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Application of the LabVIEW environment in testing automotive thermoanemometric flow meters

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Summary. With the advancement in technology in the automotive industry and with the continuous development of electronics there is a problem related to the diagnostics of components and electronic circuits used in today's automotive technology. One example of this type of system is the new generation air flow meters that are responsible for the composition of the air/fuel mixture. The purpose of the flow meter is to accurately measure the mass of the air stream drawn by the engine, depending on the load on the motor and the rotational speed and to convert that value into an electrical signal that is transmitted to the control unit [5, 16]. An on-board computer based on the flow meter characteristics stored in the controller memory and current measurements from an air flow meter, shaft position sensor and temperature sensor determines the fuel dose that is responsible for the proper operation of the drive unit.

In order to optimise as well as quickly and accurately diagnose the whole system or an element, specialised structures and information systems are used. Examples of such systems are various diagnostic testers and interfaces that, by working with appropriate software, can exclude or identify a defective component. We can also use the LabVIEW environment for the diagnostics of vehicle electronics. With this program we can perform system simulations and compare and analyse the obtained characteristics and results of measurements. Thanks to this solution and the cooperation of devices with a computer we can examine a number of systems without having to dismantle them.

Key words: anemometer, LabVIEW, flow meters.

INTRODUCTION

Air flow meters are used in air intake systems, both in diesel engines and in spark ignition engines, without which control of their operation would be very difficult. Figure 1 shows a block diagram of the internal combustion engine and the location of the air flow meter. The purpose of the air flow meter is to measure the mass of air supplied to the engine cylinders during operation, processing that information into an electrical signal that is sent to the engine control unit. The control computer compares the results obtained with the flow meter characteristics stored in its memory. Based on data from the flow meter and other sensors, it determines the optimum fuel dose. In gasoline injection systems, the information obtained through the flow meters allows to calculate the exact fuel injection duration and the ignition timing. In automatic ignition engines, information from flow meters is mainly used for exhaust gas recirculation control, injection time correction and peak fuel dosing.

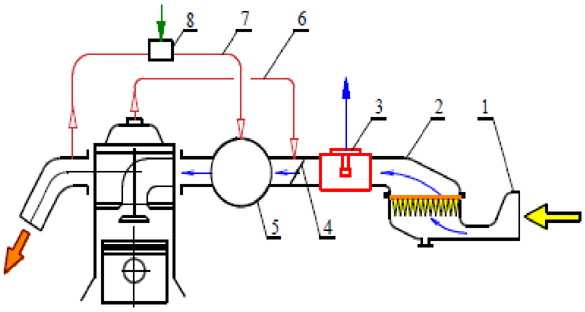


Fig. 1 Fig. 1 Location of the air flow meter in the intake manifold: 1 – air filter breather, 2 – air filter, 3 – air flow meter, 4 – throttle, 5 – intake manifold, 6 – crankcase venting system, 7 – exhaust gas recirculation system, 8 – recirculation valve [1]

The most common type of flow meters are air flow meters with an HLM thermoanemometer. They are mainly used in spark ignition engines. The operation principle of this flow meter is based on the measurement of the current that is needed to maintain the constant temperature of the electrically heated element which is cooled by the flow of air.

The basic element of the HML flow meter is a 70μm platinum wire, which is fixed perpendicular to the direction of the flow of air. Inside the cylindrical casing flows the air that cools the wire placed there, heated by the current flowing through it. The platinum wire is protected by a metal mesh from mechanical damage caused by the ingress of contaminants into the intake manifold.[6,7,9]

The biggest advantage of this HLM flow meter is the small resistance to the flow of air in the engine intake system compared to the flap flow meter. Reducing the resistance of the intake manifold will improve the performance of the combustion engines. To accurately determine the mass of sucked air, the electrical signal from the thermoanemometer must be recorded at very short intervals and the results obtained must be processed in real time at high frequencies.[10,12,17]

The HLM air flow meter is shown in Figure 2.

Fig. 2. Air flow meter with HLM thermocanometer [7]

Figure 3 shows the characteristics of the output voltage derived from the HML sensor depending on the airflow flowing through the flow meter in the engine intake system.

