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AN ATTEMPT AT AN ANALYTICAL DESCRIPTION OF BLOW-BY INTENSITY TO A CRANKCASE

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Summary. The aim of this elaboration was an attempt to determine a mathematical description of a blow-by phenomenon to engine crankcases for various types of engines on the basis of many years of the author's previous work. An effect of basic constructional and operational parameters on the value of the blow-by intensity was considered.

Key words: blow-by, combustion engine, piston, piston rings, cylinder

INTRODUCTION

The unit that consists of the piston with piston rings mounted on this piston is the sliding closure of the combustion engine workspace. Thanks to it, despite accurate execution of the piston and piston rings, there is always obtained the required clearance, which is also necessary because of thermal expansion of the used materials. It causes the blowing of some gases to the engine crankcase by slots among the piston, piston rings and the cylinder bearing surface (PRC). Sometimes, in the workshop engineering, the measurement of the blow-by to the crankcase is a diagnostic signal about wear of the PRC unit and possible necessity of its repair.

The mathematical descriptions of the blow-by phenomenon to a crankcase are hardly available in either local or foreign literature. The construction of every engine has a quite different value of the blow-by intensity. It is caused by the fact that many constructional and operational parameters affect the blow-by phenomenon. The basic constructional parameters that affect the blow-by phenomenon are, for example, the quantity of piston rings, the shape and clearance of the piston-ring joint, the piston ring unit pressures distribution, the piston ring axial height, the piston ring edges shape, the piston ring intersection shape, the piston ring distance from the piston head, the clearance of the ring part of the piston, the piston ring make accuracy and the piston ring groove, the axial clearance of the piston ring in its groove, the piston skirt clearance, the piston stroke, the cylinder diameter, the cylinder make accuracy, the cylinder deflection from the cylindrical shape, the cylinder surface quality, the quantity of cylinders, the compression ratio and many others. It is necessary to remember that, apart from the constructional parameters, the operational parameters like the engine rotational speed, the lubricating oil and coolant and the PRC unit elements temperatures, the engine load, the wears within the PRC group, the pressure course in the workspace, the sort of lubricating oil, the oil film thickness, the formation of carbon deposit, the piston ring weight, the phenomenon of piston rings vibrations and others also have an affect on the blow-by phenomenon.

An attempt at the accurate analytical description of the blow-by phenomenon is very difficult and the author realizes that an univocal description can be almost impossible in reality. Nevertheless, a few authors [Schwartz 1940, Englisch 1958] tried to estimate the rate of load losses caused by piston rings. Nevertheless, some attempts at a description were made in 1940 and 1958 for engines of older constructions. It is difficult to declare univocally and in a technically motivated way the accuracy of these methods. The method shown by Englisch does not account for changes of the rotational speed of the engine crankshaft.

Therefore, the author's efforts to provide a mathematical description of blow-by intensity to a crankcase result from many years of research executed on various types of both spark and self-ignition engines (for example SB-3.1, SW-680, 359, 115C).

SCOPE OF WORK

During the research an effect of the following constructional factors on the blow-by was analysed: the quantity of piston rings, the compression ratio, the first piston ring distance from the piston head, the clearance in the piston-ring joint and such operational parameters like: the engine rotational speed, the wear within the PRC group and the lubricating oil temperature. The blow-by measurements were also taken for the negative ambient temperatures, using research on accommodation of engines in low temperatures conducted at the Szczecin Technical University Department of Automotive Vehicles Operation. Also, the system for external drive of engines was used and the blow-by characteristics were determined for the crankshaft rotational speed below the engine idle running.

RESULTS AND DISCUSSION

The research on an effect of the piston rings quantity on the blow-by was executed at the test, one cylinder SB-3.1, self-ignition engine. The results of this research are shown in Fig 1. It can be concluded from these measurements that, in general, the scraper ring has a very little effect on the generasl sealing of the workplace. However, the use of two sealing rings in comparison to one ring caused over 20% sealing of the workspace.

The results of change of the compression ratio and its effect on the value of the blow-by is shown in Fig 2.

