The research of the random component of air flow velocity in the cylinder of the internal combustion engine.

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1. Abstract

The paper presents a possibility application of the hot wire anemometer in the investigation of the random component of velocity air flow in the cylinder IC engine. Digital signal processing allows to evaluate, parameters of the turbulent air flow in the engine cylinder. The algorithm designed for the processing of signal acquired during tests. An important consideration is the influence of static pressure at the CTA signal. The authors took into consideration this factor.

The studying flow of air in the internal combustion engines cylinder is necessary. It is one of the ways to improve the parameters of the IC engine. This task is difficult to perform due to the large span of pressures and temperatures. In the chamber of the IC engine the flow field is rapidly changing in a short space of time.

One of the passable measurement methods is the constant temperature anemometer.

2. Constant temperature anemometer - principles

In the constant temperature anemometer, the probe is connected to one of the Wheatstone bridge limbs. [Fig. 1]. The resistors of the Wheatstone bridge are made of materials having a very low value of temperature coefficient of resistance. At the beginning, voltage supplying the bridge grows until the resistance of the heating up wire of the probe has reached the present resistance value of the resistor R_d. Any attempt of throwing the bridge out of balance by stronger cooling down the heated up wire of the probe with flowing air ends with increase in the power supplied through the increase of voltage supplying the measuring bridge.

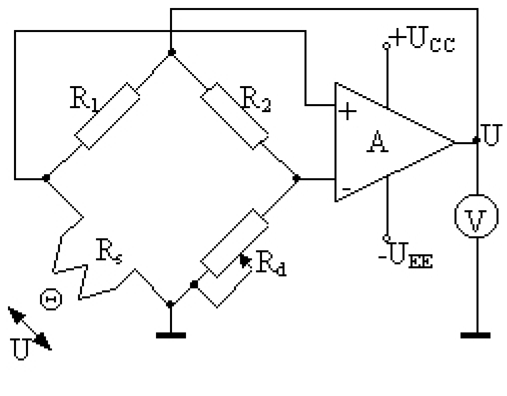


Fig. 1. A block diagram of the constant temperature anemometer.

The electric power P, supplied to the wire, due to electro-thermal transformation of energy, turns into the heat stream $\dot{Q}$:

$$P = \dot{Q}$$

where

$$P = I_S \cdot U_S = \frac{U_S^2}{R_S}$$

Drop of the voltage on the wire is part of the voltage supplying the measuring bridge:

$$U_S = \frac{R_S}{R_1 + R_2} \cdot U$$

The electric power:

$$P = \frac{R_S \cdot U^2}{(R_1 + R_2)^2}$$

The heat stream carried away by convection from the hot wire is described by:

$$\dot{Q} = \alpha \cdot S \cdot (\theta_S - \theta_O) = \alpha \cdot \pi \cdot d \cdot l \cdot (\theta_S - \theta_O)$$

where:

α - heat exchange coefficient $\left[\frac{W}{m^2 K}\right]$;

S - heat exchange surface $[m^2]$;

d - wire diameter $[m]$;

l - wire length $[m]$;

θ_S - wire temperature $[K]$;

θ_O - gas temperature $[K]$;

or

$$\frac{R_S \cdot U^2}{(R_1 + R_2)^2} = \alpha \cdot \pi \cdot d \cdot l \cdot (\theta_S - \theta_O)$$

The greatest difficulty present the proper describe of heat exchange coefficient α. This coefficient is in the form of the dimensionless numbers:

- Nusselt number:

$$Nu = \frac{\alpha \cdot d}{\lambda}$$

- Prandtl number:

$$\Pr = \frac{\eta \cdot c_p}{\lambda}$$

- Reynolds number

$$\mathrm{Re} = \frac{v \cdot d}{\nu}$$

where:

v - gas velocity, η - dynamic viscosity coefficient, ν - kinematic viscosity coefficient,

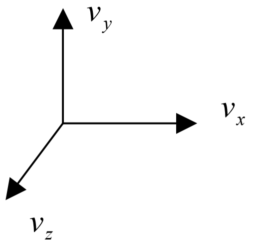
c_p - gas specific heat at $p = idem$, λ - fluid thermal conductivity coefficient,

The dimensionless equations are given in the form [2]:

$$Nu = f(\mathrm{Re}, \Pr) \quad or \quad Nu = f(\mathrm{Re})$$

3. Velocity fluctuation

The thermal processes in the piston engine cylinder are depend on position of the piston. The velocity field of gas within the combustion chamber of the piston engine is a composite function that changes in time and space. The instantaneous value of the vector of velocity v, will be defined by the values of the projections of this vector on the three axes: v_x, v_y, v_z.



