CORRELATION FLOW-METER WITH A THERMOANEMOMETRIC SENSOR

Zygmunt Biernacki [1)], Marek Kurkowski [1)], Tadeusz Zloto [2)]
[1)] Institute of Electronics and Control Systems, Czestochowa Technical University,
Al. Armii Krajowej 17, 42-200 Czestochowa, Poland,
e-mail: biernac@el.pcz.czest.pl , marekekb@poczta.onet.pl
[2)] Institute of Machine Technology and Production Automation,
Czestochowa Technical University,
Al. Armii Krajowej 21, 42-200 Czestochowa, Poland, e-mail: zloto@itm.pcz.czest.pl

Abstract: The paper describes the functioning of the measuring system of a wave thermoanemometer. The effect of the application of a thermal wave induced by forcing quasirandom signals (PRBS) is also discussed. Correlation analysis of signals generated in the receiving wires of the thermoanemometric sensor is presented.

1 INTRODUCTION

The measurements of air flow velocity within the range of a few to a few hundres centimeters per second is a complicated metrological problem. One of the methods bringing satisfactory results is the thermal wave method in which the propagation in the wave flow is examined. Wave thermoanemometers applied so far have made use of the thermal wave generated by the sending wire of the thermoanemometric sensor. The velocity is measured by determining the time it takes for a wave to cover the distance between the sensors, or by determining the phase shift between the signals from the consecutive sensors. Electric signals of rectangular shape are used as forcing impulses and the analysis of signals is done by means of complicated and prone to interference electronic systems. The recent development of microprocessor technology makes it possible to apply correlation methods, which require more advanced measuring apparatus.

2 MODIFIED WAVE THERMOANEMOMETER

A modern model of an autonomous measuring instrument consists of a number of functional blocks, such as data acquisition, data processing, generation of forcing impulses and displaying results. Nowadays, virtual instruments are commonly applied in such systems. The idea of a virtual instrument is that the traditional functions of an instrument are combined with flexible, user-defined functions of a PC. The particular functions may be realized by hardware or by softaware.

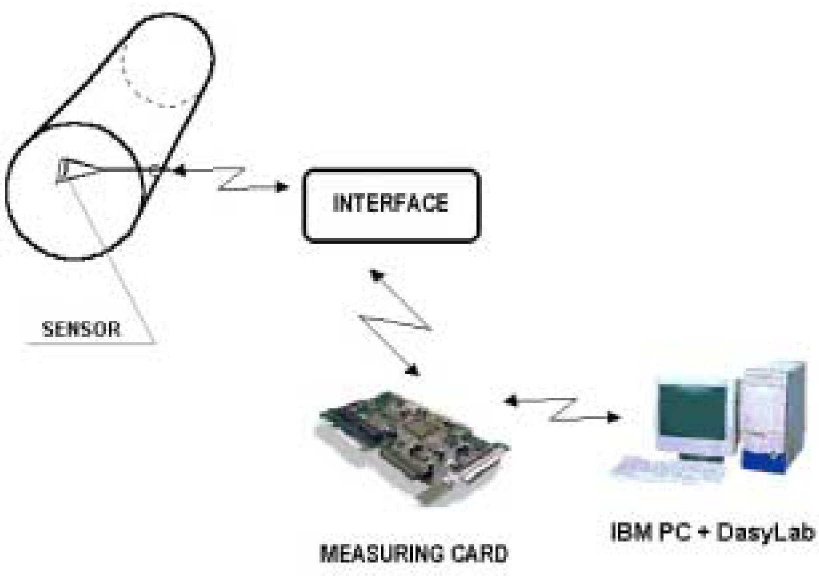

Fig. 1. Wave Thermoanemometer System WTS

In present-day measuring stands the blocks of generation, data acquisition, data processing and communication with the user are provided by a computer with a measuring card and appropriate softaware (Fig. 1).

The modified measuring system has the properties of a virtual instrument. It consists of sensor with a primary element and two detectors, input and output systems (two measuring bridges and an amplifier), and a PC with software including systems for generation and detection of thermal waves.

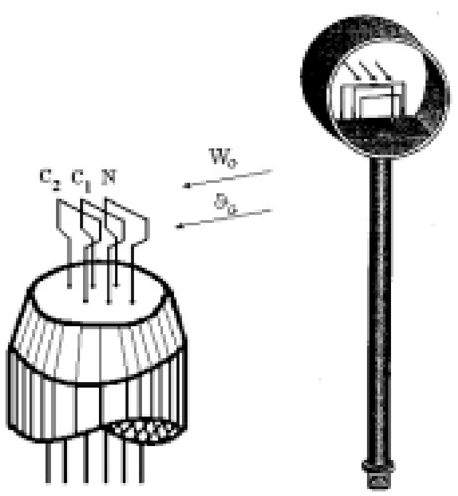

Fig. 2. Thermoanemometric sensors

The sensor construction set consists of three parallel and coplanar thermoanemometric wires (Fig.2). One wire, called thermal wave sender, is made of a tungsten and has a diameter of 10 µm and length of 20 mm. The first temperature detector is also a tungsten wire of diameter 5 µm and length 15 mm. The distance from the first detector to the sender is 3 mm. The other detector has the same parameters as the first one and the distance between the detectors is 10 mm.

