WEAR PROFILE OF THE CYLINDER LINER IN A MOTOR TRUCK DIESEL ENGINE

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Abstract

The paper presents results of investigation of cylinder liners wear. The investigation was carried out on diesel engines during long lasting operation in 5 motor trucks. Cylinder diameters were measured in two perpendicular planes on four depths using 2-point bore gauge, after removal of the cylinder head. Measurements were made every 50 000 km of vehicle mileage. Such methodology of measurements enabled to determine time course and wear profile of the cylinder liners (wear value in relation to the direction and height of the liner). It was stated that increments of diameter during the first period of operation are several times higher than during the later periods, when the wear intensity is constant. It was also found that wear of the cylinder liner in the plane perpendicular to the engine axis is bigger than in the parallel plane, and that wear in the upper part of the liner is twice as big as in its middle part.

Measurement scheme for the cylinder liner; histogram of cylinder liner diameters obtained in measurements after the technological running-in of the engine after mileage of 0, 50,000 km, 150,000 km and 250,000 km, wear profiles of cylinder liners in the two directions at different vehicle mileages are presented in the paper. Estimated profiles of the cylinder liner wear will be used as input data for the calculations of the blowby intensity with the use of mathematical model of PRC set.

Keywords: *diesel engine, wear, cylinder liner*

1. Introduction

Wear of a cylinder liner results in the increase of clearances between the cylinder and the piston as well as of the clearances in the ring-end gaps. This leads to the increase of gas leakage from the combustion chamber to the crankcase (blowby). Decrease of combustion chamber tightness is disadvantageous for the engine, as it results in drop of performance, increase of fuel consumption and emission of toxic exhaust gasses, accelerates degradation of engine oil and wear of the components, and also decreases cold start properties of the engine. Excessive increase of blowby and oil consumption is usually identified with the wear of the whole engine. Therefore, wear of the piston-rings-cylinder assembly (PRC) most often decides about durability of the whole engine or about the necessity of the general overhaul.

Cylinder liner wears mainly in the result of tribological processes related to the friction of the piston and rings against liner's surface. Because of reciprocating movements of the piston, relative velocity of friction differs at various heights of the cylinder – from zero at top and bottom dead centres (TDC, BDC) to maximum in the middle part of the stroke. Also the thrust of the piston on the cylinder liner depends on the position of the piston in the cylinder (crank angle) and differs with the direction. Above factors constitute different conditions of friction in different areas of the cylinder liner, and thus, the liner does not wear uniformly on the whole length and circumference.

Measurements of wear of the cylinder liner are usually made after withdrawing the engine from service, what allows establishing the boundary wear values, but it does not make possible the evaluation of the course of wear during engine operation. On the other hand courses of wear determined on the basis of periodic measurements of wear during test stand research can differ significantly from those, which occur during real engine operation in a vehicle.

Quantitative assessment of wear course of the cylinder liner during engine operation could allow assessing the influence of cylinder wear on the blowby intensity. That knowledge would be useful in development of mathematical models of gas flow through the crevices of PRC set [1-3], and to forecast engine durability.

This paper shows results of wear measurements of the cylinder liners of 5 truck diesel engines performed during long lasting operation in real conditions. The only disturbances of normal conditions of operation were periodic removals of cylinder head, necessary to measure the cylinders' diameters.

2. Research object and methodology

The object of research was a 6 cylinder diesel engine with swept volume 6.8 dm^3 and rated power 110 kW at 2800 rpm. The engine is equipped with wet cylinder liners made of cast iron with nominal inside diameter 110 mm. Piston stroke is 120 mm. Research was done using 5 engines mounted in motor trucks of middle payload (GVW 12 t). All vehicles were owned by one transport company and operated in similar conditions, with average monthly mileage of 10,000 km. So as to eliminate influence of engine oil on the course of wear, all engines were lubricated with the same oil CE/SF SAE 15W/40.

Diameters of cylinder liners were measured before the start of operation (after technological running-in of engines), and then were measured every 50,000 km of vehicle mileage. Measurements of diameters were made after removal of cylinder heads using Carl Zeiss 2-point bore gauge, with smallest division of 0.002 mm. Cylinder diameters were checked at two directions: parallel (A-A) and perpendicular (B-B) to the main engine axis, at four depths: 20 mm (TDC of the top ring), 35 (TDC of the second compression ring), 50 and 95 mm (Fig. 1). So as to minimize unrepeatability error of conditions and methodology, measurements were made by the same persons, using the same bore gauge and setting ring (used for setting the zero point), at the same location.