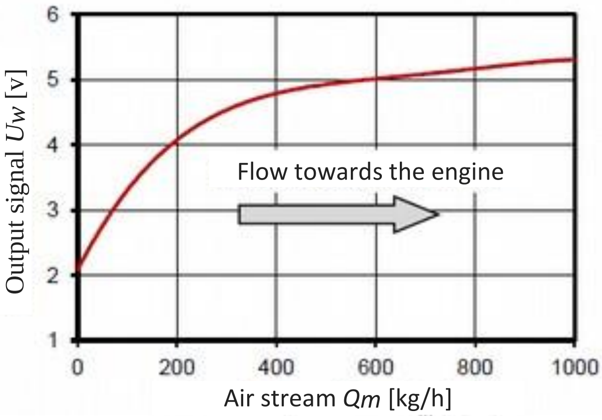


Fig. 3. Characteristics of flow meter with HLM thermoanemometer [7]

A newer flow meter with a similar operation pattern is the HFM type flow meter with a lamellar laminar thermoanemometer. Its construction is based on a sensor that resembles a very thin membrane, also called a film, on which the measuring circuits are placed. On both sides of the diaphragm there are resistors measuring their resistance depending on the temperature. When the flow meter does not flow through the air, the resistance of both resistors is the same because their temperature is the same. As the air starts to flow towards the engine, the heating element causes a temperature difference on these resistors.

The function of the electronic system in this flow meter is to keep the heating element temperature higher than the flow air temperature. The heat transferred from the heating element to the moving air depends on the airflow. Changing the temperature on the resistor measured independently of the incoming air temperature is a mass measure of the air flow delivered to the internal combustion engine, and on this basis an output signal is generated. These flow meters can measure the negative airflow towards the air filter.

The design of the HFM flow meter is shown in Figure 4.

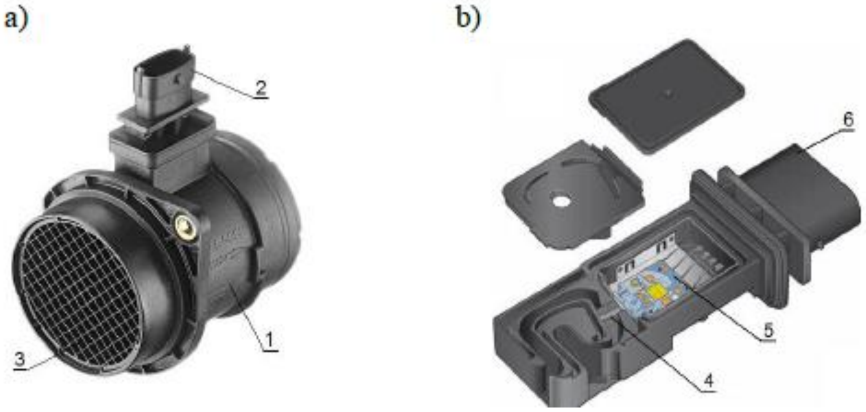


Fig. 4. Bosch HFM flow meter: a) general view 1 – housing, 2 – sensor, 3 – inlet grille, b) sensor, 4 – measuring element, 5 – electronic circuit, 6 – digital interface [2]

The dependence of the input signal on the flowing air stream is shown in Figure 5.

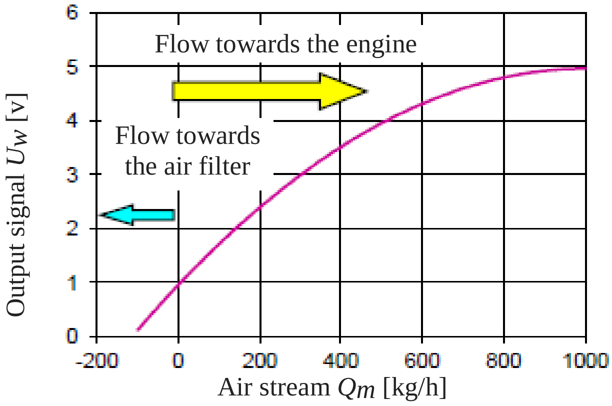


Fig. 5. HFM flow meter characteristics [2]

MEASUREMENT SYSTEM

The NI USB-6008 measurement card, which acts as an intermediary between the physical object and the data acquisition and processing system, is used for the test. The main task of a data acquisition card is the role of an interface between an analogue signal source coming from a physical object and a digital signal that is compatible with computer hardware and software.