The developed and constructed measuring system of WTS (Fig. 1) can operate both with predetermined and random signals. The generation and detection of signals is realized by means of PCL818L measuring card and a computer program developed within DasyLab package for signal generation and analysis. (Fig. 3).

The software provides a foundation for the measuring system and determines the extent to which the functional capabilities of the hardware are exploited. It provides convenient control of the measuring process, saving the data, access to them, their analysis and processing, as well as displaying the results in a required form. With DasyLab package the user may solve the problems associated with data sets and their analyses in all their complexities. The innovation of DasyLab lies in a very simple way of handling the program by creating the script for the analyses by means of icons. Connected icons make a data flow sheet, which represents the direction of data flow and their analysis.

The mathematical model of measuring converter of the wave thermoanemometer presented below was the basis for developing simulation experiments with the use of a PC. The experiments were intended for the simulation of waveforms of signals generated in the converter wire. The obtained results are close to theoretically predicted ones and thus confirm the usefulness of the converter in the wave thermoanemometer system.

The energy balance in the sender is defined as

$$\frac{I_N^2(t)\cdot R_{NC}}{m\cdot c_N}=\frac{d\vartheta}{dt}+\frac{\Psi}{m\cdot c_N}+\vartheta(t) \qquad (1)$$

where $\Psi=\alpha^{*}\cdot s_r$ is the energy given out to the environment through the surface of the unitary length sender.

The quasirandom signals are strictly determined functions, however, they appear to be governed by a random factor.

For a thermal wave modulated by signal PRBS (Pseudo Random Binary Sequences) impulse forcing current $I_N(t)$ in the sender is

$$I_N(t)=\begin{cases} I_N & \text{dla} \quad t\in<0,t_i) \\ 0 & \text{dla} \quad t\in<t_i,T) \end{cases} \qquad (2)$$

where $t_{np.}$ is the time for the falling slope,

$t_{p.}$. is the time for a rising slope.

The solution of Eqn. (1) are expressions defining temperature $\Theta_N(t)$ in the sender

$$\Theta_N(t) = \begin{cases} \Theta(t_0) + \frac{a}{b}(1 - e^{-at}) \Rightarrow & \text{dla} \quad t \in < 0, t_i) \\ \Theta(t_0) + \frac{a}{b}(1 - e^{-at}) \cdot e^{\varepsilon(t_i - t)} \Rightarrow & \text{dla} \quad t \in < t_i, T > \end{cases} \tag{3}$$

in which $a = \frac{\Psi}{mc_n}$; $b = \frac{I_N^2 R_{NC}}{mc_W}$; $\varepsilon = a$

3 EMPIRICAL STUDY

In the empirical study the system presented above was employed. The generation and analysis of signals was done by means of DasyLab package. The measurements were taken with the use of a quasirandom forcing signal. A two-wire sensor was applied and the analysis was based on the correlation method.

Adjustment ranges were the following: frequency 5 Hz to 60 Hz, signal amplitude 0,8 V to 1,2 V, velocity value in the wind tunnel 0 m/s to 3 m/s.

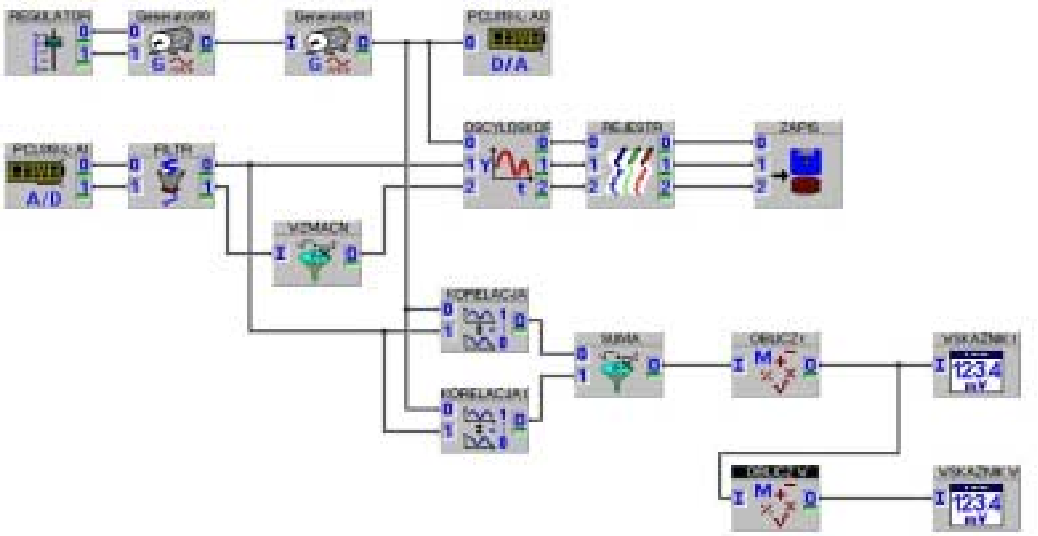

Fig. 3. System for signal generation and analysis

The system presented in Fig. 3 performs the following functions:

