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The impact of intake canal geometry on kinematics of load in combustion chamber

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S u m m a r y. The results of analysis of technical possibilities to increase engine efficiency were presented in this article. This problem was connected with kinematics properties of air inflow to the combustion chamber. The possibilities of intake airflow modulation have a positive impact on the level of engine usable parameters and emission. This issue was presented in the results of experimental research. The results of baseline research gave information about the flow resistance. On the basis of results of experimental research conclusions were made.

K e y w o r d s: supply system, engine, filling of combustion chamber.

INTRODUCTION

The efficiency of engine is the most important priority during the designing of modern engines. Those questions corresponding to the decrease of fuel consumption and decrease of impact on natural environment have become extremely important. Efficiency is also important today, where intensification of transport use has a negative impact on air clarity and economic growth is the cause for increase of fuel consumption.

The direction of sparkle ignition (SI) engine development was based on the development of automotive market and introduction of new technology which gave many new products. Now the most important aims are: the decrease of fuel consumption and fulfilling more and more radical norms of emission relating to toxic gases emissions and keeping of high level of usable engine parameters as torque and power [13].

Photochemical smoke over the city is today the „normal" effect of chemical reaction under sunrays in the big and highly industrialized cities.

In most countries the administration setup of limitation of emission was established. The toxic gases [10] are; hydrocarbons (C_nH_m), carbon monoxide (CO), nitro oxide (NO_x), molecular parts (PM) and sulfur oxide (S – mainly from the fuel pollution).

Currently, in the phase of continuous development are systems which are able to increase energy efficiency of SI engines, as well as produce better energy - ecological parameters [3,4]. By applying a combination of a few different modern constructional systems, the considerable decrease of fuel consumption and exhaust gases emission could be achieved (Fig. 1 and 2).

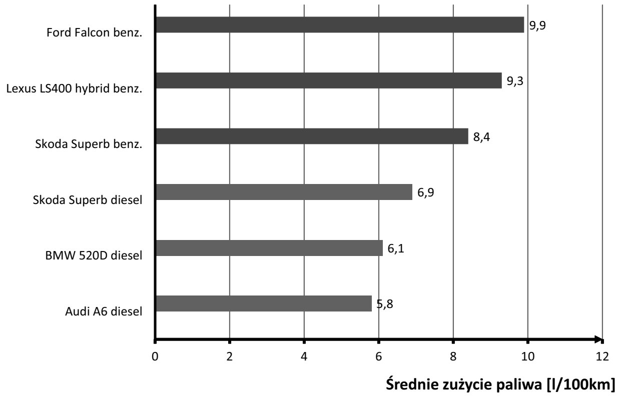

Fig. 1. The average fuel consumption by the modern cars with automatic transmission [17] (test type - ADR 81)

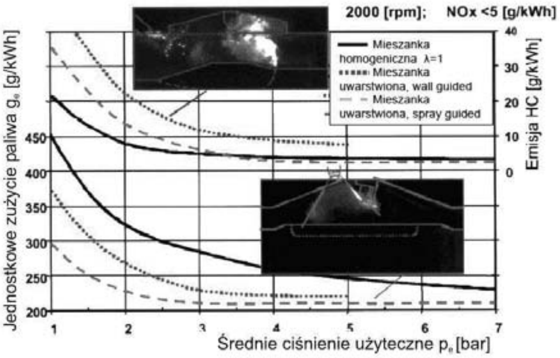

Fig. 2. Comparison of specific fuel consumption and hydrocarbons emission for GDI engine by the injection and mixture type [5]

The alternative fuels as a source of energy for the modern engine are still being developed by the quality and exploitation requirements. It can be a cause of more effective use of this fuel as renewable source of energy in the future. Except this, now we have many possibilities of adopting engine feeding system to specific properties of fuel [11, 14].

Indirect measures of these are achieved by low levels of fuel consumption and low toxic gas emissions as well as the increase (or keeping) of engine parameters like torque and power.