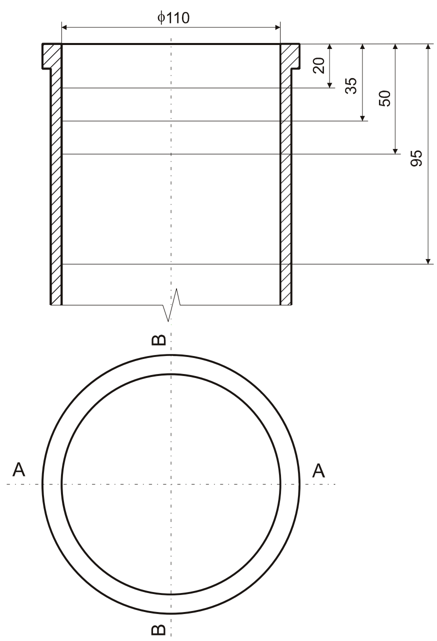

Fig. 1. Measurement scheme for the cylinder liner; A-A – direction parallel to the engine axis, B-B – direction perpendicular to the engine axis

3. Results of investigation

Figs. 2 to 5 show measurement results as histograms of cylinder diameters in parallel (A-A) and perpendicular (B-B) direction to the engine axis, at different depths and vehicle mileages. According to technical specification, cylinder liner of the investigated engine should have assembly diameter in the range 110.000÷110.022 mm. After technological running-in, diameters in the A-A direction extend beyond the given range, both in the direction of smaller and larger values. In the B-B direction, cylinder diameters have considerably larger values – more than half of measured values exceed 110.022 mm. Moreover, diameters increase with the depth of the cylinder. Above changes in the diameters of the cylinder liner during the technological running-in can be probably explained by the deformations of the cylinder resulting from the forces acting on it from the piston side in the plane of connecting-rod movements (direction B-B). Larger deformations at bigger depths could be associated with bigger distance from the point, where cylinder liner is fixed in the engine block.

Increases of diameters of cylinder liners during the first stage of operation, e.g. up to 50,000 km are big in comparison to increases during operation afterwards. This can be related to the running-in of the cylinder surface and further deformations of the cylinder during the first period of operation. Largest wear values occur on the depth of 20 mm (TDC of the top ring). Within the mileage 0÷50,000 km average wear intensities in the parallel and perpendicular directions to the engine axis on the depth of 20 mm are 6.1 and 7.0 µm/10,000 km, correspondingly. Increase of cylinder diameters in the successive investigated mileage ranges are comparable to each other, what indicates on the stabilized course of wear during this period. Average values of wear intensity for the mileages above 50,000 km on the depth of 20 mm in the parallel and perpendicular direction are correspondingly 1.1 and 1.6 µm/10000 km.

Average wear intensities decrease with the distance from the upper edge of the cylinder liner, however in the B-B direction minimum wear values were observed at the depth of 50 mm. Wear values in the plane perpendicular to the engine axis B-B are larger than those measured in the parallel plane A-A, no matter of the measurement depth.

Fig. 6 shows wear profiles of the cylinder liners in the directions perpendicular and parallel to the engine axis, made on the basis of the average values obtained during measurements.

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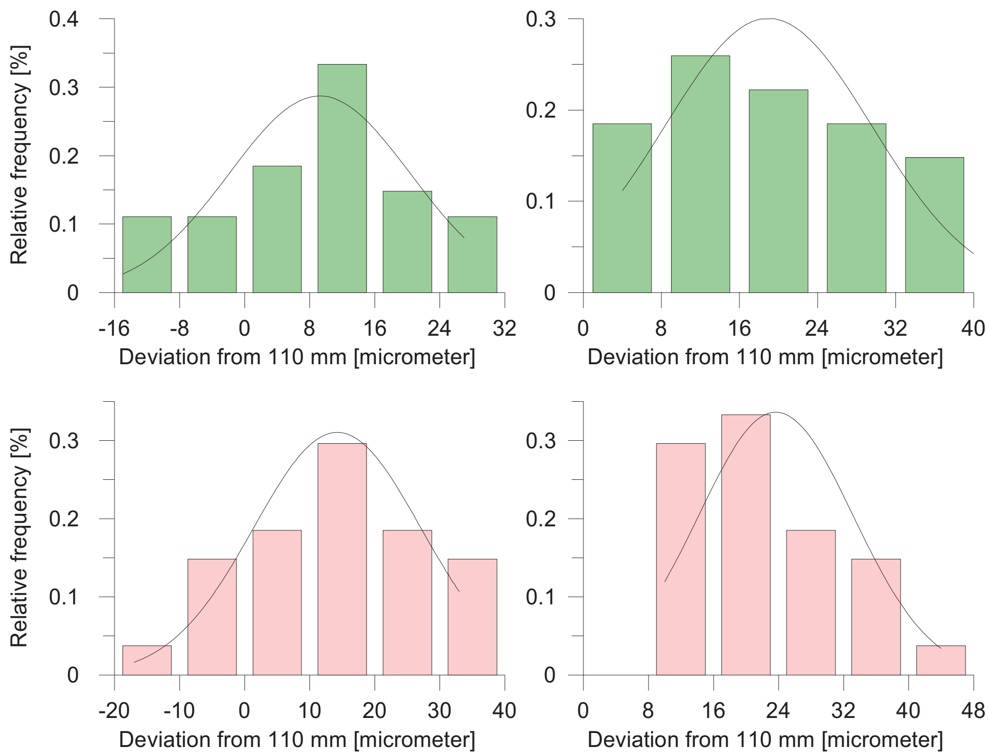
b)