The popular National Instruments NI USB-6008 measurement card, shown in Figure 6, was selected.

Fig. 6. National Instruments NI USB-6008 card [4,11]

The measurements were carried out at the measuring station shown in Figure 7. The station was equipped with a data acquisition module read from the HFM flow meter using the LabVIEW development environment. Thanks to the program's capabilities, an existing workstation can be integrated with a measurement card and the results analysed on the computer, and air flow meters installed directly in a vehicle can also be tested.

The measuring stand consists of:

- 1400W single phase commutation motor,
- 12V/0.5A stabilised power supply,
- speed controller,
- Siemens HLM thermoanemometer,
- air filter,
- inlet system,
- NI USB-6008 data acquisition module,
- PC.

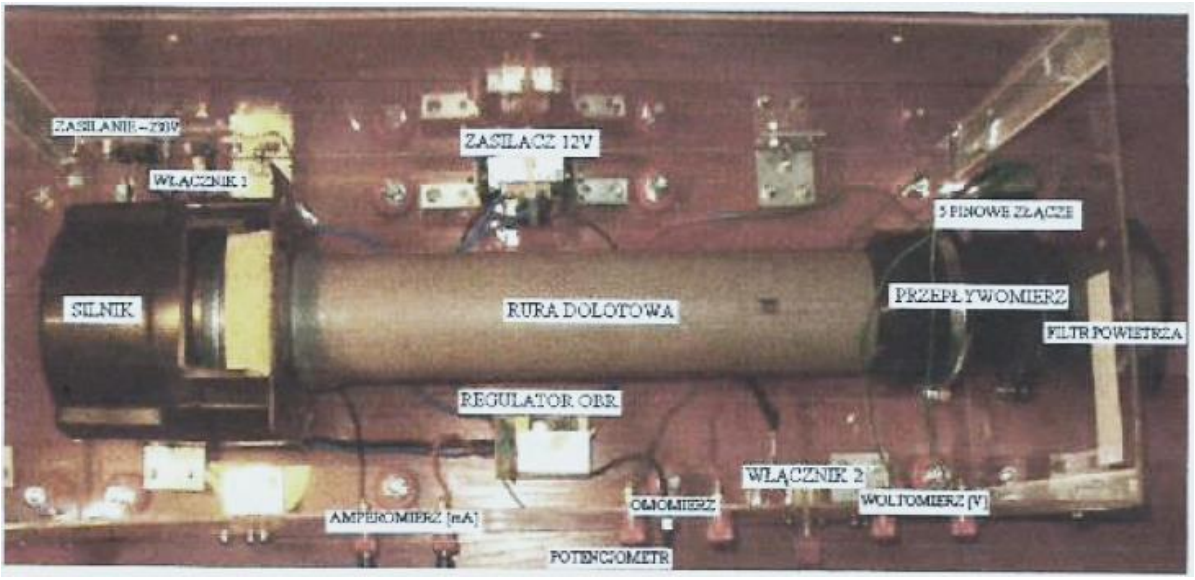
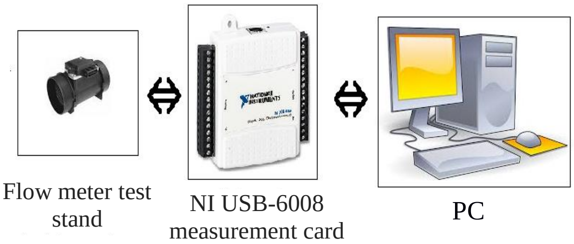


Fig. 7. View of the air flow meter test stand

The block diagram of the test bench is shown in Figure 8



Flow meter test stand

NI USB-6008 measurement card

PC

Fig. 8. Flow chart of the thermo-anemometer flow meter [11]

The NI 6008 USB data acquisition card has a USB communication port and two terminal blocks for connecting input and output devices.