Many researchers [1, 8, 9, 15] were engaged in the research on the impact of intensification of vortex in combustion chamber on heat transfer in SI engine. Others were engaged in the research on the impact of turbulence on heat creation [2, 6, 16] and stabilization of burning process in piston engines [7]. The results of this type of research in different ways have indicated the impact of swirl on engine work conditions. The authors agree that the vortex has a positive impact on air-fuel mixture formation by achievement of more homogeneous form. This conclusion was made by the achievement of decrease of level emissions of carbon monoxides and hydrocarbons. Also, the increase of nitro oxide was achieved. However, the impact of vortex on heat transfer was not clear. The possibilities of intensification of preliminary swirl in intake canal are seldom mentioned in research works. This intensification can be very important in cases of;

- formation of homogenous mixture,
- low RPM level,
- engines with a relatively small capacity of one cylinder
- use of alternative fuel by engine feeding system.

EXPERIMENTAL STAND

The experimental stand was based on the real intake system of four strokes, four cylinders SI engine with displacement of 1598 cm. The diameter of intake canal for experimental stand was 34 mm. The cause of difference between engine and model was accessibility of tubes on the local market.

The effect of swirl was achieved by using the flexible element with the 65 mm length, width 32 mm and thickness 0,4 mm steel tape assembled inside the tube. The real view of this element was presented in Figure 3.

On the basis of these assumptions the airflow experimental model in the intake canal was built. The picture of experimental stand was illustrated in Figure 4.

The value of airflow resistance (Δp) was assigned on the equation;

$$\Delta p = \rho \cdot g \cdot n \cdot l \text{ [Pa]}, \quad (1)$$

where:
ρ – density of liquid in manometer [g/ccm],
g – earthly acceleration [m/s^2],
n – manometer ratio,
l – number of gradations.

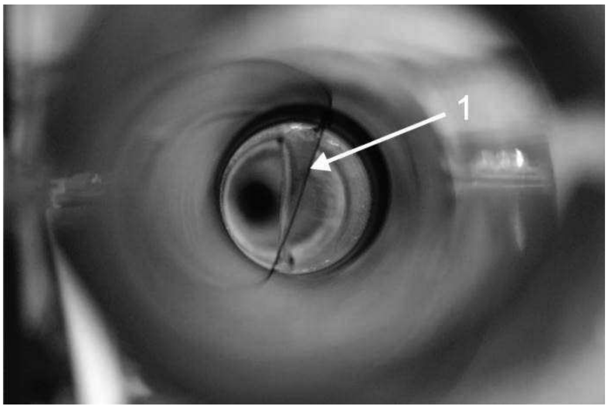

Fig. 3. The picture of canal with flexible geometry [9]; 1 – steel tape

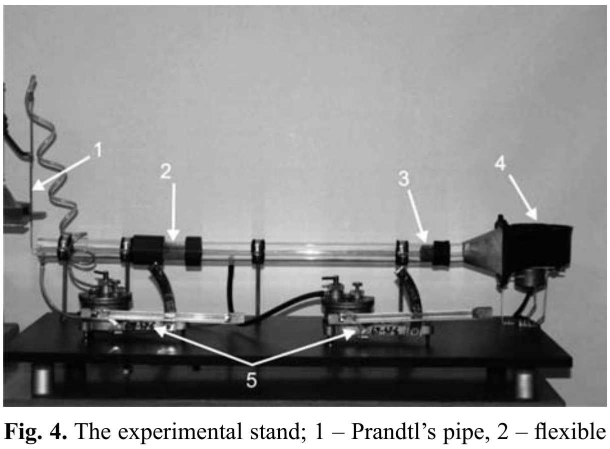

Fig. 4. The experimental stand; 1 – Prandtl's pipe, 2 – flexible tape, 3 – airflow stabilizer, 4 – ventilator, 5 – Recknagel's micro manometers

The value of velocity was achieved on the basis of dynamic pressure in two self-orthogonal plane. Measure points were based on the divided field of tube surface. The diameter of tube was divided by nine rings with 2 mm width. And so, the four measure points for each ring were achieved.

