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Szymon FINKE*
Emil WRÓBLEWSKI*
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INFLUENCE OF STEPPED PISTON BEARING SURFACE ON FRICTION LOSS IN RAIL COMBUSTION ENGINE

In designing railway combustion engines, the key objective is to reduce fuel consumption. The way to achieve this objective is reduction of friction losses in the piston – cylinder node, which is the main in combustion engine. The analysis subjected railway engine DZC6 produce by Anglo Belgian Corporation, where on the basis of the parameters was carried out simulations for pistons with revised microgeometry bearing surface.

Keywords: combustion engine, piston, friction losses

1. INTRODUCTION

Locomotive is a rail vehicle, which is powered by a engine, used for hauling or pushing wagons in direct transport of passengers or freight [Matzke 1977].

The combustion engine is part of the diesel locomotive, which has the biggest impact on operating efficiency, costs and technical readiness [Schindler 2014]. In modern combustion engines used in traction vehicles, posed a number of requirements in the area of operational, economic and ecological [Szkoda 2007]. Important issues in the design of railway engines are [MTU 2016]:

– limiting the weight and size of the external engine due to additional locomotive equipment,
– achieving high engine durability while delivering high performance,
– achieving low fuel consumption while maintaining environmental, noise and vibration standards,
– get the narrowest possible engine for shunting locomotives to improve visibility from the driver's cab,
– achieving good work dynamics (rapid reaction to accеleraltor),
– gaining operational maintainability (small outlay for current service),
– reaching easy engine starting (cold engine pre-heating)

* Institute of Combustion Engines and Transport, Poznan University of Technology.

– low engine oil consumption through fine machining and assembly of parts, and proper oil temperatures in work (oil coolers, pre-lubrication systems for electric motors),

– achieving adequate crankshaft fatigue strength due to long crankshaft and multi-cylinder.

Diesel engines used to power locomotives and the Diesle Mulitipe Units (DMU) are medium-speed about speed 800-1800 RPM and up to 2,000 kW, the most common diameter of the cylinder ranges is 140-250 mm, pistons jumps from 175 to 300 mm, and the number of cylinders, depending on the system – from 4 to 24 [Szawłowski 1964]. The locomotives are most commonly used combustion engines are in-line and V-type cylinder systems. In some railway traction vehicles are used opposite-piston engines [Spiryagin, Maksym 2016]. In principle, all the motors are also turbo charged engines, with the result that the engine power is greater than a useful average pressure reach 20 bar. Average piston speed is approx. 12 m/s [MTU 2016].

One method of improving the operating parameters of the traction motor is the reduction of friction losses at the piston-cylinder node internal combustion engine, by modifying the microgeometry bearing surface of piston. The geometry of the gap between the bearing surface of piston and the cylinder, has large effect on friction loss in the combustion engine. It turns out that the on mentioned friction losses larger impact have the area covered by the oil film than the film thickness separating the two mating surfaces. In addition, the reduction of friction losses in the piston-cylinder node contributes to reducing fuel consumption and improving mechanical efficiency combustion engine. Reducing treatment coverage is the use of the oil film stepped shape of the bearing surface of the piston. Attempts to use a stepped profile on the bearing surface of the piston were analyzed on the engines of motor vehicles and resulted in the expected reduction in friction losses [Iskra, Krzymień, Wróblewski 2015; Iskra, Babiak, Wróblewski 2015].

Step-shaped gap can be obtained through the application of refining coatings materials which have good tribological properties [Deuss, Ehnis, Rose 2011]. Commonly applied material on the bearing surface of the piston is graphite.

The paper will present the results of simulation studies aimed to reduce friction losses in the piston-cylinder node of the modern railway combustion engine, through the use of a stepped profile of the piston.

2. THE CALCULATION OF THE FRICTION LOSSES FOR THE MODIFIED MICRO-GEOMETRY SUPPORT SURFACE

The analysis will undergo engine 6DZC production Anglo Belgian Corporation parameters shown in Table 1.

