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RANDOMNESS ANALYSIS OF GAS SCAVENGE MEASUREMENTS

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Summary. The purpose of the paper was an attempt to evaluate a stochastic character of gas scavenge measurements to a crankcase. It was noticed in laboratory and workshop measurements that test results of scavenge are random and often ambiguous. In the paper the author tried to explain a reason of test result variations. Statistical analysis of gas scavenge measurements was performed on the SB-3.1 testing one-cylinder engine at selected rotational speeds of an engine's crankshaft. Selection of specified speeds was based on a course of scavenge characteristics in a rotational speed function of the engine's crankshaft.

Keywords: scavenge, combustion engine, piston, piston rings, cylinder

INTRODUCTION

Labyrinth seal of the piston-rings-cylinder assembly (PRC) should provide tightness of a cylinder working space and thus preclude gas scavenge to a crankcase. Maintaining a high gradient of pressure between a space over a piston and a crankcase has a favourable influence on the obtained engine performance. The PRC assembly has a central place in a structure of functional systems of a piston combustion engine, therefore all its unserviceability has an influence on working performance of the whole engine and a value of exhaust gas scavenge intensity to the crankcase. Increase of the scavenge intensity results in the reduction of the obtained effective work. The scavenge effect is also unfavourable due to faster deterioration and consumption of lubricating oil and some engine's elements [Abramek 2005].

A piston ring while working on a piston performs various movements in a ring groove resulting from a change of forces affecting the ring. Obviously, this condition is essential to the maintainance of a sealing operation of the ring. The ring must adhere to a cylinder bearing surface in spite of a piston's transverse movement in the cylinder, and this determines the necessity to provide a possibility of a ring's radial movement in the groove. All types of movements and vibrations of the ring have an influence on providing tightness of the PRC assembly, and thus on a phenomenon of changes of the gas scavenge intensity value to the crankcase. Moreover, movements of sealing rings can lead to a moment, when joints of all rings existing on a piston „overlap" and then an increased scavenge effect occurs.

In workshop engineering, a gas scavenge measurement to a crankcase is used to evaluate a technical condition of the engine. During scavenge measurements on the engine test house it was noticed that test results are of random character, which can have a significant meaning while evaluating the PRC assembly. Hence the attempt to determine and describe a stochastic character of scavenge test results [Abramek 2006].

TEST RESULTS AND STOCHASTIC ANALYSIS OF SCAVENGED GASES

Tests of exhaust gas scavenge to a crankcase were performed on the SB-3.1 one-cylinder testing engine at selected rotational speeds of a crankshaft: 650, 1300, 1800, 2000 rpm. The main aim of the tests was to present an influence of some operational factors (formation of carbon deposit, unevenness of a rotational speed) on a value of scavenged gases at other determined operational factors (speed, load, dosage). The complete characteristics of gas scavenge to the crankcase of the SB-3.1 engine is presented in Fig. 1. Measurement of the scavenge intensity at each, determined rotational speed is a random function $P_n(t)$, because the various value of measurements is influenced by many factors, e.g. accumulation of carbon deposit on rings, non-repeatability of engine's working cycles, unevenness of the crankshaft rotational speed. In order to examine a distribution of this function at: n_1 = 650 rpm, n_2 = 1300 rpm, n_3 = 1800 rpm, n_4 = 2000 rpm, measurements of the scavenge intensity were taken every 1 minute for 500 realizations. The scavenge intensity in each measuring cycle is considered as a random realization $p_k(t)$, where: k = 1, ..., N = 500.

It is essential for stochastic evaluation of a random function to determine a number of measurements, whose average value E[P(t)], at an assumed confidence level of 0,95, represents an expected value of the whole population. An average value for 50, 100 and 200 measurements was determined and in each case a confidence belt at a confidence level of 0,95 was determined. It was checked if an average value calculated for k_1 = 50, k_2 = 100, k_3 = 200, k_4 = N = 500 measurements is within a confidence level. As it was proven by tests, it is sufficient to make use of less than an assumed number of cycles to determine the average value with established probability.

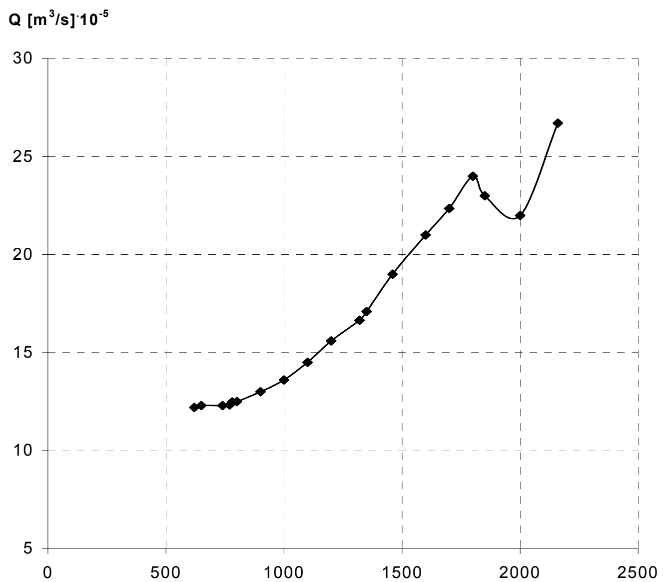

Fig. 1. Gas scavenge intensity to a crankcase for the SB-3.1 engine in a rotational speed function [Abramek 2007]