The airflow velocity (v) for each measure point was calculated by the equation:

$$v = \sqrt{\frac{2 \cdot g \cdot \rho \cdot n \cdot l}{1,3}} \text{ [m/s]}. \qquad (2)$$

The average value of velocity for the field of tube surface was achieved from;

$$\overline{v} = \frac{1}{A} \cdot \sum_{n=1}^{9} \frac{(v_{n1} + v_{n2} + v_{n3} + v_{n4})}{4} \cdot A_n, \text{ [m/s]}, \qquad (3)$$

but:

$$A_n = \pi \cdot \frac{(d_{n1}{}^2 - d_{n2}{}^2)}{4}, \text{ [m}^2\text{]}, \qquad (4)$$

where:

A – field of surface of orthogonal canal intersection [m²],

A_n – field of surface for n –ring,

n – number of the ring,

$v_{n1 \div 4}$ – airflow velocity for the successive n - ring and measure point,

d_{n1} – outside diameter for n – ring,

d_{n2} – inside diameter for n – ring.

THE RESULTS OF EXPERIEMENTAL RESEARCH

The research concerned the assessment of impact of flexible geometry canal on airflow velocity and flow resistance. Also changing of airflow extreme of velocity positioning was important for evaluation of velocity profile. As it was mentioned, the steel tape was a flexible element of intake canal. One end of tape was fixed to the tube by the first ring, but the second end of tape could change its position by the moving of second ring.

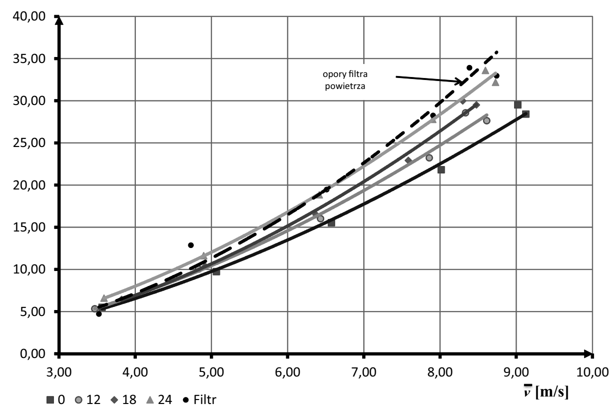

Fig. 5. The airflow resistance (Δp) by average airflow velocity ($\overline{v}$) and different angle of twist tape (0, 12, 18, i 24°) and air filter flow resistance

In this way, steel tape was twisted. The second ring was able to provide steel length compensation, too. The angle of tape twist was from 0÷24°, however the obtained average velocities were from 3,5÷9,2 m/s. The composition of experimental research results concerning the assessment of airflow resistance by average velocity and the angle of tape twist were presented in Figure 5.

A very important conclusion from analysis of Figure 5 is that the use of flexible element of intake canal has no significant impact on airflow resistance and the airflow resistance is even less than for the clear air filter flow. The difference between the lowest and the highest resistant value for the tape twist 24° for achieved airflow velocity was only a bit more than 5 Pa, while the measure deviation of airflow resistance was 0,96 Pa.

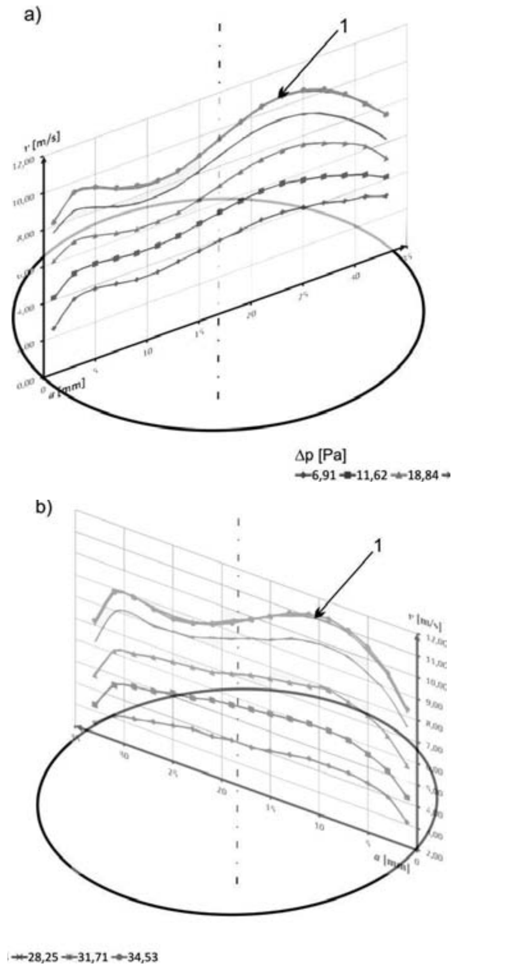

Fig. 6. The composition of velocity profiles of airflow for two mutually perpendiculars planes (a, b) inside the canal; 1 - the highest of airflow velocity (11,2 m/s)