Table 1. Specifications of engine [7]

Cycle	4 strokes
Cylinders	inline 6
Power	1500 kW
Engine speed	300–1000 [rpm]
Bore	256 [mm]
Stroke	310 [mm]
Swept volume	95700 [cm^3]
Compression ratio	12,1:1
Injection	Direct a single pump on the cylinder

Adopted microgeometry shape of the bearing surface of the piston is a continuation of previous studies [Iskra, Babiak, Wróblewski 2015]. The authors assume applying to the support surface of the piston graphite layers in the H-shaped thereby obtaining a stepped profile bearing surface of the piston. In order to analyze the friction losses in the piston-cylinder node two shapes have been developed on bearing surface of the piston with different thickness of the bare in H shape Fig. 1–2.

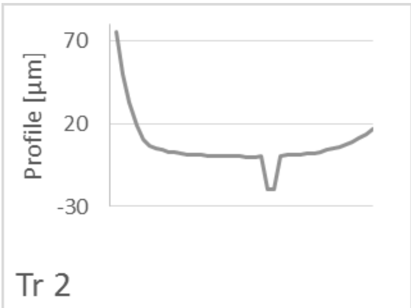

Fig. 1. The profile bearing surface of the piston TR2

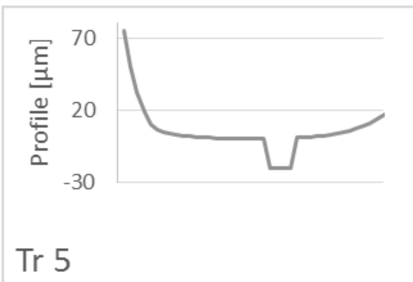

Fig. 2. The profile bearing surface of the piston TR5

Crossbar letter H can be extended by an area of high pressure hydrodynamic simultaneously obtaining the effect of reducing internal friction in the oil film. The problem is to determine the ratio between the thicknesses of the crossbar in the letter H, which guarantees a high load-bearing capacity of the oil film, with limited strength and internal friction.

3. RESULTS

Calculation of the oil film and friction losses were made for different geometries of the piston support surface, either from the surface of the barrel and ending with a modified piston side surface. The analysis was conducted for the following conditions:

– speed 750-1000 RPM, (operating conditions - maximum load),

– the initial thickness of the layer of oil on the strokes of the cylinder 70 microns,

– the engine oil temperature in cylinder 120 °C.

It should be noted that the simulation program is based on the theory of hydrodynamic lubrication and does not take into account such factors as tribological properties of pair materials under conditions of boundary friction. The simulations were aimed at defining the characteristics of a stepped profile in terms of fluid friction, that is, the conditions that prevail most of the time combustion engine. Conditions resulting simulations are summarized in Fig. 3–4.

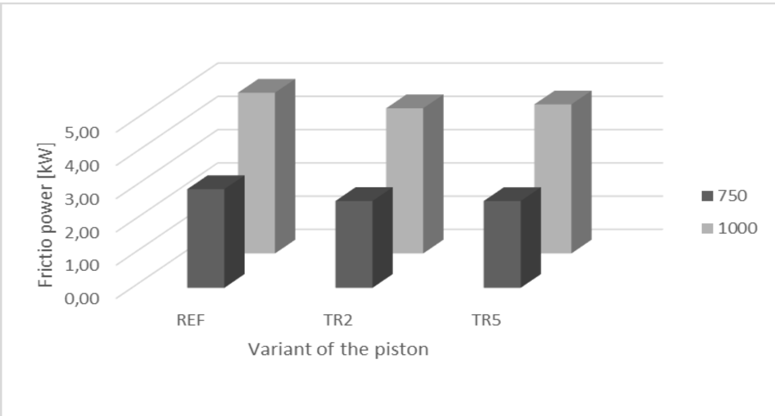

Fig. 3. The results of the simulation under the friction bearing surface of the piston and of the reference to the modified geometry as a function of engine speed