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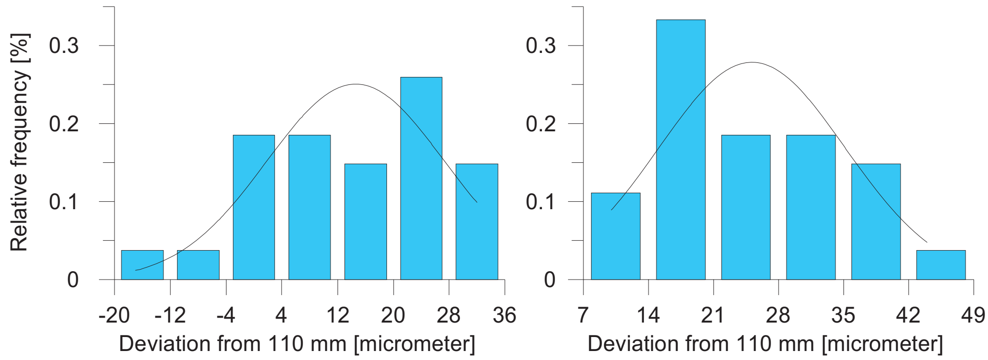

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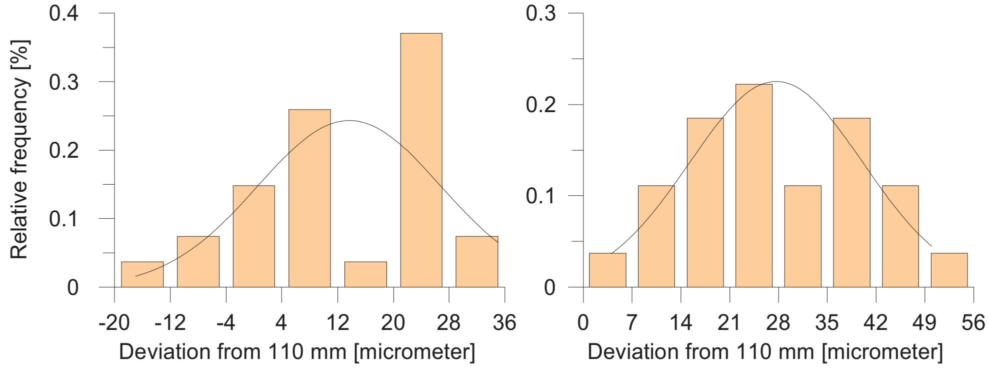
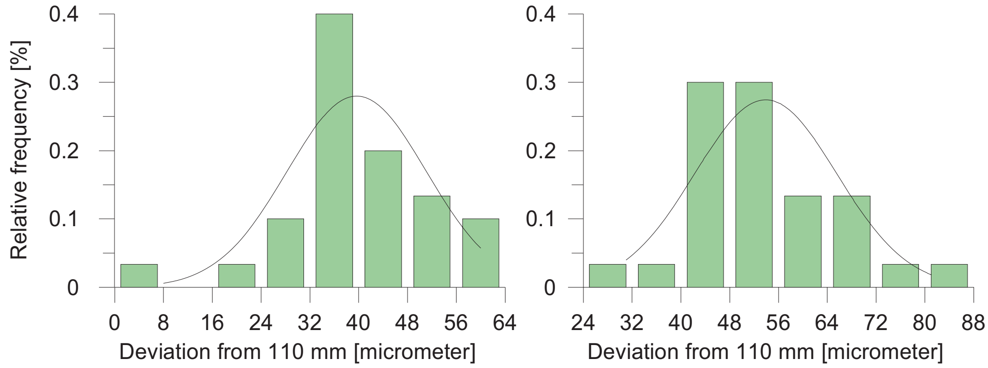