Correct operation of the module is signaled by an LED, whose cyclical flashing informs about proper operation. The card is equipped with modular connectors; each of the module connectors is the type of signal that can be connected. The first connector with pin numbers 1-16 allows for the analogue signals to be connected to the module, and the 17-32 connector does that for the digital signals. Analogue inputs AI 0-7 enable simultaneous measurement of four voltages up to a maximum of 20V in the DIFF mode or up to eight voltages, but for a maximum of 10V in the RSE asymmetric mode with respect to the GND mass.

Each input channel can be configured independently, as symmetric (DIFF) and asymmetric (RSE). Symmetric inputs allow for greater selection of measuring ranges and measurement of larger voltage signals. The distribution of analogue inputs for individual signals for symmetric and asymmetric operation is shown in Figure 9.

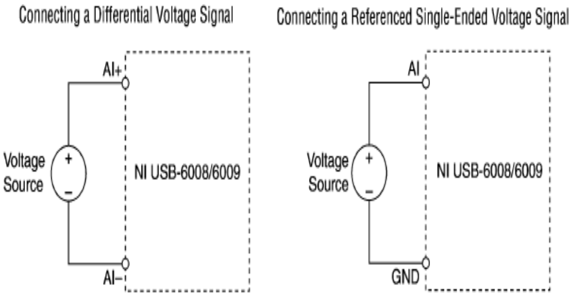


Fig. 9. Connection of the signal to the RSE and DIFF card [11]

At the measuring station, the source of the signal is the voltage coming from the air flow meter. In order to ensure reliable measurement, the test flow meter should be connected to the module as shown in Figure 10.

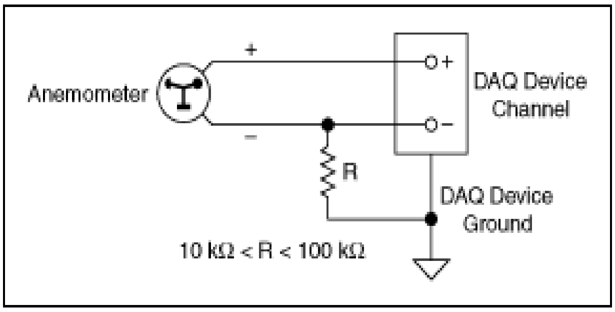
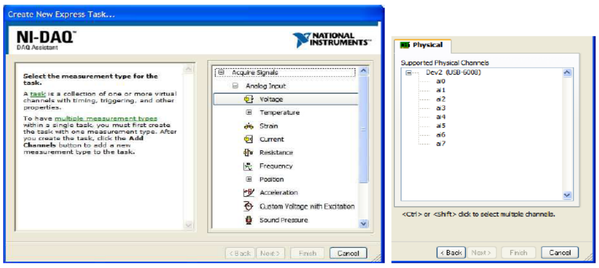


Fig. 10. Flow meter connection diagram with data acquisition device [11]

In order to carry out the measurements used for the analysis, a data acquisition system was built. This system was created based on the DaQ Assistance program which offers the opportunity to create a virtual measuring instrument that works with the NI 6008 USB module. The system creation window is shown in Figure 11, where the physical channel of the NI USB 6008 card is selected.



Select the measurement type for the task.

A task is a collection of one or more virtual channels with timing, triggering, and other properties.

To have multiple measurement types within a single task, you must first create the task with one measurement type. After you create the task, click the **Add Channels** button to add a new measurement type to the task.

<Ctrl> or <Shift> click to select multiple channels.

Fig. 11. Window of a new physical channel configuration creator in DaQ Assistance

During the virtual configuration of the instrument, the most important parameters of the test signal are set, such as voltage range, sampling frequency or signal amplitude. Once the configuration of the virtual measuring device has been completed, we get the icon shown in Figure 12. It enables the test device to work with the data acquisition card, which is compatible with LabVIEW and its software for analysing and interpreting the results obtained. [15,14,15]

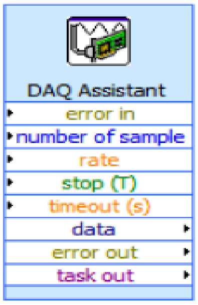


Fig. 12. Graphical interpretation of a virtual instrument in a LabVIEW environment

The installed software and the program for the configuration of the data acquisition card allows the user to test the module during the initial configuration of the device. Thanks to this device and software specification, the user can exclude and eliminate any errors in the initial programming stage.