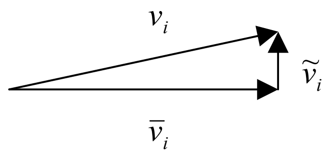


Fig. 2. The velocity vector

Knowledge of values of the components v_x, v_y, v_z from the local vector of velocity v determined in the same point of the combustion chamber and at the same position of the crankshaft φ, but in different cycles of engine operation, the mean velocity of the components of local velocity vector can be calculated, as arithmetically averaged for N successive cycles:

$$\bar{v} = \frac{1}{N}\sum_{i=1}^{N} v_i$$

The fluctuation of velocity is the difference between value of local velocity determined for one cycle and the value of the average value of velocity.

$$\tilde{v}_i = v_i - \bar{v}_i$$

One of the important quantities that characterize the turbulence of flow is turbulence intensity.
When we have isotropic turbulence:

$$\tilde{v}_x^2 = \tilde{v}_y^2 = \tilde{v}_z^2 = \tilde{v}^2$$

then, the turbulence intensity:

$$\varepsilon = \frac{\sqrt{\frac{1}{3}\left(\tilde{v}_x^2 + \tilde{v}_y^2 + \tilde{v}_z^2\right)}}{\bar{v}} = \frac{\sqrt{\frac{1}{3}\tilde{v}^2}}{\bar{v}}$$

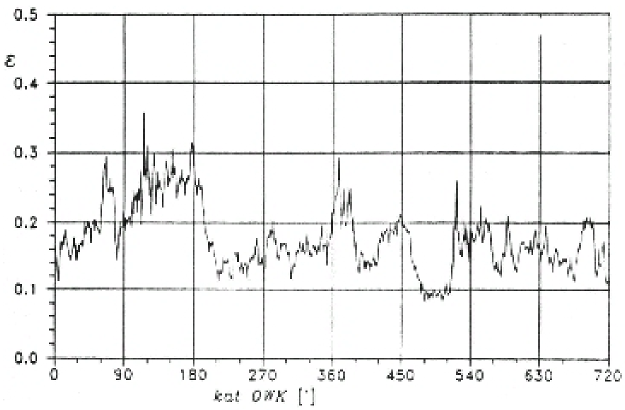


Fig. 3. Variation of the turbulence intensity of air flow [1].

The kinetic energy of flowing gas, related to the unit mass:

$$E_K = \frac{1}{2} v^2$$

The equation of the average kinetic energy takes on the form:

$$\overline{E}_K = \frac{1}{2}\overline{v}_i^2 + \frac{1}{2}\cdot\frac{1}{N}\sum_{i=1}^{N}\widetilde{v}_i^2$$

and, the turbulent kinetic energy (TKE) indicate equation:

$$E_{TKE} = \frac{1}{2}\cdot\frac{1}{N}\sum_{i=1}^{N}\widetilde{v}_i^2$$

The calculated values of the turbulent kinetic energy of air flow in the cylinder[1]:

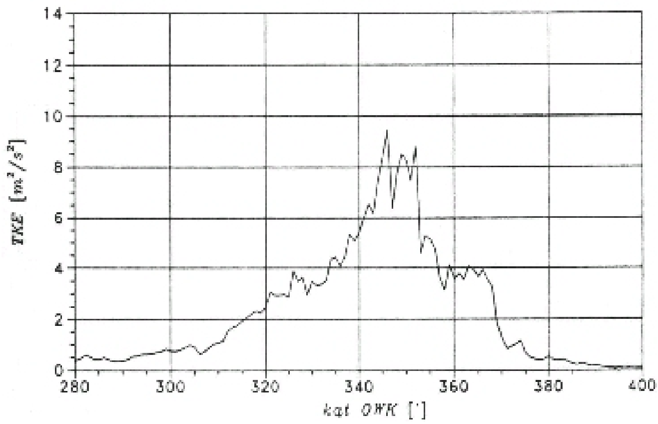


Fig. 4. Variation of the turbulence kinetic energy [1].

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