Acta Technica 62 No. 4B/2017, 1–8

Innovative mass consumption definition technology of air for automobile vehicles engines on the new type sensor basis[1]

Y. A. Kryukov[1], M. A. Mikheyev[1], V. V. Ivanov[2], O. E. Naumov[2]

Abstract. In this article the innovative technology of air mass consumption measurement in modern automobile vehicles is described. The technology is based on development and use of the new type air mass consumption sensor which has a number of advantages in comparison with the existing designs: higher precision, big resource and wide working temperature range, lower cost. In the developed sensor acts as a sensitive element established in an inlet branch pipe of the engine; it has elastic bent blade integrated proportional to air mass consumption. The sensor is manufactured on the basis of semiconductor materials. The sensitive element of the sensor is executed by drawing strain-gauge scheme on the metal elastic element of primary converter of air mass consumption perceiving effort. As an insulating layer and external sheeting of resistance strain gauge the diamond-like membrane, and as strain gages - resistance strain gauge on the basis of sulfide of samarium (SMS) is used.

Key words. Vehicles, power unit, converters of physical quantities, air mass sensor.

1. Introduction

The major tendencies exerting impact on touch structure of the car are: fuel consumption optimization, fuller compliance to the current and future norms of issue,

[1]Article is prepared within performance of applied scientific research and experimental developments (PNIER) under the Agreement on granting a subsidy No. 14.607.21.0174 with financial support of the Ministry of Education and Science of the Russian Federation. PNIER RFMEFI60717X0174 unique identifier.

[2]State-funded Educational Institution of the Higher Education of the Moscow region "International University of the Nature, Society and Person Dubna (State University "Dubna"), Moscow Region, Dubna, Universitetskaya St., 19

[3]CJSC Interregional Production Association of Technical Completing "TEKHNOKOMPLEKT" (CJSC MPOTK TEKHNOKOMPLEKT), Moscow Region, Dubna, Shkolnaya St., 10a

obligatory introduction of ESC (a security system or control and engine management) and other measures for safety increasing. These processes are resulted by new scopes of sensors, new touch technologies are developed. A main goal of such developments is achievement of fuller compliance to continuously raising automobile requirements for functionality, accuracy and reliability.

Recently in this segment the steady tendency in decrease in issue of products of combustion of engines of automobile vehicles is observed that raises a role of sensors of operation of the engine. Engines with electronic dispensing of supply of fuel as the main managing director of parameter use air mass consumption. Optimization of processes of combustion (fuel efficiency) allows improving dynamic characteristics of the vehicle in the course of the movement, to save fuel and by that quantitatively to reduce issue of products of combustion. For this reason practically all sensors of control systems of the engine work for the Powertrain system and for the control system of issue in which main role is carried out by the air mass consumption sensor.

2. Modern sensors of the air mass consumption

In petrol engines the signal from the air mass consumption sensor together with signals of other sensors helps to regulate supply of fuel mix in the engine. In diesel engines the air mass consumption sensor helps to control process of recirculation of the fulfilled gases and to calculate the maximum number of injection. The air mass consumption is defined at its passing by an inlet branch pipe of the engine where the sensor is installed. The maximum mass of the spent air depends on the effective power of the engine and is in range of 400–1000 kg/h.

In the existing automobile systems the air mass consumption sensor represents the system consisting of three sensitive elements, one of which determines air temperature and two others heat up to the known temperature exceeding air temperature. In the course of operation of the engine the air arriving to it cools the heated elements. Classical, but a little outdated technique of definition of air mass consumption consists in measurement of electric power or the current necessary for maintenance of the set excess of temperature. Today the micromechanical MEMS flowmeters of mass of air including thin-membrane the heated and operating electronic elements placed on one substrate (Fig. 1) are urgent [1]. At the same time the heated and measuring resistors are carried out in the form of the thin platinum layers deposited into a surface of a crystal of silicon which is established on a distinguished substrate. The sensor of temperature of a heater and the sensor of temperature of air help to support the heating resistor at the constant level of excess of temperature.

Hitachi also makes sensors of air mass consumption on the basis of temperature sensor. At the same time sensors of a mass consumption of Visteon air have the air assessment camera working in the wide dynamic range.