STRUCTURE OF THE TEST STAND PROGRAM

The structure of the program written in a graphical language is based on a virtual measuring instrument that works with an NI USB 6008 measurement card, which, after proper configuration, works with the rest of the program. The purpose of the program is to calculate the mean value of the results obtained during the air flow meter test, to plot the flow rate characteristic of the flow meter as a function of time, and to display the calculated instantaneous value of the flowing air through the flow meter tested. In addition, it includes the calculation and display of the mass flow of air through the system as well as the engine speed. The next step in the flow of information in the program is writing it to the file. The structure of the program is shown in Figure 13.

The operator panel was built to provide an intuitive readout of the parameters obtained during the measurement of the flow meter. It is shown in Figure 14.

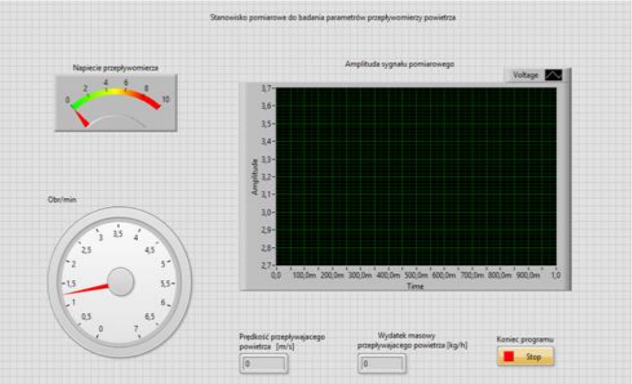


Fig. 14. Operator terminal of the test stand

MEASUREMENT RESULTS FROM THE AIR FLOW METER TESTED

The designed stand was used to test the HFM air flow meter with the thermoanemometer used in Vag diesel engines. The measurements were carried out in an operational and working vehicle under appropriate conditions. The engine of the tested car was heated and unloaded to provide the most accurate and stable measurement of the flow meter voltage value and the reading of the amount of air flowing through the engine intake system at various engine speeds. The results of the measurements are shown in Table 1.