Fig. 2. Histogram of cylinder liner diameters obtained in measurements after the technological running-in of the engine (vehicle mileage 0 km; left: A-A direction; right: B-B direction):
a) depth 20 mm; A-A: mean – 9.2 μm. std. dev. – 11.3 μm; B-B: mean – 19.0 μm. std. dev. – 10.8 μm
b) depth 35 mm; A-A: mean – 14.2 μm. std. dev. – 13.1 μm; B-B: mean – 23.7 μm. std. dev. – 9.7 μm
c) depth 50 mm; A-A: mean – 14.6 μm. std. dev. – 13.0 μm; B-B: mean – 25.1 μm. std. dev. – 10.2 μm
d) depth 95 mm; A-A: mean – 13.7 μm. std. dev. – 13.4 μm; B-B: mean – 27.7 μm. std. dev. – 12.6 μm

a)



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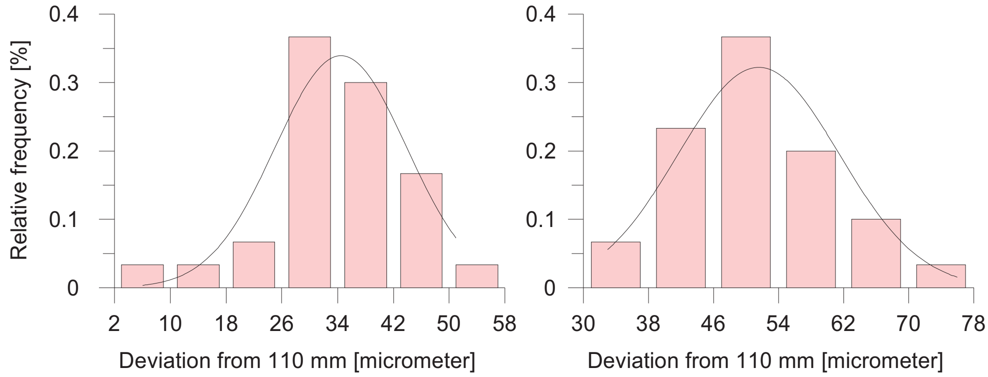

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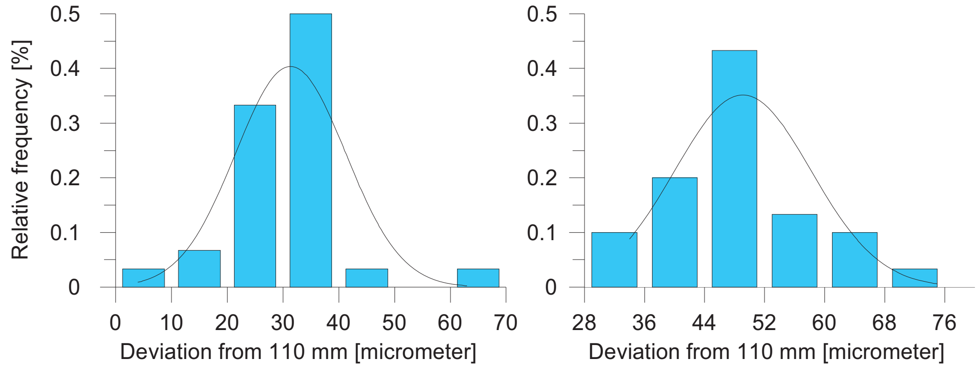

