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THE IMPACT OF INTAKE CANAL GEOMETRY ON KINEMATICS OF LOAD IN COMBUSTION CHAMBER

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Summary. 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. Results of baseline research gave information about the flow resistance. On the basis of the results of experimental research the conclusions were made.

Key words: supply system, engine, combustion chamber

1. INTRODUCTION

The efficiency of engine is the highest 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, when intensification of transport use has had a negative impact on air clarity and economic growth and is the cause of an increase in fuel consumption.

The direction of sparkle ignition (SI) engine development was based on the development of automotive market and introduction of new technology which has given 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 as well as the keeping of high level of usable engine parameters such as torque and power.

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

In most of the countries the administrative limits have been imposed on fumes emissions. The toxic gases involved are; hydrocarbons (C_nH_m), carbon monoxide (CO), nitric oxide (NO_x), molecular parts (PM) and sulfur oxide (S – mainly from the fuel pollution).

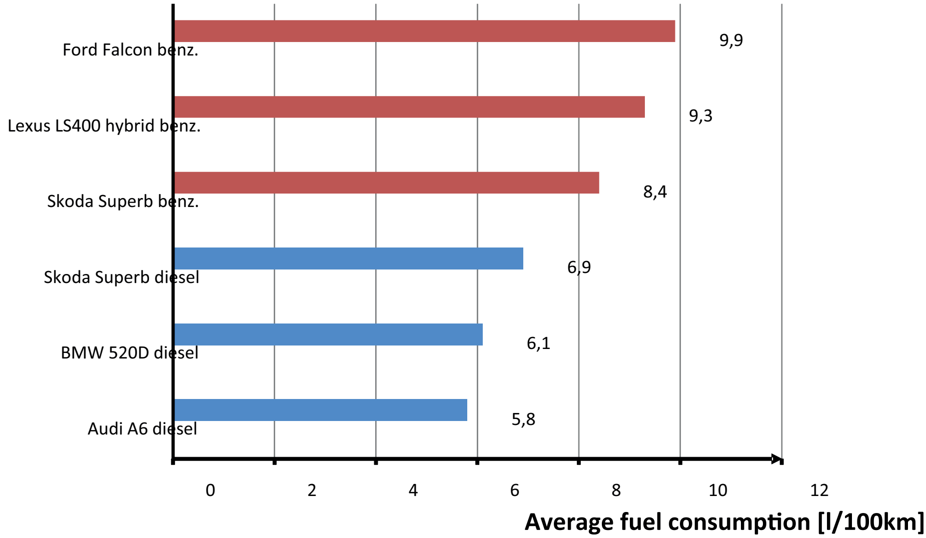

Fig. 1. Average fuel consumption by modern cars with automatic transmission[12] (test type - ADR 81)

Currently, in the phase of continuous development are systems which are able to increase energy efficiency of SI engines, as well as achieve better energy - ecological parameters. 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).

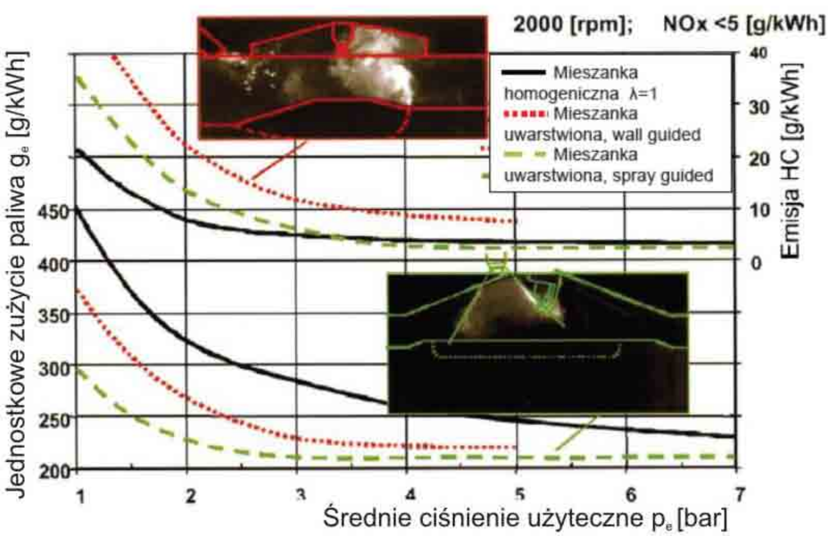

Fig. 2. Comparison of specific fuel consumption and hydrocarbons emission for GDI engine by the injection and mixture type [3]

