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Change of a compression ratio and its influence on the gas scavenge effect

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The paper presents the influence of change of compression rate on value of intensity of exhaust gas blow-by and gas pressure in the crankcase of examined one-cylinder engine SB-3.1. Blow-by intensity characteristics and gas pressure courses characteristics in function of rotational speed were made for engine driven from an extraneous source of power (by means of 3-phase electrical engine).

1. Introduction

A piston combustion engine is still the primary and the most common source of the drive of vehicles and means of transport. Forecast on depleting the worldwide crude oil stocks and increasing natural environment contamination have the influence on main directions while designing and operating of engines. Increase of life and reliability and longer periodical survey periods result in high requirements for engine's main elements, particularly the piston-piston rings-cylinder sleeve assembly (PRC). Co-operation of a piston and rings with a cylinder bearing surface has the essential influence on life of a whole engine and working parameters, which shall not be subject to change during operation and charge losses resulting from leakage of the assembly. Leak tightness of the PRC assembly has the essential meaning during the start-up of the cold engine, when ambient temperature is below zero, a battery is in a bad technical condition (low starting current, low capacity caused by wear and below zero temperature), low crankshaft rotational speed, thick lubricating oil (a good oil film is difficult to be formed), which seals the PRC assembly in an unsatisfactory way.

Designers' efforts in combustion engine development are based mainly on improving the engine effective power. Power increase can be obtained, for example, by supercharging the engine. The supercharging and thus increasing of mean effective pressure, imply higher mechanical loads manifested by higher maximal pressure and increased heat loads (mainly pistons and rings). The compression degree is reduced to prevent these unfavourable loads of the engine. This is a reason of author's interest on the influence of a change of the compression degree (eliminating the influence of other factors) on a value of the lost charge as gas scavenge to the crankcase.

Measurements of the gas scavenge intensity through leakage of the piston-piston rings-cylinder bearing surface assembly can serve to evaluate a technical condition of the piston combustion engine [1, 2]. Precise determination of the working space leak tightness on the basis of calculations is practically impossible due to unacquitance of physical phenomena occurring and accompanying the gas scavenge through leakage of the piston-rings-cylinder assembly. Therefore only experimental research can be a reliable source of information about the scavenge intensity.

While measuring the gas scavenge intensity to the crankcase it should be remembered, that apart from operational wear of a cylinder, a piston and rings, other operational parameters have the influence on measurement results (e.g. temperature of the engine, load, rotational speed) and also other constructional parameters (e.g. a compression ratio, a type and a supercharging pressure, number of rings, etc.) [3].

2. Testing object and measuring devices

The SB-3.1 test engine is a one-cylinder version of the SW-680 engine (the head is a section of one cylinder of the SW-680 engine), consisting of the following elements: a piston with rings and a piston pin, a connecting rod with a bearing bushing, a cylinder liner, valves and its drive, an injector.

Main dimensions of the engine are: cylinder diameter 0,127 m, piston stroke 0,146 m. The engine construction enables a change of a compression ratio in a range from 13,75 to 17,75 by change of replaceable washers between a cylinder flange and a body. Admissible, maximal rotational speed is n_{max} = 2400 rpm.

Before the tests, a technical condition of the engine was checked. A condition of a cylinder bearing surface, control of valve clearance, control of an injection advance angle, determination of a start-up fuel quantity at 190 mm^3/injection were checked. Moreover, the engine is equipped with devices to measure the oil pressure in a lubricating system and to measure its temperature. Control of the injection advance angle was facilitated by an angle scale marked on a flywheel.

A test stand for scavenge intensity testing, presented in Fig. 1, was prepared in the Faculty of Motor Vehicle Operation of the Szczecin University of Technology.
In order to measure the scavenge intensity, a measuring device (6) was connected with the crankcase of the test engine (1) using a rubber pipe inserted to an oil inlet. Pressure formed in the crankcase during the engine operation caused the exhaust gas flow to an equalizing tank (9), filled with steel chips to eliminate pulsation and to purify initially the exhaust gas from oil mist. Then exhaust gas passed through a filter (8), where it was thoroughly purified and reached a laboratory gas meter (6). An additional device, i.e. a gas concentration pressure meter in the crankcase of the test engine (1) served to control the gas flow resistance, showing a value of pressure concentration in the crankcase.

