THE EFFECT OF ENGINE RUN IRREGULARITY LEVEL ON OIL FILM OVER CYLINDER LINER SURFACE

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Abstract

At idle run the engine operates in extremely unfavorable conditions because of vibrations generated by cyclic forces which makes that oil film parameters on liner surface become critical as well. This paper presents one of the crankshaft vibrations results namely the speed that differs from a generally known dependence described with two harmonics $r\omega \sin\varphi$ *and* $1/2\lambda r\omega \sin2\varphi$. *Taking into consideration the deterioration of oil film - the thickness in particular - at low idle speed, a further speed decrease could cause the oil film rupture. This means that in the case of piston-cylinder assembly elements the process of abrasive wear occurs first of all at idle run. Avoiding such situations leads to a considerable extension of engine life.*

The minimum piston speed outside both dead centers could be increased by the rise in idle run speed. Unfortunately, this leads to an increase in fuel consumption, e.g. when waiting for a green light in urban traffic. The only way to improve the oil film parameters at idle run is to improve the engine speed irregularity level δ. *Certain possibilities in this field are offered by the hybrid drive. This paper presents an introductory analysis of possible improvement in oil film parameters over cylinder liner achieved by the decrease in speed irregularity level* δ.

Keywords: *oil film, engine run irregularity*

1. A piston momentary speed at high speed irregularity level δ

It is commonly known that with an engine speed decrease the level of irregularity deteriorates. This is why an average automotive engine idle speed is not lower than 800 rpm. In particular, for an odd cylinder number in-line engine an unfavorable piston speed decrease outside the dead centers can be observed which could lead to a number of undesirable phenomena, e.g. in the area of oil film parameters between piston rings and mating cylinder surface. Fig. 1 presents a course of piston speed for low irregularity level, while Fig. 2 presents the opposite case.

It can be noticed in Fig. 2 for a crank angle of about 240^o that piston speed falls to near 0 which generate a number of problems relative to vibrations in drive train but also the oil film parameters on cylinder liner could suddenly deteriorate.

The next chapter will present an analysis of ring pack generated oil film essential parameters. However, presenting a characteristics of piston speed momentary value one should consider the ways the course of speed could be influenced. Sudden reduction in speed at considerable distance from TDC or BDC is undesirable, because it is accompanied by significant axial forces by low slide speed. Moreover, a low slide speed does not allow for effective wedge effect which leads to a moderate oil film thickness between ring and liner and eventually to a rapid wear of both elements. In the case of engines of even cylinder number the phenomenon of sudden drop in piston speed beyond the dead centers is less intensive - see Fig. 3.

Nevertheless, recently the 3 - and 5-cylinder engines are often used as passenger cars drive and problems presented in this paper grow in importance.

2. Parameters of oil film on cylinder surface at engine speed high irregularity

High values of engine run irregularity result first of all from variability of torque generated during carried out thermodynamic cycle. Usually, the run irregularity level δ can be improved increasing the number of cylinders. It is far more difficult to counteract the rotational speed variability when the speed is low. In such case the usual way is to increase the flywheel moment of inertia. Alas, such measures worsen the engine dynamic characteristics and engine becomes heavier. Application of two - and three inertia flywheels is a possible solution. Even better solution is a replacement of flywheel with an electronic control system governing the crankshaft instantaneous speed. Unfortunately, such control is possible only for an engine coupled to electric motor like in hybrid drives. It should be stressed here that the improvement of engine run irregularity level using electric motor is the question of distant future. Thus it is necessary to analyze the effect of engine run high irregularity on oil film parameters, especially in order to clarify if engine operation at low idle speed is possible. A positive answer to this question raise the hope for lowered fuel consumption in cars moving in conditions of hindered urban traffic, an universal problem of modern cities.