- modelling of the forcing signal (modules REGULATOR, GENERATORY);
- generation of the electric signal (module PCL818L AO);
- acquisition of the value of electric signal from the measuring card (module PCL818L AI);
- filtering of the signal (module FILTR);
- finding the value of the similarity function between the recorded signal and the software-generated determined signal (modules CORRELATION, SUM CALCULATE t, INDEX t);
- finding the measured value of the flowing gas velocity (modules CALCULATE W, INDEX W);
- displaying and saving of data – OSCILLOSCOPE, SAVE, RECORD.

4 CONCLUDING REMARKS

The experiment and analysis have been performed concerning the operation of a wave thermoanemometer with a quasirandom forcing signal generated in the sending wire of the wave thermoanemometer sensor. The study contributes toward further modification of the method for measuring flow velocity. A wave thermoanemometer system having the features of a virtual instrument have been constructed. The system provides the possibility of parameter adjustment for forcing signals in the sending wire and of the complete analysis of signals coming form the receiving wire(s), including the calculation of flow velocity. The generation and analysis of signals was performed by means of the graphic programming language DasyLab, which is a useful tool for programming measuring systems.

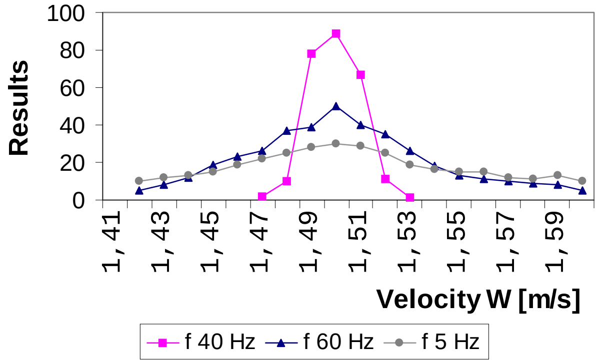

Fig. 4. Comparison of the obtained velocity values for various values of the forcing signal (PRBS) frequency

The comparative analyses of the measuring systems and simulation experiments have indicated that

⇒ the presented method is a synthesis of two methods for measuring flow velocity – correlation method and thermoanemometric method;
⇒ full automation of measurements and elimination of measuring errors is achieved by the use of a computer both as a control unit and data processing unit;
⇒ the method of generating forcing signals by the computer is fast and provides the possibility of the initial checking for the correct operation of the system;
⇒ it is possible to set the configuration of a mesuring system, to design an algorithm for data processing on the basis of available procedures and to create one's own graphic interface for displaying results of measurements and of processing by means of specialized software packages;
⇒ the accuracy and stability of signal parameters depends mainly on the input and output systems collaborating with the measuring card;
⇒ the presented applications can generate thermal waves of wide frequency and amplitude ranges in the wave thermoanemometer converter;
⇒ in comparison to other methods, the accuracy of measurements, the possibility of processing and metrological analyses of the results are improved;
⇒ the presented system is open-ended so that it can be modified and further developed.

REFERENCES

[1] S. J. Bendat, A. G. Piersol: Metody analizy i pomiaru sygnałów losowych (Methods for analysis and measurements of random signals). PWN, Warszawa 1976.
[2] Z. Biernacki: Sensory i systemy termoanemometryczne (Sensors and thermoanemometric systems). WKiŁ, Warszawa 1997.
[3] Z. Biernacki, M. Kurkowski: Przetwornik anemometryczny z wybranymi sygnałami wymuszającymi (Anemometric converter with selected forcing signals). Materiały III Conference – Numerical Methods and Computer Systems in Automatic Control and Electrical Engineering, s. 154 – 157, Częstochowa – Poraj 1999.
[4] J. Kiełbasa: Pomiar wolnych przepływów (Measurements of free flow). Materiały XXVIII Międzyuczelnianej Konferencji Metrologów MKM'96, t.1 s. 392-399, Częstochowa 1996.
[5] J. Lal-Jadziak: Metody korelacyjne i ich dokładność (Correlation methods and their accuracy). Wyd. Politechniki Zielonogórskiej 1996.
[6] D. Sankowski: Zastosowanie pseudolosowych ciągów binarnych do identyfikacji własności dynamicznych wybranych elektrotermicznych obiektów sterowania. (Application of quasirandom binary sequences for the identification of dynamic properties of selected electrothermal controlled objects) Praca doktorska, Łódź 1979.
[7] W. Winiecki: Organizacja komputerowych systemów pomiarowych.(Organization of computer measuring systems) Wyd. P.W. 1998.