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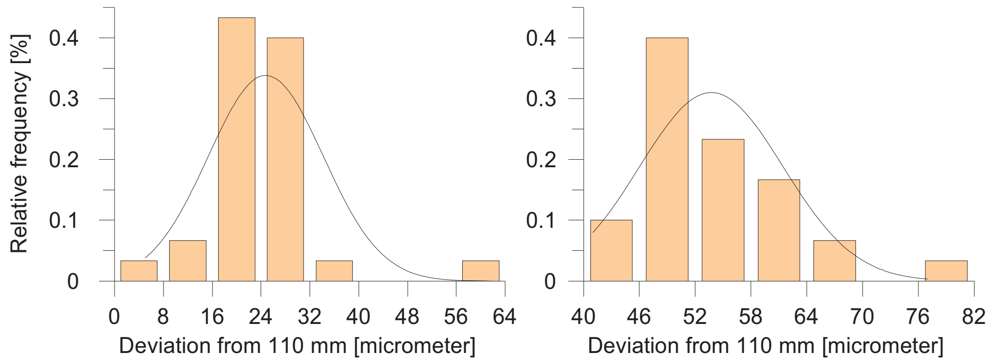
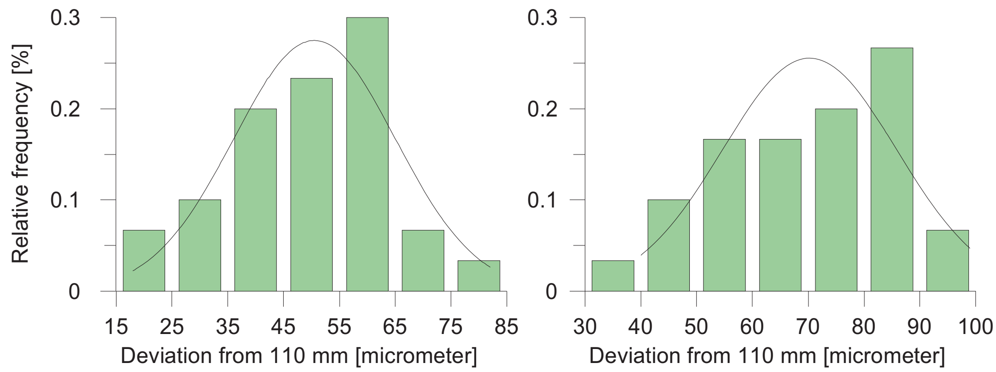


Fig. 3. Histogram of cylinder liner diameters obtained in measurements after mileage of 50,000 km (left: A-A direction; right: B-B direction):
a) depth 20 mm; A-A: mean – 39.7 µm. std. dev. – 11.6 µm; B-B: mean – 53.9 µm. std. dev. – 11.8 µm
b) depth 35 mm; A-A: mean – 34.5 µm. std. dev. – 9.6 µm; B-B: mean – 51.6 µm. std. dev. – 10.1 µm
c) depth 50 mm; A-A: mean – 31.4 µm. std. dev. – 10.1 µm; B-B: mean – 49.1 µm. std. dev. – 9.2 µm
d) depth 95 mm; A-A: mean – 24.8 µm. std. dev. – 9.6 µm; B-B: mean – 53.7 µm. std. dev. – 7.9 µm

a)



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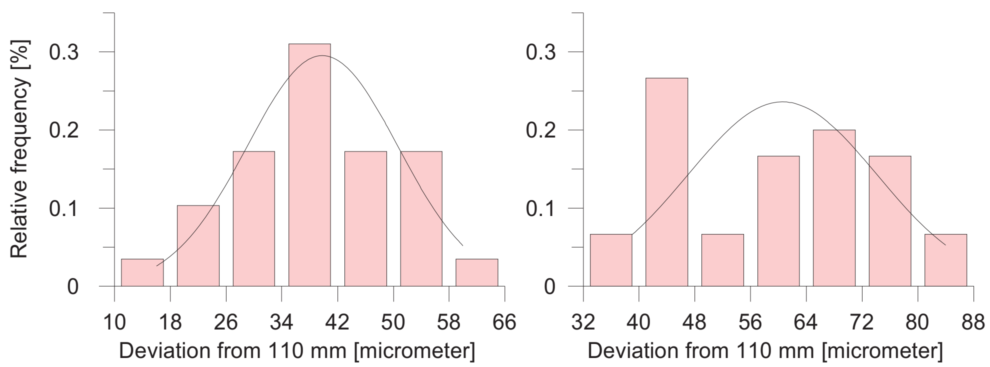

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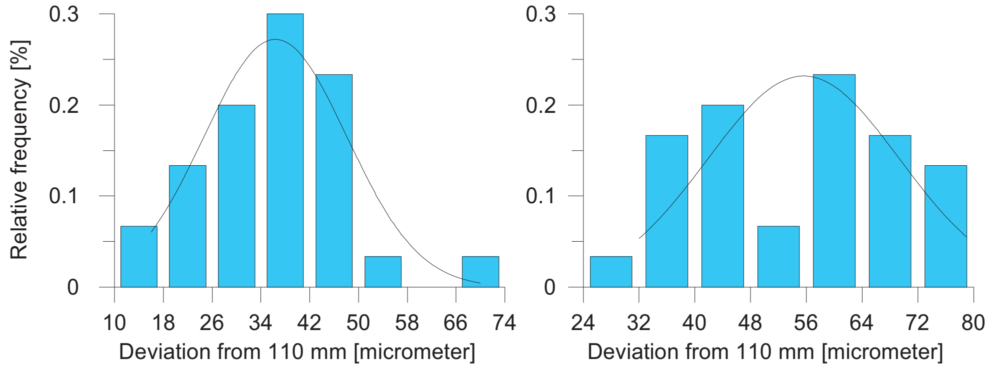