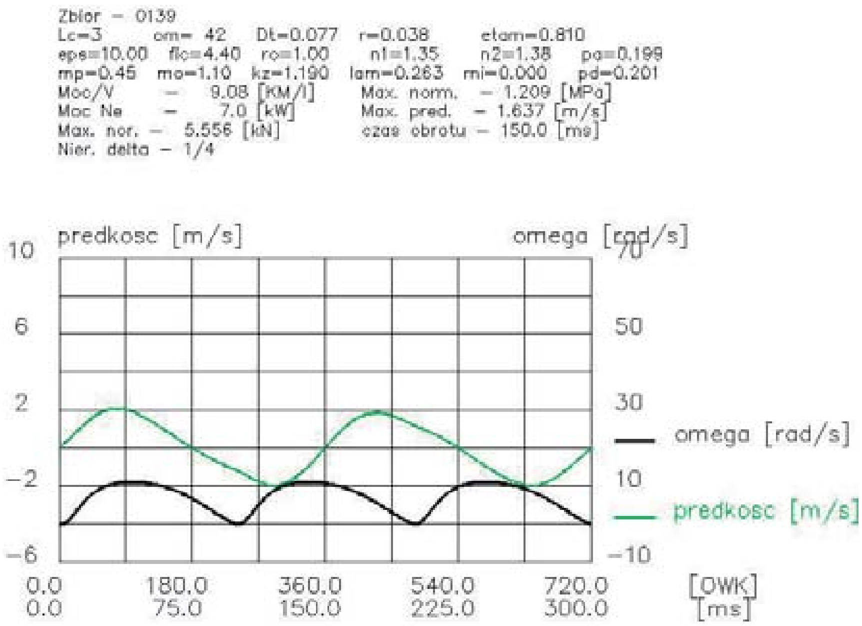

Fig. 1. Course of engine crankshaft momentary angular speed - black line and course of piston speed - green line; 3 - cylinder in-line engine with flywheel of high inertia moment

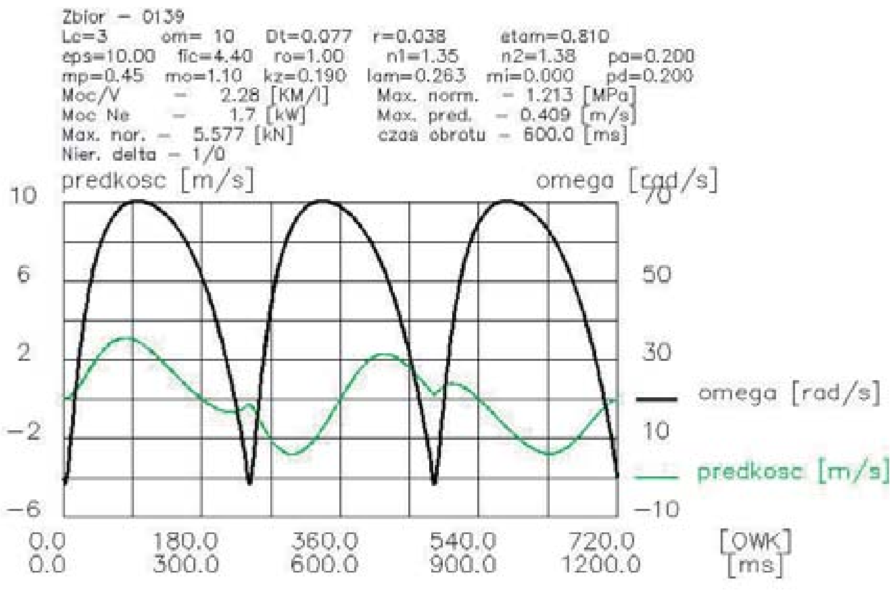

Fig. 2. Course of engine crankshaft momentary angular speed - black line and course of piston speed - green line; 3 - cylinder in-line engine with flywheel of low inertia moment

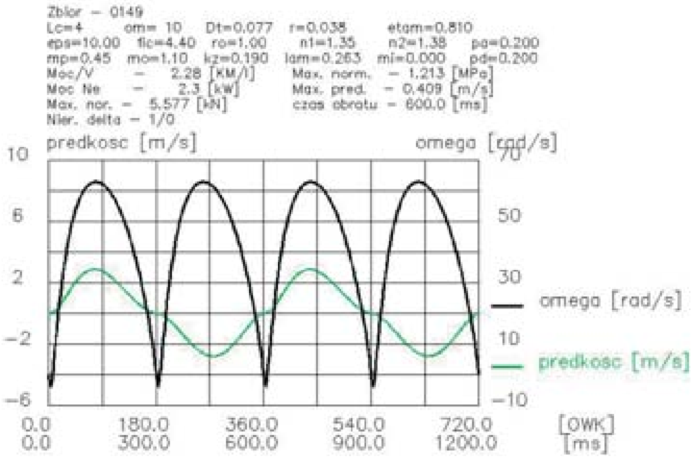

Fig. 3. Course of engine crankshaft momentary angular speed - black line and course of piston speed - green line; 4 - cylinder in-line engine with flywheel of low inertia moment

Principal parameters of oil film are: film thickness and friction force [1]. Fig. 4 presents oil film parameters for operational conditions corresponding to speed courses in Fig. 1 while those in Fig. 5 correspond to data from Fig. 2.