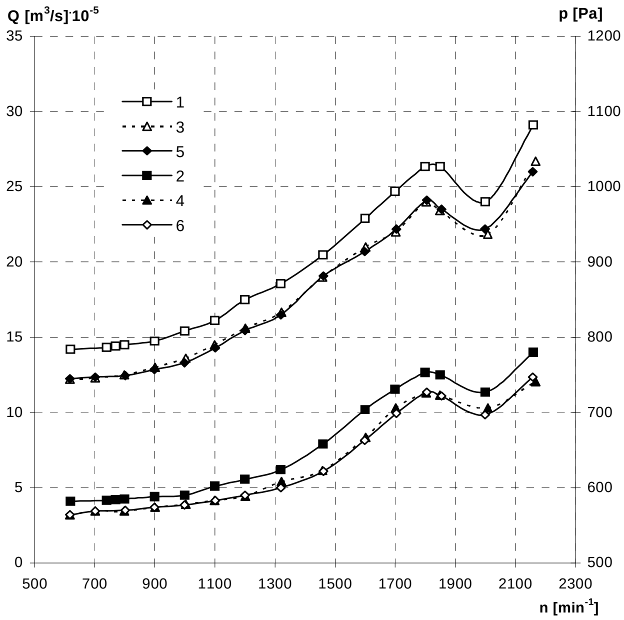

Fig. 1. The influence of number of rings on blow-by for SB-3.1 engine: 1 – blow-by-speed characteristics for one of compression ring and for one of oil scraper rings, 2 – backgas in the crankcase for one of compression rings and for one of oil scraper rings, 3 – blow-by into the crankcase for two of compression rings and for one of oil scraper rings, 4 – backgas in the crankcase for two of compression rings and for one of oil scraper ring, 5 – blow-by gases for two of compression rings without oil scraper ring, 6 – backgas in the crankcase for two of compression rings without oil scraper ring

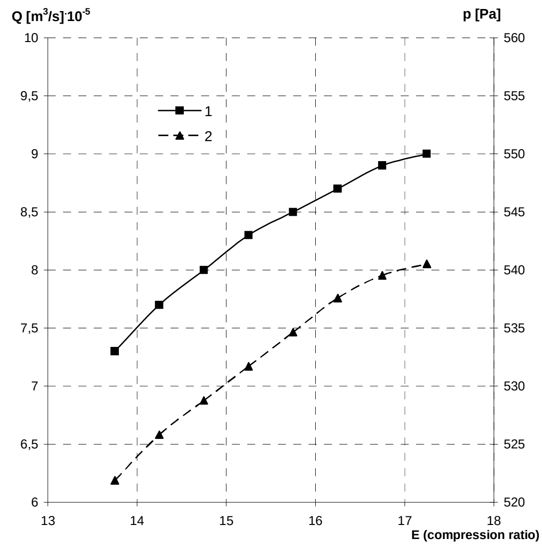

Fig. 2. The influence of compression ratio on blow-by and backgas in the crankcase of SB-3.1 engine for speed 289 rot, 1 – blow-by to the crankcase, 2 – backgas in the crankcase

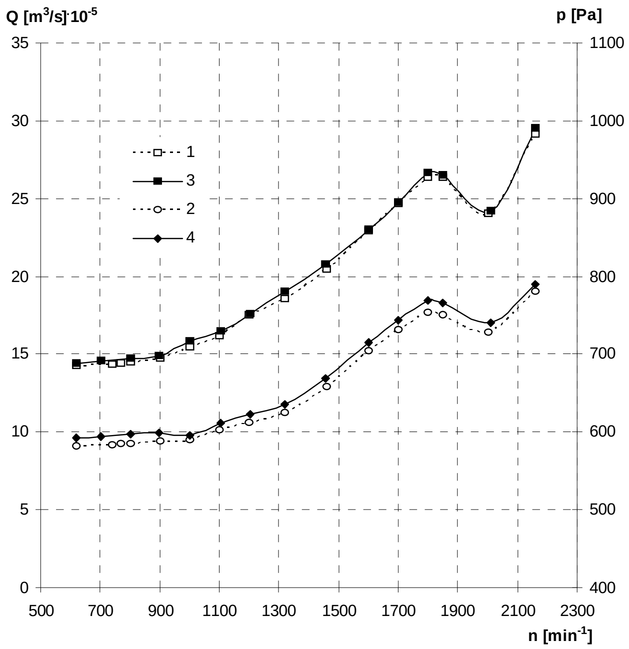

Fig. 3. The influence of distance of first ring from piston head on blow by for SB-3.1 engine
1 – blow-by for one of compression rings installed in first piston ring groove, 2 – backgas in the crankcase for one of compression rings installed in first piston ring groove, 3 – blow-by for one of compression rings installed in second piston ring groove, 4 – backgas in the crankcase for one of compression rings installed in second piston ring groove

An effect of the compression ratio on the quantity of the blow-by intensity and the gases concentration in the crankcase at the speed n = 289 min^{-1} for the SB-3.1 engine is shown in Fig 3.