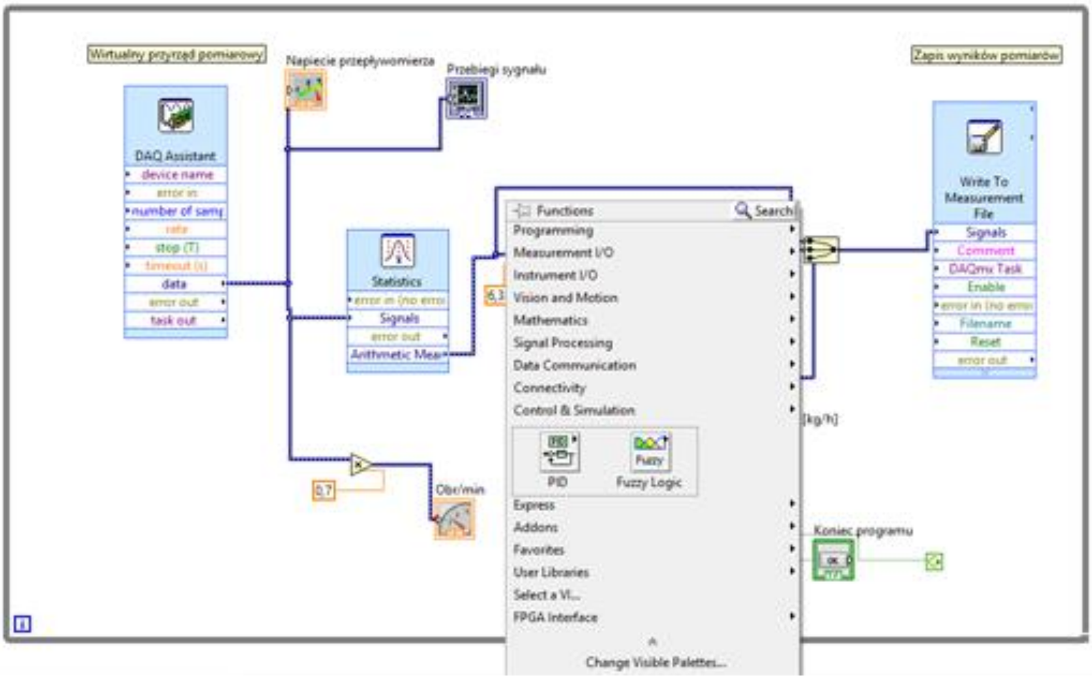


Fig. 13. Program code fragment in LabVIEW environment with subprograms supporting the NI USB 6008 measurement card

Table 1. Results of measurements from an anemometric air flow meter in a 1.9 TDI engine

Lp.	Voltage meter	Air speed	Air mass flow
---	[V]	[m/s]	[kg/h]
1	1,10	7,01	153,14
2	1,45	9,24	201,73
3	1,53	9,69	211,58
4	1,60	10,14	221,44
5	1,62	10,27	224,26
6	1,65	10,27	224,26
7	1,70	10,49	229,19
8	1,76	11,17	243,97
9	1,84	11,65	254,53
10	1,90	11,65	254,53
11	1,95	12,07	263,69
12	1,98	12,40	270,73
13	2,03	12,85	280,59
14	2,07	13,14	286,93
15	2,11	13,14	286,93
16	2,15	13,36	291,85
17	2,19	13,59	296,78
18	2,24	14,17	309,46
19	2,28	14,46	315,79
20	2,30	14,59	318,61
21	2,33	14,75	322,13
22	2,33	14,78	322,83
23	2,36	14,98	327,06
24	2,37	15,04	328,47
25	2,38	15,07	329,17
26	2,39	15,07	329,17
27	2,39	15,14	330,58
28	2,41	15,24	332,69
29	2,44	15,46	337,62
30	2,47	15,65	341,84
31	2,49	15,82	345,37
32	2,52	15,94	348,18
33	2,53	16,01	349,59
34	2,55	16,14	352,41
35	2,57	16,27	355,23
36	2,58	16,34	356,63
37	2,64	16,69	364,38
38	2,73	17,27	377,05
39	2,74	17,37	379,16
40	2,76	17,50	381,98
41	2,78	17,59	384,09
42	2,79	17,66	385,50
43	2,88	18,27	398,88
44	2,92	18,49	403,81
45	2,91	18,40	401,70
46	3,05	19,33	422,12
47	3,10	19,66	429,16
48	3,14	19,88	434,09

49	3,18	20,14	439,72
50	3,19	20,24	441,83
51	3,22	20,37	444,65
52	3,28	20,79	453,80
53	3,41	21,63	472,11
54	3,49	22,14	483,37
55	3,53	22,37	488,30
56	3,59	22,72	496,05
57	3,64	23,04	503,09
58	3,65	23,14	505,20
59	3,67	23,24	507,31
60	3,68	23,30	508,72
61	3,69	23,37	510,13
62	3,70	23,43	511,54
63	3,71	23,49	512,91
64	3,72	23,56	514,36
65	3,72	23,59	515,06
66	3,73	23,65	516,47
67	3,75	23,75	518,58
68	3,76	23,85	520,69
69	3,77	23,88	521,40
70	3,79	23,98	523,51
71	3,79	24,01	524,22
72	3,79	24,04	524,92
73	3,81	24,11	526,33

Figures 15, 16 and 17 show the waveform of the flow meter signal at various engine speeds.