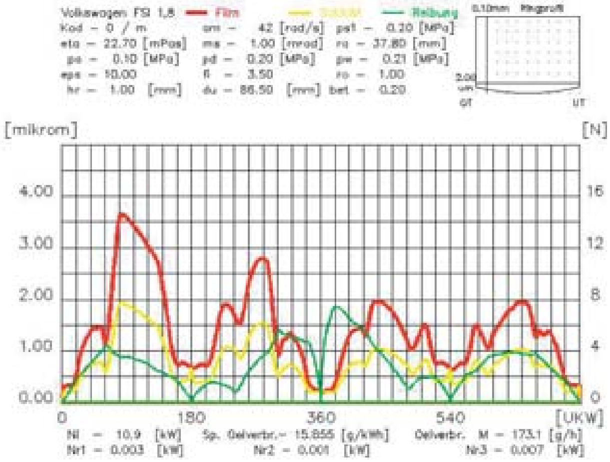

Fig. 4. Course of oil film thickness between upper compression ring and cylinder surface - red line and course of friction force - green line; the thickness of oil film left over cylinder surface marked with yellow; courses obtained for high engine run irregularity

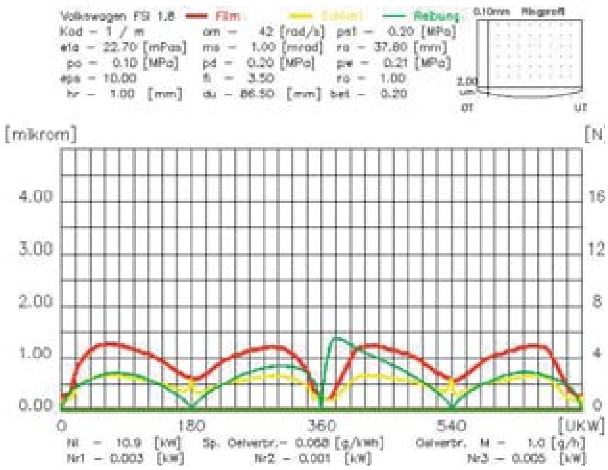

Fig. 5. Course of oil film thickness between upper compression ring and cylinder surface - red line and course of friction force - green line; the thickness of oil film left over cylinder surface marked with yellow; courses obtained for low engine run irregularity

Operational parameters of the engine for which the simulation has been carried out can be found above Fig. 4-5 while beneath the charts are some results obtained. No 1 denominate the power lost as a result of internal friction in oil film generated by the upper compression ring.
Comparison of oil film thickness courses show that the high level of run irregularity, i.e. conditions assumed for construction of charts in Fig. 4, generally does not cause the decrease in oil film thickness.

Quite the contrary - within the predominant sector of crank angle the oil film thickness in Fig. 4 is higher than that in Fig. 5. Therefore the friction forces should be lower in conditions of high run irregularity than those for the stable run. Alas it is not so. It is clearly noticeable in Fig. 4 that within the crank angle between 60 and 140 deg CA the friction force intensely increases.

Such high increase can be caused only by the increased filing ratio of the oil gap between ring face and cylinder surface. In order to confirm this thesis relevant simulations have been carried out and the results obtained are brought together in Fig. 6-7.

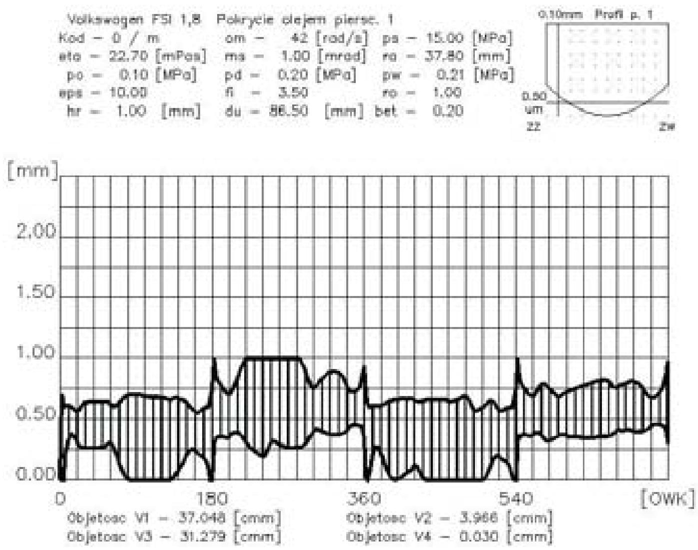

Fig. 6. Upper compression ring face covered with oil film for high engine run irregularity