Fig. 4 presents an effect of the rotational speed on the value of the blow-by intensity and the gases concentration in the SW-680 engine crankcase. It can be seen that the blow-by increases violently for the range of speeds from 1500 min^{-1} to 1800 min^{-1}. It is caused by the sealing rings vibrations. The similar phenomena take place also for other types of engines.

For example, for the 359 engine the extremes of the blow-by maximum can be seen at two ranges of the rotational speeds: 1500 min^{-1} and 2100 min^{-1}. Estimating that we do not take into consideration the phenomena of rings vibrations for the range of the engine rotational speed, at which the normal operation takes place, the characteristic of the blow-by changes can have the dependence close to the linear one. There can be seen quite a different situation below the idle running. For the 359 engine the blow-by intensity increases up to the speed of about 50 min^{-1}, the next decreases up to the speed of about 189 min^{-1} and above this the speed increases again. The initial blow-by rise is caused with a very high growth of the compression pressure. However, the blow-by increase for the speed above 189 min^{-1} is caused by the formation of the first ignitions in the cylinder.

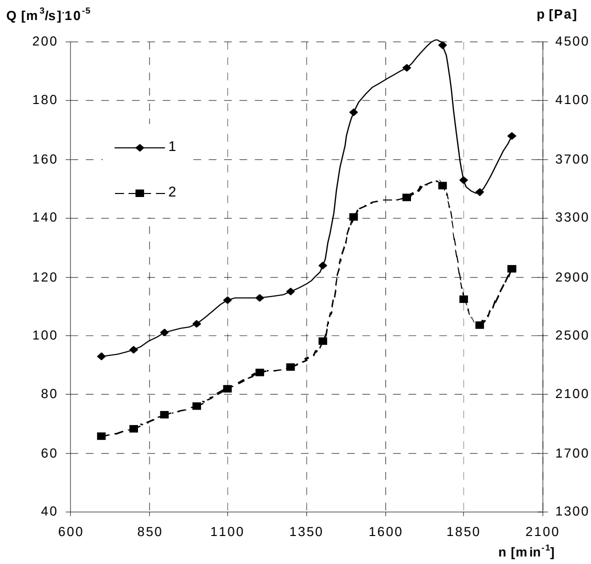

Fig. 4. The blow-by (1) and concentration of gases (2) characteristics depending on the rotational speed of the SW-680 engine

It is necessary to determine some conditions for the blow-by measurement in an attempt at an analytical description of the blow-by intensity for different types of engine. The research shows that any disturbances in the operation of the ring sealing, for example the fixing of the ring, collection of the excessive quantity of carbon deposit and vibrations of rings can cause an impetuous rise of the blow-by intensity or delimit the loss of the factor. For example, just the temperature of lubricating oil can affect not only the change of the blow-by intensity value, but also the changes in the course of the blow-by characteristic, which should be described with a quite different mathematical function. Therefore, the conditions must be determined for which the analytical blow-by description will be obligatory. According to the general assumptions, the formula is referred to the normal range of the engine operation. For the operational temperature of lubricating oil (the engine warmed up to the normal operational temperature), the degree of the engine wear does not create any serious reservations as to the normal operation or any problems with starting this engine. In a certain range of the course of operation (for the 359 engine up to 300 000 km) the value of the blow-by changes to the crankcase has (with a certain approximation) the linear characteristic [Abramek 2002].

CONCLUSIONS

As the research showed, the blow-by intensity Q depends on many constructional and operational parameters:

$$Q = f(n, \varepsilon, p_i, T, D, d_z, z, i, l_i, s, k, \rho, \tau) \quad (1)$$

where:

n – the rotational speed of the engine crankshaft,
ε – the compression ratio,
p_i – the mean indicated pressure,
D – the cylinder diameter,
z – the wear within the PRC group,
i – the quantity of cylinders,
T – the temperature,
d_z – the shape and clearance of the piston-ring joint,
l_i – the quantity of piston sealing rings,
s – the piston stroke,
k – the kind and shape of the sealing ring edges,
ρ – the kind of lubricating oil,
τ – the kind of cycle: two or four stroke.