The alternative fuels as a source of energy for the modern engine are still developed by the quality and exploitation requirements. It can be a cause of more effective use of these fuels as a renewable source of energy in the future. Apart from this, now we have many possibilities of adopting engine feeding system to specific properties of fuel [8].

These indirect measures of have helped to achieve lower levels of fuel consumption and toxic gases emissions as well as the increase (or maintaining) of engine parameters like torque and power.

Many researchers [1, 6, 7, 10] were engaged in the research on the impact of intensification of vortrex in combustion chamber on heat transfer in SI engine. Others were engaged in the research on the impact of turbulence on heat growth [2, 4, 11] and stabilization of the burning process in piston engines [5]. The results of this type of research are indicative in a different way of the impact of swirl on engine work conditions. The authors agree that the vortrex has a positive impact on air-fuel mixture formation by achievement of a more homogeneous form. This conclusion was made by the achievement of decrease of level emissions of carbon monoxides and hydrocarbons. Also, the increase of nitric oxide was achieved. However, the impact of vortrex 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
- application of alternative fuel in the engine feeding system.

2. 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 a flexible element with the 65 mm length, width 32mm and thickness 0,4mm steel tape assembled inside the tube. The real view of this element is 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 is illustrated in Figure 4.

The value of airflow resistance (*Δp*) was determined using the equation;

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

where;

ρ – density of liquid in manometer [g/ccm],

g – Earth acceleration [m/s^2],

n – manometer ratio,

l – number of gradations.

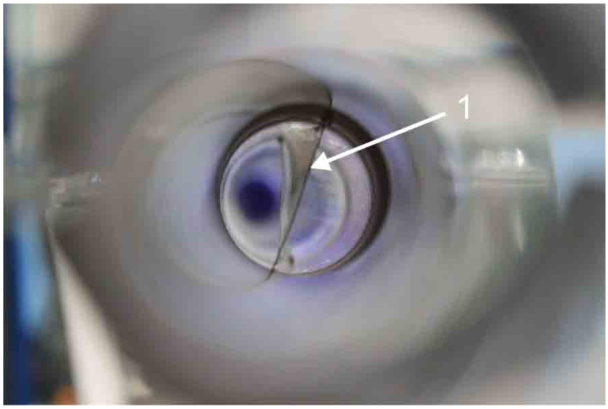

Fig. 3. The picture of canal with flexible geometry [9]; 1 – steel tape

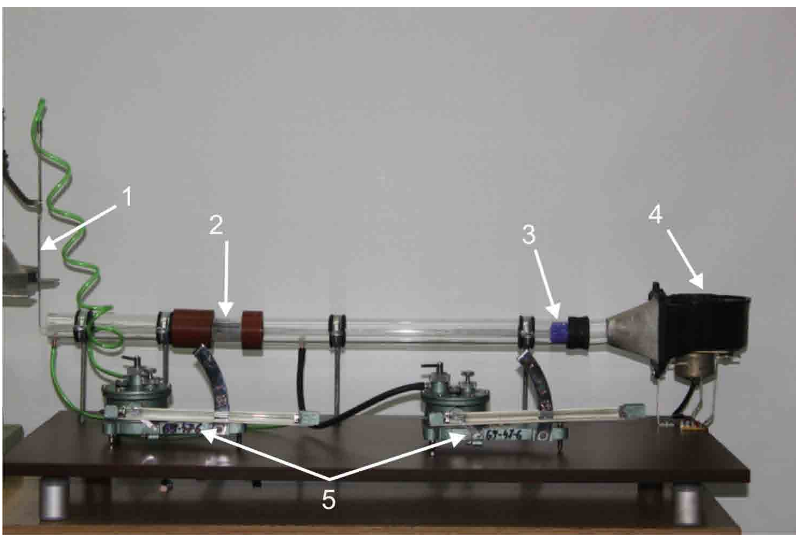

Fig. 4. The experimental stand; 1 – Prandtl's pipe, 2 – flexible tape, 3 - airflow stabilizer, 4 – ventilator, 5 – Recknagel's micro manometers