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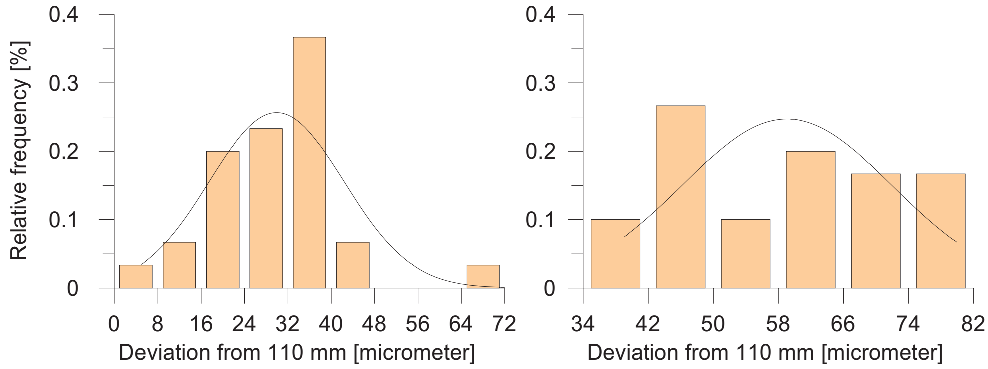
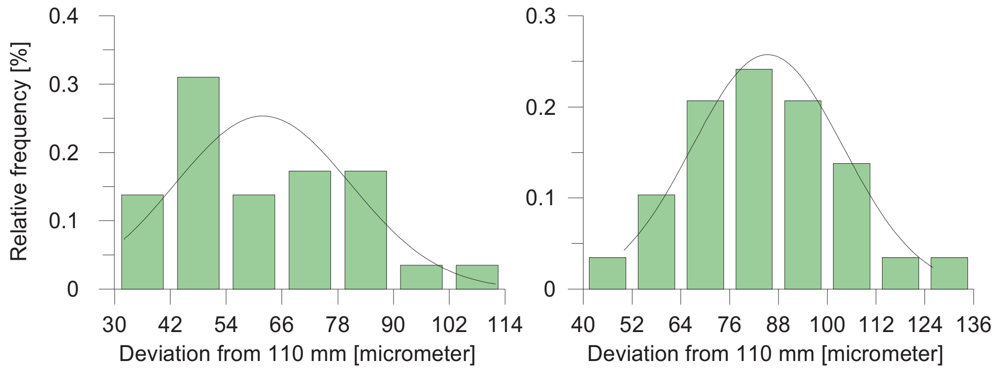


Fig. 4. Histogram of cylinder liner diameters obtained in measurements after mileage of 150,000 km (left: A-A direction; right: B-B direction):
a) depth 20 mm; A-A: mean – 50.5 µm. std. dev. – 14.8 µm; B-B: mean – 70.2 µm. std. dev. – 15.9 µm
b) depth 35 mm; A-A: mean – 40.8 µm. std. dev. – 12.0 µm; B-B: mean – 60.6 µm. std. dev. – 13.8 µm
c) depth 50 mm; A-A: mean – 36.4 µm. std. dev. – 11.9 µm; B-B: mean – 55.6 µm. std. dev. – 14.0 µm
d) depth 95 mm; A-A: mean – 29.9 µm. std. dev. –12.6 µm; B-B: mean – 59.1 µm. std. dev. – 13.1 µm

a)



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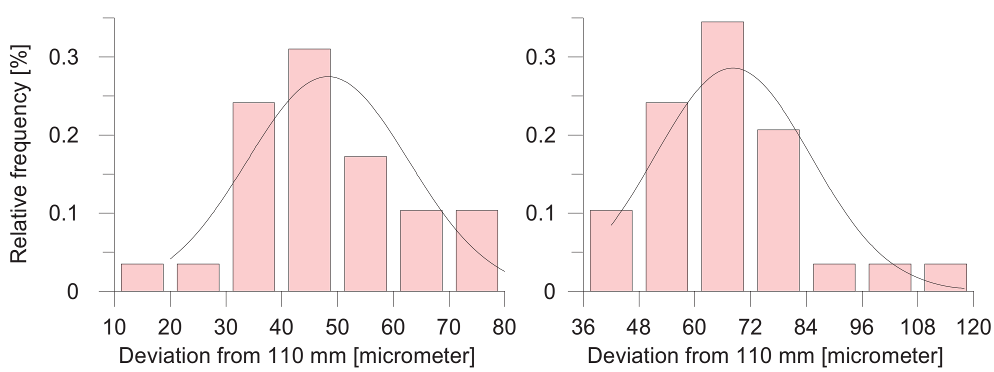