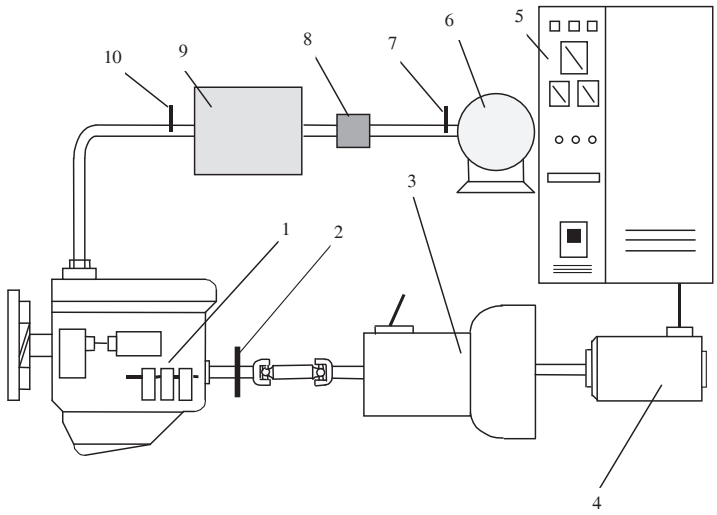

Fig. 1. Diagram of the test bed [4]:
1–engine, 2–one-way clutch, 3–gearbox and friction clutch, 4–three-phase motor, 5–control desk, 6- laboratory gas meter, 7- gas temperature meter, 8- filter, 9- equalizing tank, 10- gas temperature meter.
Rys. 1. Schemat stanowiska badawczego [4]:
1-badany silnik, 2-sprzęgło jednokierunkowe, 3-skrzynia biegów i sprzęgło, 4-silnik trójfazowy, 5-pulpit sterowniczy, 6-gazomierz laboratoryjny, 7-miernik temperatury gazów, 8-filtr, 9-zbiornik wyrównawczy, 10-miernik temperatury gazów.

3. Test results

Tests of influence of the compression degree on the scavenge intensity were performed on the SB-3.1 test engine. Measurements were taken both for the start-up speed (n = 193 rpm) and the whole range of the rotational speed.

As it is known for engines with compression ignition, both a slow-suction one and a supercharged one, the compression ratio ε must be selected to ensure an autoignition of diesel oil injected to the combustion chamber. Due to that, the compression ratio is selected to achieve the end compression stroke temperature of about 200 K higher than that of the fuel oil self-ignition temperature [6, 7]. So high temperature ensures to obtain a relatively short preparation period of the ignition (an ignition delay period) and thus „soft" operation of the engine. The compression degree is selected to enable the start-up of the cold engine, in various climatic conditions. It should be remembered that applying too high compression degrees is unfavourable, because it results in too high combustion pressure, and thus increases frictional resistance and decrease of mechanical efficiency. Due to that it is necessary to use the high-power starters. Therefore it can be stated that a value of the compression ratio is selected taking into account other criteria, mentioned as an example, and not considering a value of the lost charge intensity.

The compression ratio ε is determined as a theoretical value:

$$\varepsilon = \frac{V_s + V_k}{V_k} \tag{1}$$

where:
V_s - cylinder swept capacity,
V_k - end volume.

Influence of the compression degree on the scavenge intensity and gas concentration in the crankcase at the start-up speed of n_{roz} = 193 rpm for the SB-3.1 engine is presented in Fig. 2.