The value of velocity was achieved on the basis of dynamic pressure in two self-orthogonal planes. 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 according to the equation;

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

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

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

but;

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

where;
A – field of surface of orthogonal canal intersection [m^2],
A_n – field of surface for n –ring,
n – number of the ring,
$v_{n1\div4}$ – airflow velocity for the successive n - ring and measure point,
d_{n1} – outside diameter for n – ring,
d_{n2} – inside diameter for n – ring.

3. RESULTS OF EXPERIMENTAL RESEARCH

The research was concerned with 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 the second ring.

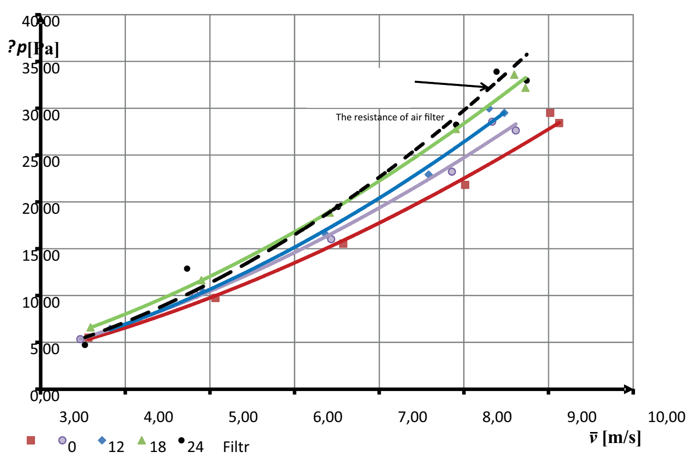

Fig. 5. The airflow resistance (Δp) by average airflow velocity ($\bar{v}$), different angle of twist tape (0, 12, 18, i 24°) and air filter flow resistance

In this way, the steel tape was twisted. The second ring was able to make the steel length's compensation. 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 concerned the assessment of airflow resistance by average velocity and the angle of tape twist was presented in Figure 5.

A very important conclusion from the 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 lower than for the clear air filter flow. The difference between the lowest and the highest resistant value for the tape twist 24° for the achieved airflow velocity was only a bit more than 5 Pa, while the measure deviation of airflow resistance was 0,96 Pa.