Sensors of air mass consumption of the described types have a number of essential shortcomings: a small resource, the high error caused by swift pollution of sensitive elements, tolerance to contraflow lane reversal of air, the high cost caused by use of platinum as material of a sensitive element.

Let us consider some constructive technical solutions declared in patents which

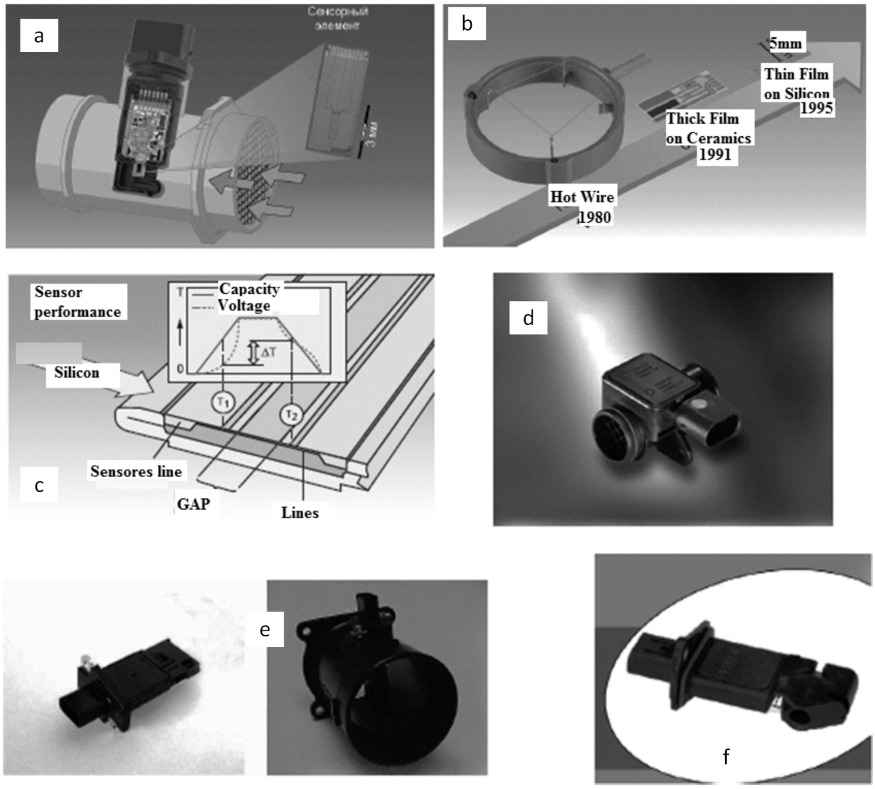

Fig. 1. Modern automobile sensors of air mass consumption: a–the micromechanical sensor of a mass consumption of Bosch air, b–evolution of measuring Bosch technologies, c–the measuring principle of the micromechanical touch Bosch element, d–sensors of a mass consumption of Hitachi air, e–sensors of an air mass consumption of Visteon, f–membrane

could become a basis for performance of the air mass consumption sensor. The flowmeter for liquids and gases [2] contains the case with the wing-shaped sensitive element established on rotary to a shaft, passing through its reinforced part, and the converter. A lack of this flowmeter at application in various pipelines is existence of the weight parasitic loadings influencing the sensor of force and reducing reliability and accuracy of measurement.

In the patent [3] the sensor of a flowmeter in which sleeve of the case the membrane with fixed on it by a core and strain gauge transducer is established is described. On the end of a core the sensitive element which perceives force of front resistance of a stream and having the rhombus form in cross section is strengthened. Strain gauge transducer is executed in the form of a sapphire plate with silicon elements of the bridge scheme. The flowmeter for liquids contains a touch element with the sensor of electric signals in pipelines [4] and the electronic block of reception and processing of signals. The touch element is executed in a look is elastic the bent blade which one end is rigidly strengthened on a pipeline wall orthogonally of its surface. A lack of this decision is use as strain gauges of the foil KFG-10-120 resistance strain gauge possessing strain-sensitive coefficient $v \sim 2$ that limits the accuracy of measurements. On the basis of the review of the existing designs given above it is possible to conclude that the problem of development of the air mass consumption sensor is urgent for automobile vehicles, free from the listed shortcomings.