For the random function P(t) the following were determined and calculated:

- standard deviation $\delta(t) = \sqrt{V[P(t)]}$,
- arithmetic average = $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$,
- median (a value in an ordered observation sequence, below which there are 50% of data),
- modal value (a random variable value, at which a probability density function has a local maximum),
- geometric average $\overline{x_g} = \sqrt[n]{x_1 \cdot x_2 \cdot \ldots \cdot x_n}$,
- variance $s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$,
- standard error $s_e = \frac{s}{\sqrt{n}}$,
- the lowest value x_{min},
- the highest value x_{max},
- range ($x_{max} - x_{min}$),
- lower quartile (a value in an ordered data sequence below which there are 25% of data),
- upper quartile (a value in an ordered data sequence above which there are 25% of data),
- range between quartiles,
- coefficient of a range asymmetry $\gamma = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{s^3}$,
- coefficient of concentration, excess $K = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{s^3} - 3$.

Calculation results of statistical quantities for the gas scavenge to a crankcase of the SB-3.1 engine at selected rotational speeds n = 650, 1300, 1800, 2000 rpm are presented in Table 1. Scavenge intensity values are presented in [m^3/s]$\cdot 10^{-5}$.

Table 1. Summary of calculation results of measurement data statistical quantities for the gas scavenge to a crankcase of the SB-3.1 engine at selected rotational speeds of a crankcase n = 650, 1300, 1800, 2000 rpm

Statistical quantities	**Speed 650 rpm**	**Speed 1300 rpm**	**Speed 1800 rpm**	**Speed 2000 rpm**
standard deviation	0,095	0,168	0,320	0,097
arithmetic average	12,30	16,38	24,32	22,87
median	12,69	16,29	24,29	22,74
modal value	12,79	16,41	24,21	22,52
geometric average	13,89	16,34	24,29	22,85
variance	0,0323	0,1109	0,1347	0,0937

Statistical quantities	Speed 650 rpm	Speed 1300 rpm	Speed 1800 rpm	Speed 2000 rpm
standard error	0,2135	0,3104	0,2218	0,2875
the lowest value	11,83	15,71	23,98	21,96
the highest value	13,26	19,33	24,79	23,16
range	1,43	3,62	0,81	1,20
lower quartile	12,59	16,09	24,13	22,46
upper quartile	12,81	16,71	24,37	22,93
range between quartiles	0,22	0,62	0,24	0,47
coefficient of a range asymmetry	0,639	1,101	1,003	0,937
coefficient of concentration, excess	0,309	0,289	0,325	0,248

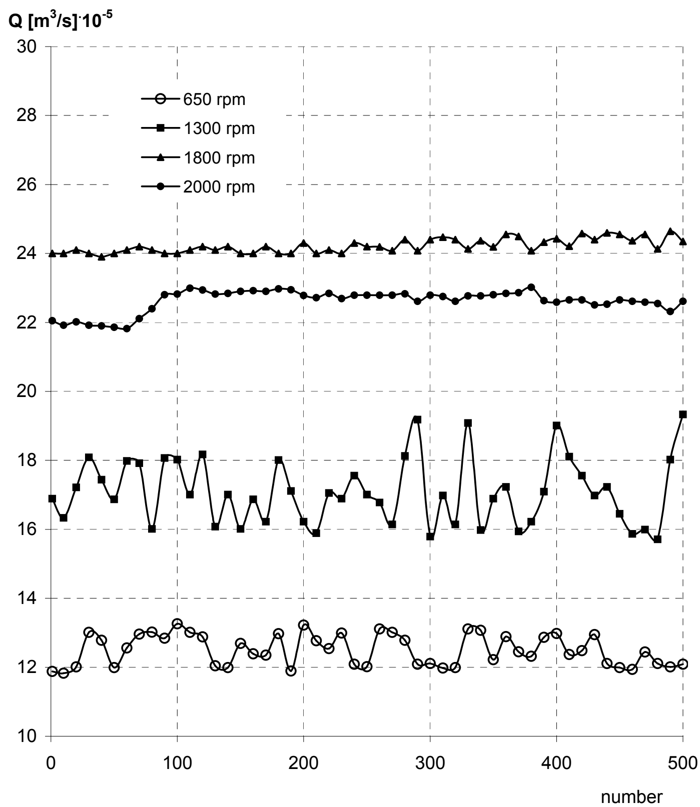

Fig. 2. Example of further scavenge realizations P(t) for the SB-3.1 engine at selected rotational speeds