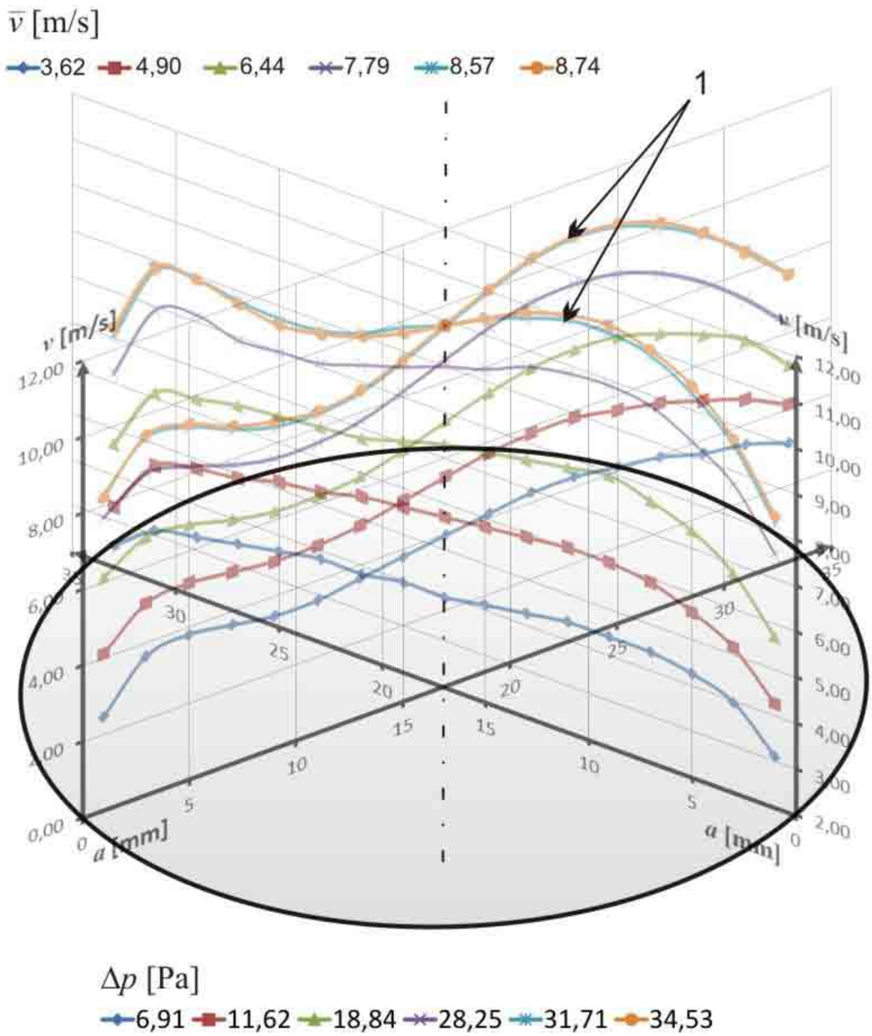

Fig. 6. The composition of velocity profiles of airflow for two mutually perpendicular planes inside the canal; 1 - the highest airflow velocity (11,2m/s)

These results are very promising for the 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 extremes 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 an insignificant increase of flow resistance (about 7%). Suitable positioning of flexible element inside intake canal for intake valves has a positive impact on the effect of load swirl penetration from intake's canal to the combustion chamber.

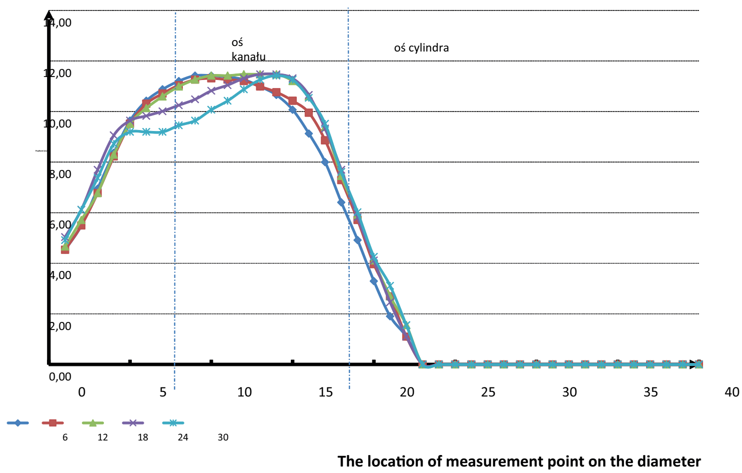

Fig. 7. The view of change of airflow velocity profile during inlet to the cylinder for parallel canal

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 an unexpected, not axial deformation of tape during the twist – which will be dealt with 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 the positive action of swirl from intake canal, which displaced the 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.

4. FINAL CONCLUSIONS

On the basis of the results of experimental research the following conclusions can be drawn:

1. Implementation of geometrically flexible element of intake canal has no significant impact on the flow resistance (even less than impact of air filter).

2. The velocity of airflow and the angle of tape twist have an impact on the kind of velocity profile change.

3. The change of airflow velocity profile can be the cause of decrease of turbulence from valve head.

4. Effect of load swirl during filling of combustion chamber has an impact on the achievement of better condition of mixture preparation (the mixture is more homogeneous)

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

Streszczenie. 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.

Slowa kluczowe: system zasilania, silnik, komora spalania