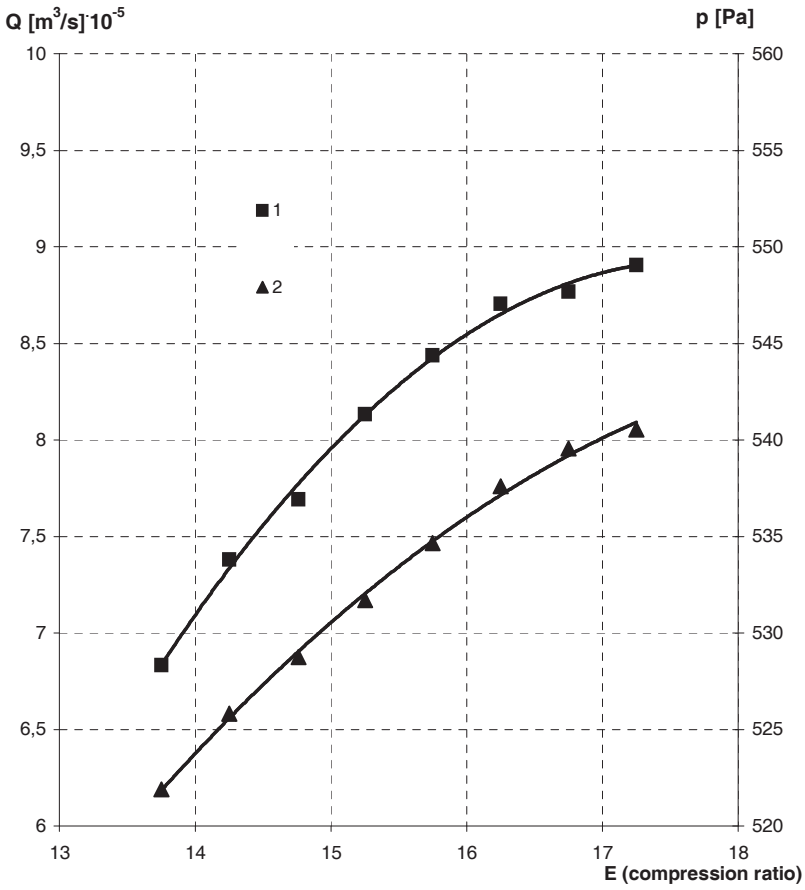

Fig. 2. The influence of compression ratio on blow-by and pressure in the crankcase in SB-3.1 engine for speed 193 rpm: 1-blow-by to the crankcase, 2-pressure in the crankcase.
Rys. 2. Wpływ stopnia sprężania na wielkość przedmuchów i spiętrzenie gazów w skrzyni korbowej silnika SB-3.1 przy prędkości 193 min^{-1}: 1-przedmuchy gazów do skrzyni korbowej, 2-spiętrzenie gazów w skrzyni korbowej.

Considering a course of changes in a value of scavenge and gas concentration in the crankcase, a considerable increase of the lost charge due to a change of the compression ratio can be noticed. For the start-up speed of 193 min^{-1}, so high increase of scavenge through leakiness of the PRC assembly can be caused by increase of the end compression pressure. As a result of such assumptions, a diagram of the influence of the compression ratio on the compression pressure was prepared and presented in Fig. 3. As resulting from the figure, a course of increase of the compression pressure has a similar character as increase of the gas scavenge to the engine's crankcase. This increase of the compression pressure causes increase of the lost charge intensity in a form of gas scavenge through a ring sealing assembly.

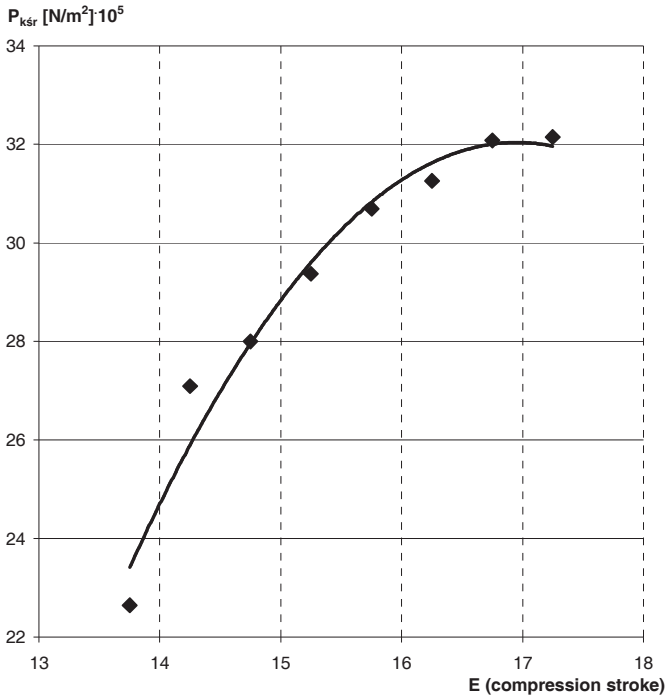

Fig. 3. The influence of compression ratio on compression pressure for speed 193 rpm for SB-3.1 engine.
Rys. 3. Wpływ stopnia sprężania na ciśnienie końca suwu sprężania przy prędkości 193 obr/min^{-1} dla silnika SB-3.1.

A summary characteristics of scavenge, depending on the rotational speed of the crankshaft, was prepared for selected compression ratio. A course of scavenge characteristics is constant in relation to the compression degree, however a value of the lost charge is subject to change. While the values are slightly higher than a measuring error range, however they can have influence on the process of faster oil deterioration due to increased scavenge [8, 9, 10]. The situation is presented in Fig. 4.