These results are very promising for achieved change of airflow velocity profile for the cross intersection. Suitable velocity profile can help to deliver cylinder load without the meeting with valve head and the intensity of turbulence will decrease, than it can decrease filling loses.

From the analysis of results illustrated in Figure 6 we can see that by the change of angle tape's twist, the change of airflow velocity profile was achieved. It was very effective for the angle of tape twist 24°. There the two of extreme for velocity profile next to inside tube's walls appeared. This experiment can be very useful for implementation of flexible intake canal for air inflow to combustion chamber to the piston engines. In this way, we can get not significant increase of flow resistance (about 7%). Suitable positioning of flexible element inside intake canal for intake valves has a positive impact on effect of load swirl penetration from intake's canal to the combustion chamber.

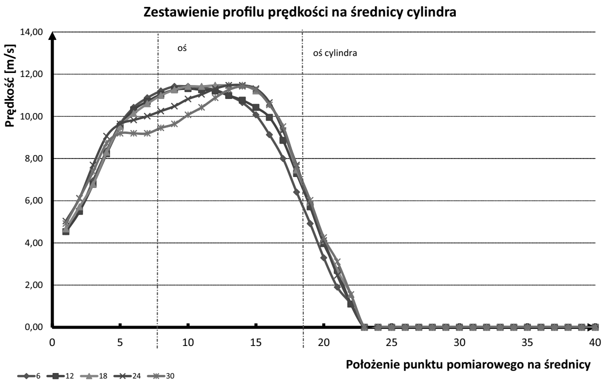

Fig. 7. The view of change of airflow velocity profile during inlet to the cylinder for parallel canal

It will be very useful for the mixture preparation. On the composition of speed profile (Fig. 6) the displacement of the minimum from the center was achieved. The cause of this was unexpected not axial deformation of tape during the twist – what will be involved during the next experimental research.

In Figure 7 the change of airflow speed profile during inlet to combustion chamber was illustrated. There we can see positive action of swirl from intake canal, which displaced of center of intake airflow to the center of cylinder. It will be very helpful from the points of view of the mixture preparation and combustion process.

CONCLUSIONS

On the basis of experimental research results the conclusions are the following;

1. Implementation of geometrically flexible element of intake canal has no significant impact on the flow resistance (it is even lesser than the impact of air filter).
2. The velocity of airflow and the angle of tape twist have impact on the kind of velocity profile change.
3. The change of airflow velocity profile can be a cause of decrease of turbulence from valve head.
4. Effect of load swirl during filling of combustion chamber have impact on achievement of better condition of mixture preparation (mixture more homogeneous)

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WPŁYW GEOMETRII KANAŁU DOLOTOWEGO NA KINEMATYKĘ RUCHU ŁADUNKU W PRZESTRZENI ROBOCZEJ SILNIKA TŁOKOWEGO

S t r e s z c z e n i e. W artykule przedstawiono wyniki badań eksperymentalnych oraz analizy literatury pod względem możliwości technicznej realizacji pracy silnika z uwagi na ograniczenie emisji spalin oraz zmniejszenie zużycia paliwa. W pracy przedstawiono zagadnienia związane z możliwością wykorzystania zjawiska zawirowania ładunku na tle uzyskiwanych wartości parametrów pracy. Zamieszczone wyniki badań eksperymentalnych przeprowadzone na stanowisku modelowym pozwoliły uzyskać odpowiedź na zagadnienia oporów przepływu oraz pozwoliły określić wnioski dotyczące technicznej możliwości implementacji do silnika badawczego.

S ł o w a k l u c z o w e: układ zasilania, silnik, napełnianie, komora spalania