3. Development of the new type air mass consumption sensor

In the developed design of the air mass consumption sensor as a sensitive element it is offered to use it is elastic the bent blade which integrated bend is proportional to air mass consumption. At the same time for measurement of an integrated bend of the blade the semiconductor strain gauges located in certain points on its surface will be used. The design of the blade is carried out taking into account obtaining optimum elastic flexibility within the set integrated deflection.

Novelty of development consists in creation and application of the new technical solutions based on detailed modeling of structural elements of the converter of physical quantities (the air mass consumption sensor), and pilot studies. The ultimate goal of work consists in receiving and the subsequent application as a part of modern automobile vehicles of the air mass consumption sensor which would have high precision, a big resource and wide working temperature range.

As material for resistance strain gauge it is expedient to use sulfide of samarium (SMS) [5]. The unique electronic zonal structure of this semiconductor allows combining stability of operation of metal resistance strain gauge and high sensitivity of semiconductor. In comparison with the existing analogs resistance strain gauge on the basis of sulfide of samarium have the high linear output signal caused by big coefficient of a strain-sensitive ($T_0 = 30 - 100$), the wide range of output resistance (from 0.2 to 20 kΩ) and working temperatures (from –70 °C to +200 °C) that allows to increase the accuracy of measurements and to expand a criteria range of their operation.

The scheme of the sensor is represented in the Fig. 2. The sensitive element represents the triangular blade 1 of elastic and flexible material, on frontal and back (in relation to a stream) which parties there are resistance strain gauge 2 (on two resistance strain gauge from each party of the blade) measuring static deformation of the blade. The triangular geometry of the blade provides the minimum resistance to a stream and the minimum quantity of fashion of own fluctuations of the blade. Material of the blade of the sensor is chosen depending on type of the flow environment, and also dynamics of a current. The sensor is installed on an inlet branch pipe 3.

In Fig. 3 the scheme of the resistance strain gauge is submitted.

Resistance strain gauge is manufactured as follows. On one of the parties of the blade 1 at first the isolating layer 2 of a monoxide of silicon (SiO) is spattered. Good adhesion allows besieging dielectric membranes of SiO on many types of elastic materials, and close indicators of temperature coefficients of the linear SiO and SMS expansion allow creating strain gauges without essential temperature mechanical tension. Further the method of explosive evaporation in vacuum through masks

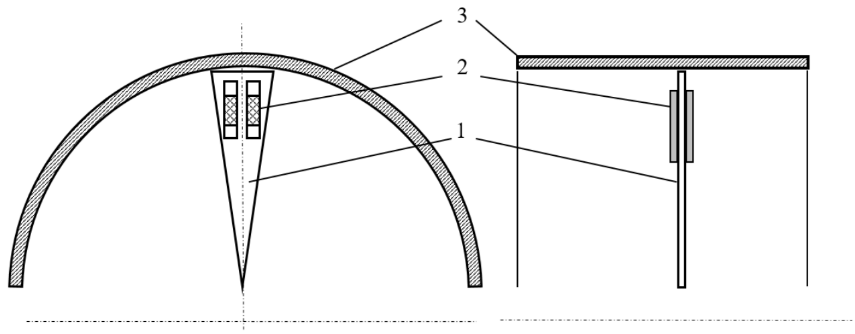

Fig. 2. The scheme of the developed air mass consumption sensor [5]: 1–triangular blade, 2–resistance strain gauge, 3–inlet branch pipe

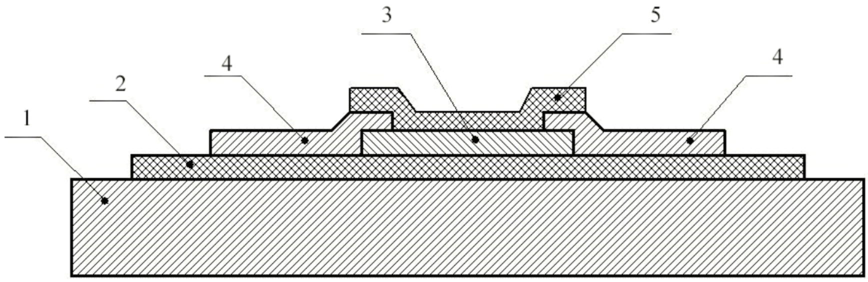

Fig. 3. Scheme of the resistance strain gauge: 1–blade, 2–isolating layer, 3–strain gauge element, 4–contact platforms, 5–sheeting

puts strain gauge element 3 of samarium sulfide. Then the method of resistive evaporation through masks spattered metal contact platforms 4 which provide signal renting from a strain gauge element. Over a layer of monosulfide of samarium one more layer of a monoxide of silicon 5 which provides protection of a piezoresistive layer against influence of the environment is put. If necessary, SiO can be replaced with dioxide of silicon (SiO_2) or nitride of silicon (Si_3N_4).