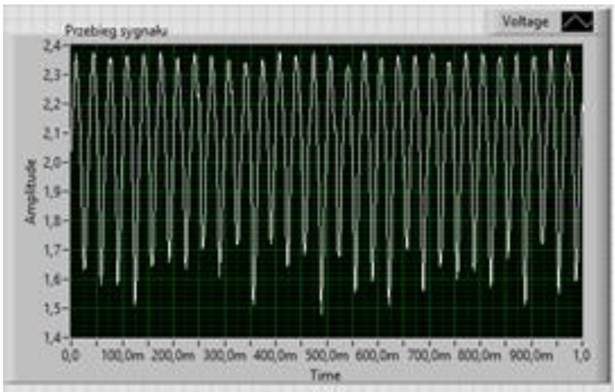


Fig. 15. Amplitude of signal from air flow meter at idling engine

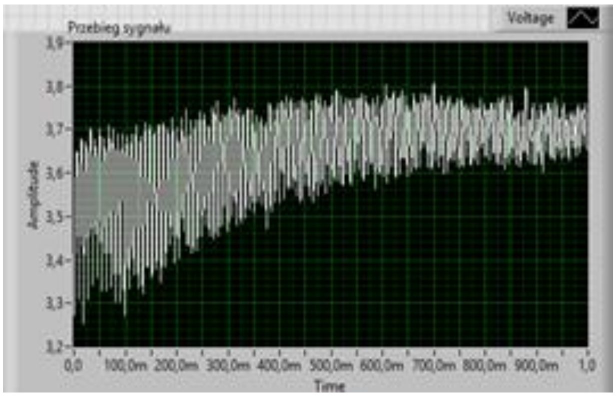


Fig. 16. Amplitude of signal from air flow meter at increasing engine speed

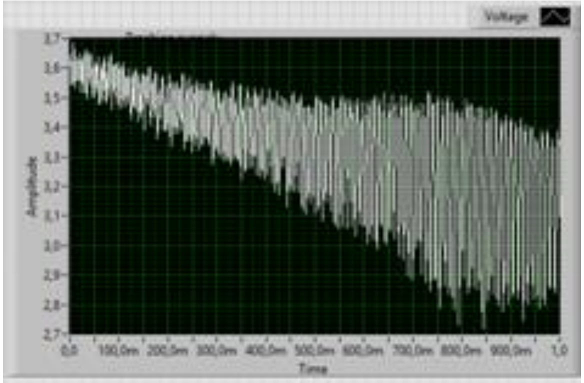


Fig. 17. Amplitude of signal from air flow meter at engine speed decreasing

From the results of the measurements the characteristics of the air flow meter are determined. They show the dependence of the voltage received from the flow meter as a function of the volume of air flow. The characteristics obtained are almost identical to those of a new flow meter of this type.

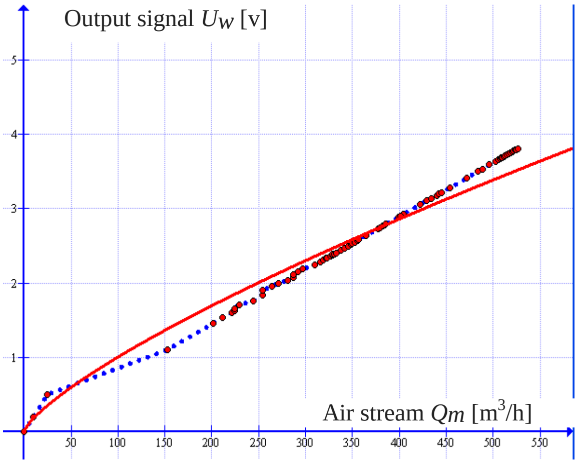


Fig. 18. Comparison of flow meter test data with manufacturer data

CONCLUSIONS

Contemporary internal combustion engines, thanks to the use of modern electronic systems such as air flow meters, have a significant effect on reducing and diminishing the toxicity of exhaust gases. Over time, flow meters gradually wear out. It is difficult to notice flow meter failure. Its malfunction can be attributed to uneven engine operation, jerking, extinguishing, problems with smooth acceleration, idling fluctuations or even startup trouble.

The LabVIEW application and the appropriately-adapted measurement card has created a measuring instrument that allows a rapid and efficient diagnosis of air flow meters used in modern motoring. The program reads the signal from the flow meter in real time, as well as outlining the amplitude characteristics of the signal.

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