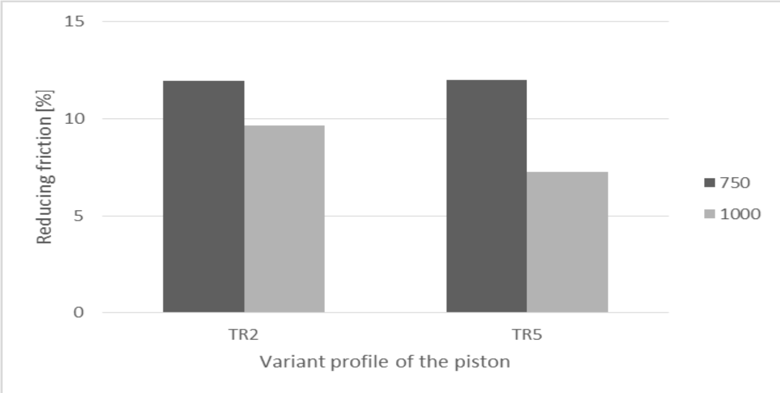

Fig. 4. Percentage reduction of total losses piston ring package with a modified geometry as a function of engine speed

Based on the obtained results it can be seen that both variants pistons with a stepped profile of the bearing surface yielded the expected reduction in friction losses in the piston-cylinder node pistons terms of reference.

As a result of simulation variants TR2 and TR5 showed marked reductions in friction losses in the piston-cylinder node. On the basis of the results can also be observed that the reduction of friction loss is greater at the speed of 1000 RPM. This is a very important observation because when engine speed increase due to the larger friction losses it being converted to heat followed by rapid heating of engine components and lubricating oil, and this contributes to a reduction of viscosity, which may lead to the occurrence of boundary friction conditions. This phenomenon can also have a positive effect on reducing friction losses under the assumption that no boundary friction will occur at the interface between the bearing surface of the piston and the cylinder.

4. CONCLUSIONS

The results allow to conclude that:

– the use of a stepped shape of the bearing surface of the piston relative to the barrel allows for the reduction friction losses and reduces fuel consumption, while increasing mechanical efficiency of the engine,

– a stepped surface can be achieved by applying to the support surface of the piston layers lubricants such as graphite,

– a layer of lubricants are particularly desirable in terms of occurrence lack continuous of oil film.

REFERENCES

Anglo Belgian Corporation, http://www.abcdiesel.be (accessed 29.04.2016).

Deuss T., Ehnis H., Rose R., Künzel R., 2011, Reibleistungsmessungen am Befeuerten Dieselmotor-Einfluss von Kolbenschaftbeschichtungen, MTZ 4.

Iskra A., Krzymień P., Wróblewski E., 2015, Geometry of the improved layer over a piston skirt, Combustion Engines, 162(3), p. 192–196.

Iskra A., Babiak M., Wróblewski E., 2015, Wpływ schodkowego profilu powierzchni nośnej tłoka na straty tarcia silnika spalinowego, Technika Transportu Szynowego, 12, p. 644–647.

Iskra A., Babiak M., Wróblewski E., 2015, Geometric shape of the support surface of the piston, Journal of KONES Section, Vol. 22, No. 4, p. 95–101.

Matzke W. 1997, Silniki wysokoprężne pojazdów szynowych, WKŁ, Warszawa.

MTU, http://www.mtu-online.com (accessed 2.05.2016).

Schindler C., 2014, Handbuch Schienenfahrzeuge, EUrail press, Hamburg.

Spiryagin, Maksym et al., 2016, Design and simulation of heavy haul locomotives and trains. CRC Press.

Szawłowski K., Silniki spalinowe wysokoprężne okrętowe i kolejowe, WNT, Warszawa 1964.

Szkoda M, 2007, Koszt cyklu trwałości jako kryterium efektywności modernizacji lokomotyw spalinowych, Zeszyty Politechniki Krakowskiej, z. 3, s. 159–169.

WPŁYW SCHODKOWEGO PROFILU POWIERZCHNI NOŚNEJ TŁOKA NA STRATY TARCIA KOLEJOWEGO SILNIKA SPALINOWEGO

Streszczenie

W projektowaniu współczesnych kolejowych silników spalinowych, kluczowym warunkiem jest uzyskanie niskiego zużycia paliwa. Drogą do spełnienia tego założenia jest redukcja strat tarcia w węźle tłok–cylinder, który stanowi główny węzeł silnika spalinowego. W artykule, analizie poddany został zmodyfikowany tłok ze zmienioną mikrogeometrią powierzchni nośnej, pochodzący z silnika kolejowego DZC6 produkcji Anglo Belgian Corporation, gdzie na podstawie jego parametrów pracy przeprowadzono symulacje strat tarcia.

Słowa kluczowe: silnik spalinowy, tłok, straty tarcia