The sensor functions are as follows. At change of stream hydrodynamic speed the impact of a stream on the measuring blade changes. At the same time the integrated size of deformation of the blade, and also deformation of the resistance strain gauge applied on the blade changes: at frontal resistance strain gauge electric resistance increases, while at back it decreases and, therefore, balancing of the measuring bridge changes. Signals from the measuring bridge come to the electronic scheme where on the set algorithm the air consumption is calculated.

The size of effort with which the moving air stream influences the blade, is defined by the ratio:

$$F = \left[\left(\rho w^2\right)/2\right] \cdot C_{\mathrm{x}} s\,, \tag{1}$$

where ρ is the density of air, w denotes the speed of an air stream, C_{x} stands for the coefficient of front resistance depending on a form of the blade and Reynolds's number and s represents the middle area of the blade.

The air mass consumption G is defined by the area of live section, density of the moving environment and its speed:

$$G = \rho s_0 w\,, \tag{2}$$

where s_0 is the area of live section of a stream. Considering expression (1) and dependence (2), after their transformations we obtain

$$G = s_0\sqrt{\frac{\rho F}{C_{\mathrm{x}} s}}\,. \tag{3}$$

From this it follows that if to measure effort with which the moving stream of air presses on the blade then it is possible to find air mass consumption through this section.

The sensors of air mass consumption executed on the presented technology have the good potential for wide use as a part of modern automobile vehicles as have a number of advantages in comparison with the existing designs, namely: higher precision, a bigger resource and wide working temperature range, potentially smaller cost at the expense of an exception of expensive materials (platinum).

4. Conclusion

In article it is shown that the existing types of air mass consumption sensors applied in cars have a number of essential shortcomings: a small resource, a considerable error, tolerance to contraflow lane reversal of air, high cost. The technology of air mass consumption measurement on the basis of the sensor of new type in which as a sensitive element it is used established in an inlet branch pipe of the engine is as an alternative offered it is elastic the bent blade which integrated bend is proportional to air mass consumption. The manufacturing techniques of the sensor provide formation of resistance strain gauge on the dielectric layer applied directly on the metal elastic element perceiving effort, as an insulating layer and an external sheeting it is expedient to use a diamond-like membrane. As material for resistance strain gauge serves sulfide of samarium (SMS) that provides big coefficient of a strain-sensitive, the wide range of output resistance and working temperatures. In comparison with analogs the offered sensor has high sensitivity, accuracy of measurements, stability of work and high wear resistance in aggressive temperature conditions. The scheme of the sensor and technology of its production is submitted.

References

[1] N. Maloo, S. Seetharaman, B. Rao, D. Kumar, I. J. Nishane: *Standardization of the baseline study to plan for roads and transportation in villages: Case of Chikurde and Bhulane in Maharashtra*. Transportation Research Procedia *17* (2016), 193–202.

[2] U. S. EPA: *Assessing the emissions and fuel consumption impacts of intelligent trans-*

portation systems (ITS). EPA 231-R-98-007. U. S. Environmental Protection Agency, Washington, D. C. (1998).

[3] A. Shaheen, E. Timothy: *Reducing greenhouse emissions and fuel consumption: sustainable approaches for surface transportation*. IATSS Research *31* (2007), No. 1, 6–20.

[4] S. Midenet, F. Boillot, J.-C. Pierrelée: *Signalized intersection with real-time adaptive control: on-field assessment of CO_2 and pollutant emission reduction*. Transportation Research, Part D: Transport and Environment *9* (2004), No. 1, 29–47.

[5] H. Rakha, M. van Aerde, K. Ahn, A. A. Trani: *Requirements for evaluating traffic signal control impacts on energy and emissions based on instantaneous speed and acceleration measurements*. Transportation Research Record *1738* (2000), 56–67.

Received October 12, 2017