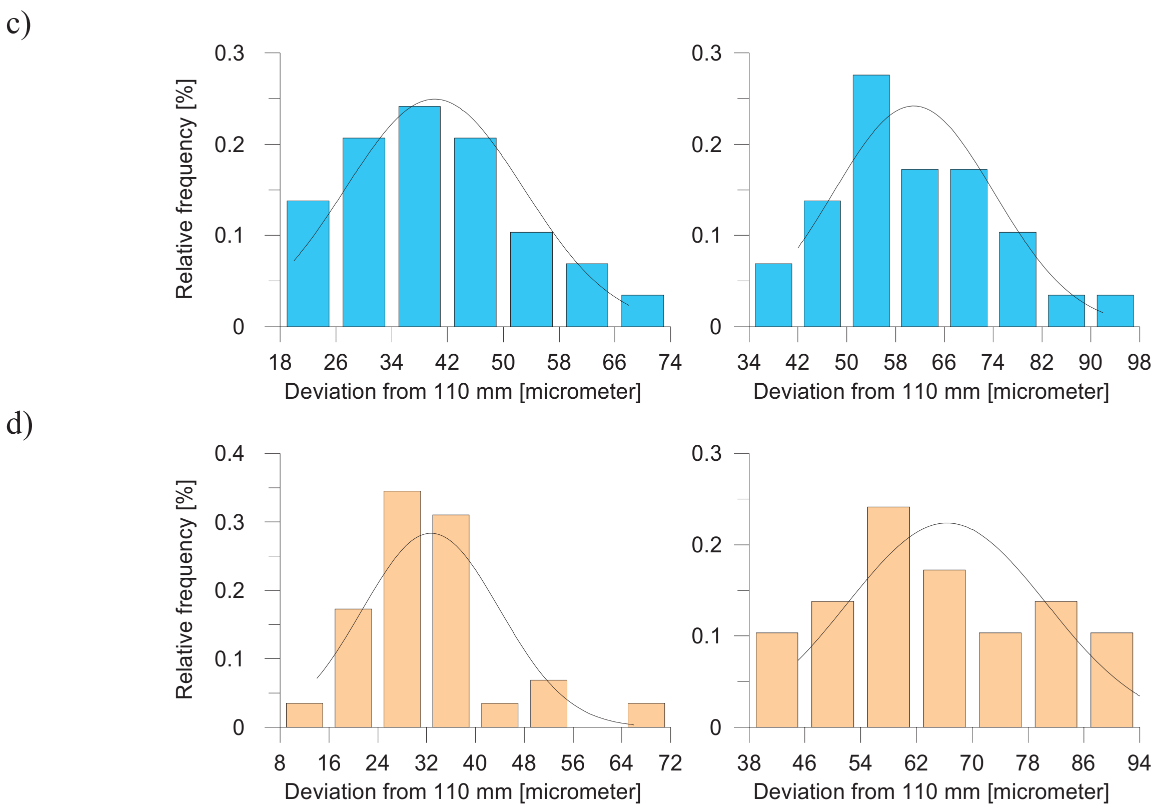

Fig. 5. Histogram of cylinder liner diameters obtained in measurements after mileage of 250,000 km (left: A-A direction; right: B-B direction):
a) depth 20 mm; A-A: mean – 61.9 μm. std. dev. – 19.2 μm; B-B: mean – 85.3 μm. std. dev. – 18.9 μm
b) depth 35 mm; A-A: mean – 48.3 μm. std. dev. – 14.8 μm; B-B: mean – 68.2 μm. std. dev. – 17.0 μm
c) depth 50 mm; A-A: mean – 40.1 μm. std. dev. – 13.0 μm; B-B: mean – 61.0 μm. std. dev. – 13.4 μm
d) depth 95 mm; A-A: mean – 32.7 μm. std. dev. –11.5 μm; B-B: mean – 66.3 μm. std. dev. – 14.5 μm