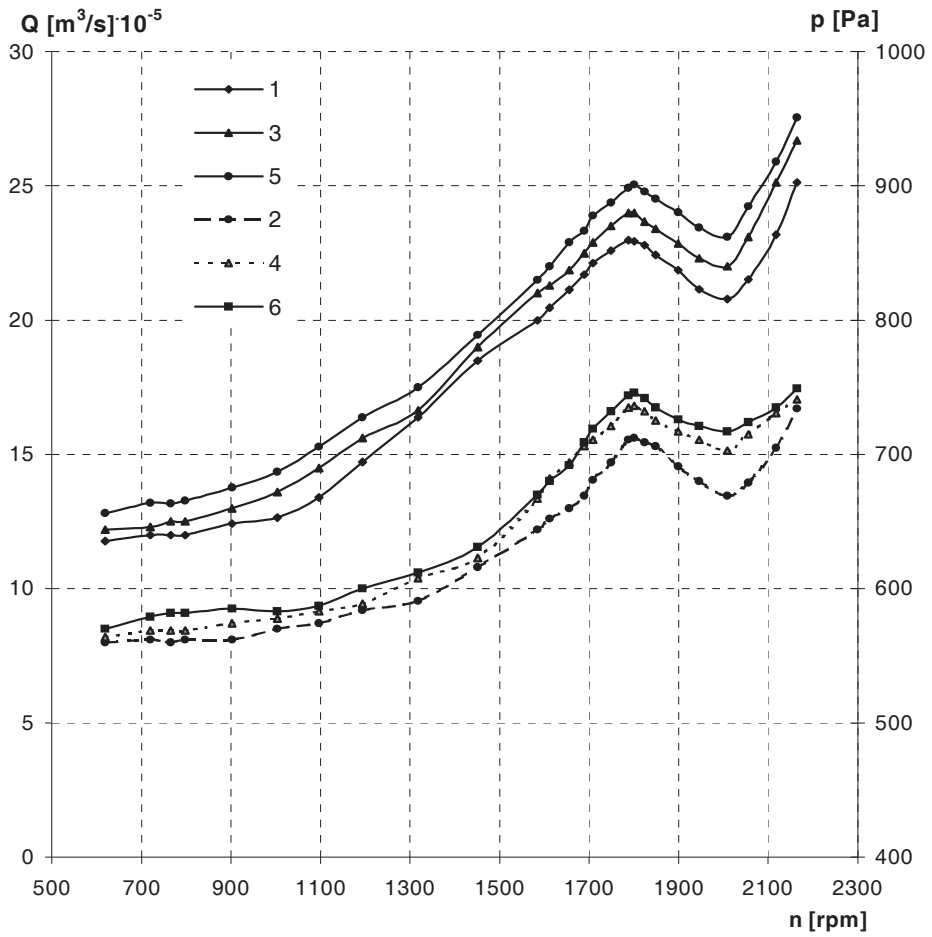

Fig. 4. Cumulative blow-by characteristic and pressure in crankcase for selected compression ratios for speed function for SB-3.1 engine [4]:
1- blow-by characteristic for compression ratios ε = 13,75, 2- pressure in crankcase for compression ratios ε = 13,75, 3- blow-by characteristic for compression ratios ε = 15,75, 4- pressure in crankcase for compression ratios ε = 15,75, 5- blow-by characteristic for compression ratios ε = 17,75, 6- pressure in crankcase for compression ratios ε = 17,75

Rys. 4. Zbiorcza charakterystyka przedmuchów i spiętrzenia gazów dla wybranych stopni sprężania w funkcji prędkości obrotowej dla silnika SB-3.1 [4]:
1-charakterystyka przedmuchów dla stopnia sprężania ε = 13,75, 2-charakterystyka spiętrzenia gazów w skrzyni korbowej dla stopnia sprężania ε = 13,75, 3-charakterystyka przedmuchów dla stopnia sprężania ε = 15,75, 4-charakterystyka spiętrzenia gazów w skrzyni korbowej dla stopnia sprężania ε = 15,75, 5-charakterystyka przedmuchów dla stopnia sprężania ε = 17,25, 6-charakterystyka spiętrzenia gazów w skrzyni korbowej dla stopnia sprężania ε = 17,25

4. Conclusions

When analyzing the obtained results of the exhaust gas scavenge measurements to the crankcase of the SB-3.1 engine at different compression ratio, obtained by change of washers under the head, it can be noticed that a change of the geometric compression degree resulted in a difference in the gas scavenge intensity. The change was noticed both for the start-up speed and for the whole range of the engine rotational speed without load. It means that increase of the compression ratio results in increase of the compression pressure (as presented in Fig. 3) and simultaneous increase of the charge loss in a form of scavenge through leakiness of the piston-rings-cylinder assembly. Some scientists think that the charge loss has a form of critical flows through the PRC assembly [11]. As proved by the presented measurement results, increase of the compression resulted in increase of the scavenge intensity. It could mean that there are no critical flows between rings, a piston and a cylinder. However, this statement shall be subject to further research.

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Zmiana stopnia sprężania i jej wpływ na zjawisko przedmuchów gazów

S t r e s z c z e n i e

W referacie przedstawiono wpływ zmiany stopnia sprężania na wielkość natężenia przedmuchów spalin i ciśnienia gazów w skrzyni korbowej jednocylindrowego, badawczego silnika SB-3.1. Charakterystyki natężenia przedmuchów oraz przebiegów ciśnień gazów w funkcji prędkości obrotowej sporządzono dla silnika napędzanego z obcego źródła napędu (silnikiem trójfazowym).