Some parameters affecting the blow-by value can be grouped and divided into certain groups. The first group consists of the geometrical parameters *G*, to which the following can be included: the cylinder diameter, the piston stroke, the quantity of sealing rings. The second group includes the shape parameters: the shape and clearance of the piston-ring joint, the kind and shape of the piston ring edge, the piston accuracy, the piston rings and cylinder make. The third group includes the parameters of wear determined with the piston, piston rings and cylinder wear, for example by the mileage in kilometres or particular wears: the cylinder liner, the quantity of the piston-ring joint or the piston wear.

For the defined and constant temperature (T = const) the blow-by Q is the function that depends mainly on the geometrical parameters, the engine rotational speed, the quantity of cylinders and the parameters of wear:

$$Q = f(G, n, z, i) \quad (2)$$

For general estimation of the load losses rate in the form of the blow-by, the dependence can be shown in the shape:

$$Q = \alpha \cdot n + \beta \quad (3)$$

where:

α – the factor that takes into consideration the parameters of wear and the engine crankshaft rotational speed,
β – the factor that takes into consideration the geometrical and shape parameters,
n – the engine crankshaft min^{-1} rotational speed.

The factors α and β were determined in an experimental way and are referred to the certain, limited and constructionally close to considered collection of self-ignition combustion engines. The conception „constructionally close" means the similar geometrical dimensions and considered constructions of free-suction engines. The α factors can be read from the nomogram (Fig. 5) determined in an experimental way, in which nomogram takes into consideration the cylinder liner wear and the engine rotational speed.

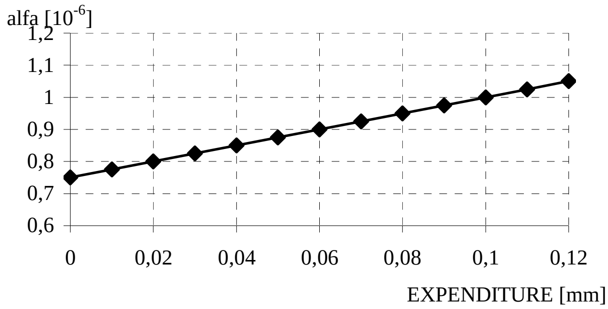

Fig. 5. The quantity of the α factor in the function of the cylinder liner wear

Whereas the β factor is calculated from the formula:

$$\beta = \frac{S \cdot ln\left(i + \sqrt{i+1}\right) \cdot \sqrt{D^3}}{30 \cdot \sqrt[3]{l_i}}$$

where:

S – the piston stroke, m,
i – the quantity of cylinders,
D – the cylinder diameter, m,
l_i – the quantity of piston sealing rings.

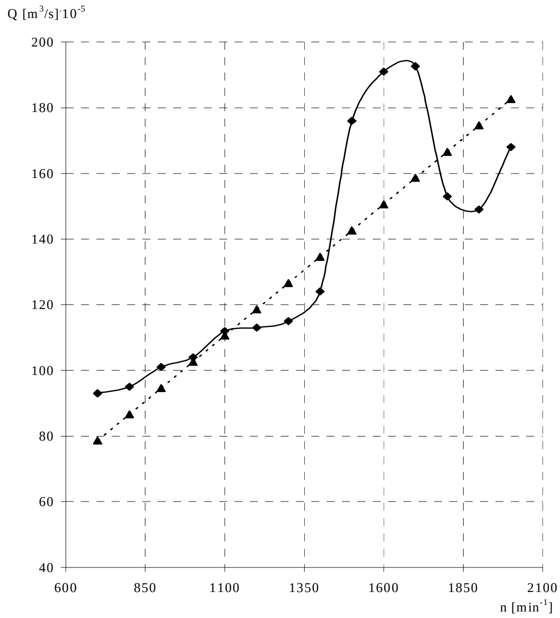

Fig 6. The blow-by characteristic depending on the SW-680 engine rotational speed determined in the experimental way (the full line) and calculated on the basis of proposed formulas (the broken line). The cylinder liner wear 0.02 mm

To determine the correctness of the formulas used, an exemplary diagram (Fig. 6) is shown of the blow-by measurements for the SW-680 engine and the diagram calculated from the dependences shown, marked on this exemplary diagram.

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