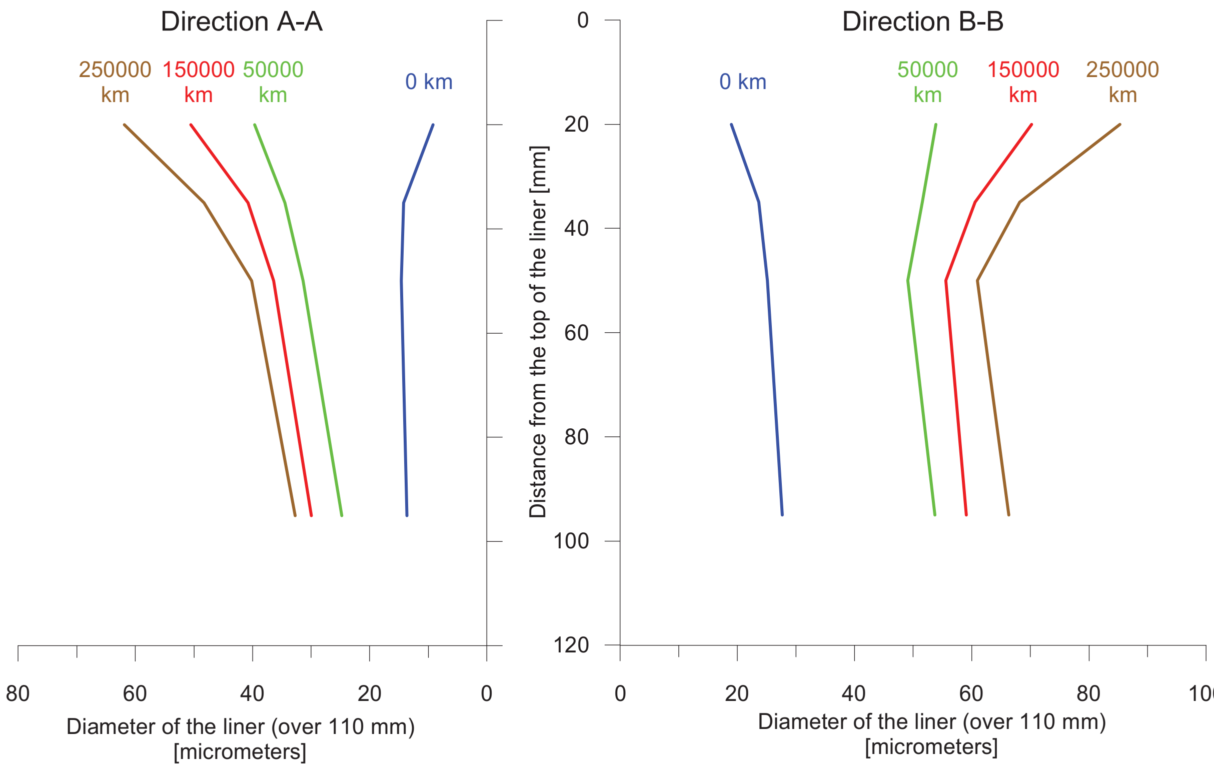

Fig. 6. Wear profiles of cylinder liners in the direction parallel A-A and perpendicular B-B to the engine axis at different vehicle mileages

4. Summary

On the basis of micrometric measurements, which were made every 50,000 km of vehicle mileage in 5 motor trucks used in real conditions of operation, wear courses of the cylinder liners were estimated. It was observed that during the first stage of operation (from 0 to 50,000 km – running-in period) increase of cylinder diameter is approx. 5-times bigger than during the later period (stabilized wear).

Highest cylinder wear takes place in the TDC area of the top compression ring and it is 2-times larger than at the depth of cylinder corresponding to half of the piston stroke. It was also observed that wear in the plane perpendicular to the engine axis (connecting-rod movement plane) is larger than in the parallel plane.

Estimated profiles of the cylinder liner wear will be used as input data for the calculations of the blowby intensity with the use of mathematical model of PRC set.

References

[1] Koszałka, G., *Modelling the blowby in internal combustion engine, Part 1: A mathematical model*, The Archive of Mechanical Engineering, Vol. LI, No. 2, pp. 245-257, 2004.

[2] Koszałka, G., *Modelling the blowby in internal combustion engine, Part 2: Primary calculations and verification of the model*, The Archive of Mechanical Engineering, Vol. LI, No. 4, pp. 595-607, 2004.

[3] Richardson, D. E., Krause, S. A., *Predicted Effects of Cylinder Kit Wear on Blowby and Oil Consumption for Two Diesel Engines*. Journal of Engineering for Gas Turbines and Power, Vol. 122, pp. 520-525, 2000.