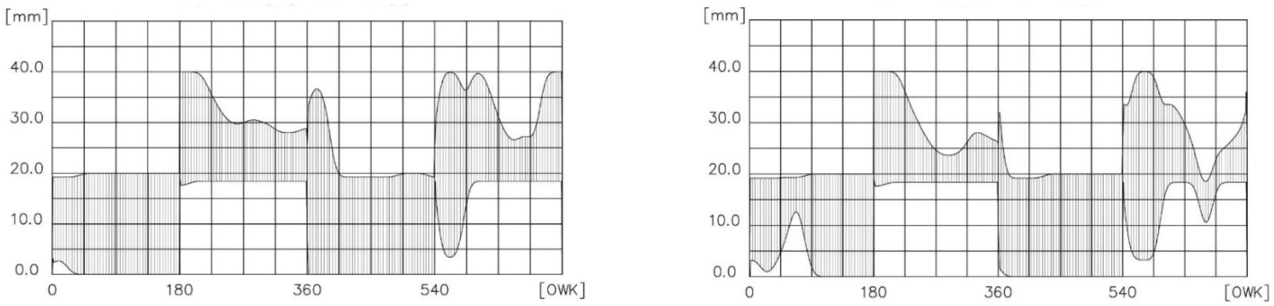

Fig. 9. Oil film height on the TR2 piston skirt for 850 rev/min (left) and 5000 rev/min (right)

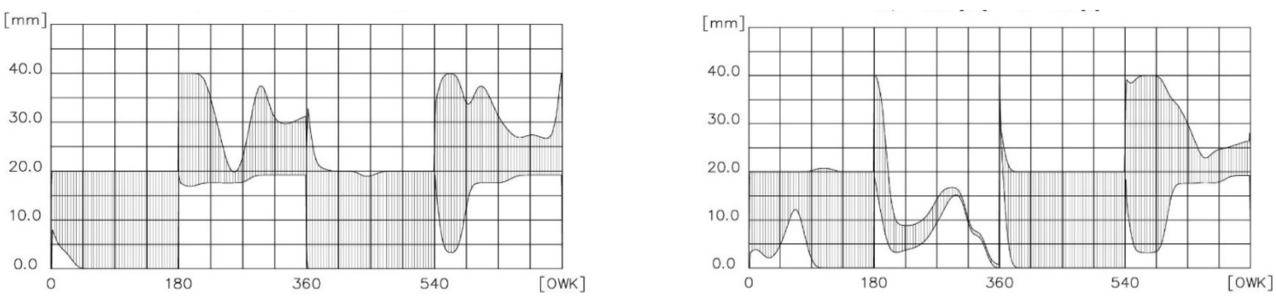

Fig. 10. Oil film height on the TR5 piston skirt for 850 rev/min (left) and 5000 rev/min (right)

Comparing the oil films on the piston skirts one can observe that intense oil film results in an increased friction loss. If the differences in the oil film level on the piston skirt are small, even minimum variations are impactful on the friction loss. The oil film thickness is greater for the stepped profile in the central position.

Summary

- The shape of the microgeometry-bearing surface of the piston guaranteeing improved engine performance parameters, must take into account the following parameters of the oil film: the ability to induce reaction of the oil film, both as a result of a slip and squeezing the friction loss between layers of oil, and the maximum pressure in the film.
- Assessment of the oil film between the bearing surface of the piston and cylinder wall, must take into account the movement of the oil film layers, both in the direction of movement of the piston caused by the crank mechanism, and in the circumferential direction of the piston.
- Considered cases the shape of the bearing surface microgeometry pistons prove that you can design the piston, the reaction to the oil film caused by the effect of the slip and the reaction caused by the effect of squeezing was greater than classical barrel profile.
- Replacing the barrel-shaped piston skirt with the stepped one may yield a reduction of the friction loss.
- The stepped surface can be formed by applying coats such as graphite.

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