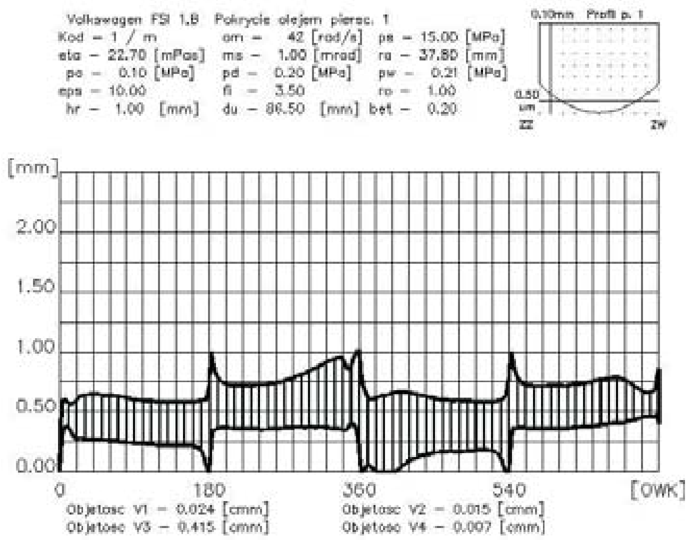

Fig. 7. Upper compression ring face covered with oil film for low engine run irregularity

It is easily noticeable in Fig. 7 the filing ratio of ring-cylinder gap is far higher for conditions of high run irregularity than for stable run (see Fig. 6). Sweeping of considerable amount of lube oil to the combustion chamber is the consequence of ring immersion in oil film within the regions of decreasing angular speed. This results in an increased oil consumption. For the case illustrated in Fig. 4 and 6, i.e. for high run irregularity d specific oil consumption is 15.8 g/kWh, whereas for low δ (see Fig. 5 and 7) there is hardly 0.088 g/kWh. As it has been proved, this phenomenon is characteristic for in-line engines of odd cylinder number. For the conditions of 4-cylinder engine, assumed in Fig. 8, the specific oil consumption is still not negligible (about 3 g/kWh) but far lower than for the 3-cylinder engine (almost 16 g/kWh).

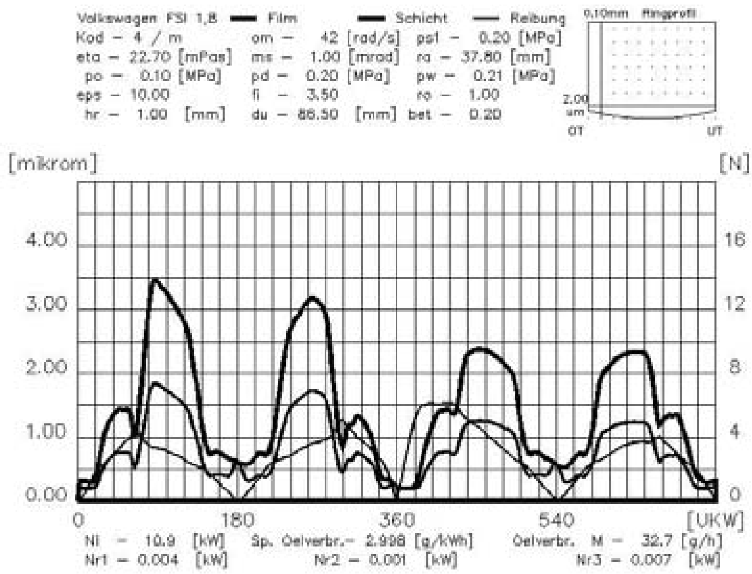

Fig. 8. Course of oil film thickness between upper compression ring and cylinder surface - bold line and course of friction force - thin line; oil layer left over cylinder surface marked with medium width line; courses obtained for 4-cylinder in-line engine of high run irregularity

3. Conclusions

1. A significant run irregularity, typical for low rotational speed, does not cause deterioration in oil film parameters, and gives even better value of basic parameter, i.e. oil film thickness.
2. High run irregularity in engine of odd cylinder number can bring about an increased oil consumption. Especially this phenomenon will intensify at reduced idle run speed.

References

[1] Iskra, A. *Studium konstrukcji i funkcjonalności pierścieni w grupie tłokowo-cylindrowej*. Wydawnictwo Politechniki Poznańskiej - Poznań 1966.

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