As proven by tests, values of the gas scavenge intensity to the crankcase at the given, selected rotational speed of the SB-3.1 engine are not constant and they are subject to change more or less regularly. All random differences in the scavenge intensity values are caused mainly by uneven operation of the engine (uneven fuel dosage, maintained uneven rotational speed of the engine), however cyclic unevenness in measurements of the scavenge intensity is caused by formation of carbon deposit, which in some extent seals the working space (the charge loss is made difficult due to carbon deposit accumulation on rings). Accumulated carbon deposit causes reduction of free section, where scavenge takes place, and therefore the gas scavenge intensity values are lower. As it was noticed (considering the scavenge intensity values), carbon deposit is accumulated to a specified limit quantity and then it is removed automatically, which results in a sudden increase of scavenge. The presented situation can be observed at each rotational speed of the engine (tests were performed at the speeds of n = 650, 1300, 1800, 2000, 2100 [rpm]). Only at the speed of 1800 min^{-1} cyclic changes in the scavenge values are lower than at other selected rotational speeds of the engine's crankshaft. It is caused by a phenomenon of piston rings vibrations at the speed of 1800 rpm (as proven in literature [1]) and accumulation of carbon deposit is made difficult or attached carbon deposit has slight properties for flow damping (at the speeds of rings free vibrations n = 1800 rpm). The situation is presented in Fig. 2.

SUMMARY

When analyzing the scavenge measurements at selected rotational speeds, a random character of obtained test results can be noticed. It is caused by variable working conditions of piston rings and different types of movements, both of a piston and sealing rings. While engine operation, an oil film distribution on a cylinder bearing surface changes as well, and this also has a particular meaning for variation of the obtained scavenge test results. It was also noticed that in particular but very rare cases, the gas scavenge to a crankcase reaches a disproportionately high value in relation to the average value of scavenge. The phenomenon is short-lasting. Presently, no tests in this scope have been performed, but it is probably caused by setting the sealing rings' joints in one plane, which results in considerable leakiness of the PRC assembly.

Test results and calculations presented in the paper are the first stage of broader studies aiming at a determination of an influence of ring vibrations on sealing functions of piston rings, and thus on the lost charge intensity in the form of gas scavenge to the crankcase and determination of the influence of contamination and carbon deposit accumulation on rings on the scavenge quantity. The obtained measurement results prove that the scavenge intensity values are not constant at the given rotational speed of the engine. Therefore a reason of changes in scavenge intensity values shall be thoroughly examined and it should be remembered that an actual course of the charge loss in the form of scavenge shall be regarded as the random function and described using a theory of stochastic processes.

REFERENCES

Abramek K. F. 2005: Effect of scavenging of gases to crankcase on actual compression ratio during start-up. Problems of Applied Mechanics International Scientific Journal. Georgian Committee of The International Federation For The Promotion of Mechanism And Machine Science. Tbilisi. Nr 2(19)/2005.

Abramek K. F. 2005: Wpływ prędkości obrotowej na właściwości rozruchowe silników z zapłonem samoczynnym. Materiały V Międzynarodowej Konferencji Naukowo-Technicznej nt. Motoryzacja i Energetyka Rolnictwa. Komisja Motoryzacji i Energetyki Rolnictwa Polskiej Akademii Nauk Oddział w Lublinie. Lublin – Odessa.

Abramek K. F. 2006: Effect of use of two sealing rings in one ring groove to starting speed. Международный Сборник Научных Трудов. Издательство Калининградский Государственный Технический Университет. Kaliningrad.

Abramek K. F. 2006: Porównanie wybranych metod oceny stanu technicznego węzła tłok – pierścienie – cylinder. Motoryzacja i Energetyka Rolnictwa. Wydawca Komisja Motoryzacji i Energetyki Rolnictwa Polskiej Akademii Nauk Oddział w Lublinie. Lublin. Tom 8A

Abramek K. F. 2007: The study of crankcase exhaust gas blow-up phenomenon. Silniki Spalinowe. 2007-SC1.

Abramek K. F. 2007: Affect of phenomenon of piston sealing rings vibrations on tightness of PRC unit. Journal of Polish CIMAC. 2007.

Abramek K. F. 2007: Attempt to describe blow-by intensity to crankcase in analytical way. Teka Komisji Motoryzacji i Energetyki Rolnictwa Polskiej Akademii Nauk Oddział w Lublinie. Vol. VII.