SIGNAL GENERATION AND ACQUISITION IN THE CORRELATION WTS

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

Key words: Correlation, anemometer, measuring signals

Summary: The paper deals with problems of signal analysis. Examples of system modelling by means of Dasylab package are discussed.

Measurements, analysis and visual presentation of selected signals were performed by means of measuring card PCL818 and Dasylab package. They are also described in the present paper [7].

1. INTRODUCTION

Measuring flow velocity of air within the range of small velocities, that is from a few to a few hundred centimeters is a complicated metrological problem [2,5,6]. One of the methods yielding satisfactory results is the thermal wave method, in which the propagation within a wave flow is examined. In wave thermoanemometers used in the not so distant times the thermal wave flow was generated by a sending wire, and velocity was measured by determining the dutation of wave flow between the sensors, or by determining the phase difference between signals coming from the sensors. Electric signals of rectangular shape were applied as forcing signals, and analysis was performed by means of complicated and highly sensitive to external interference electronic systems. The development of microprocessor technology brought about the possibility of the applicaion of correlation methods, which can now be fully exploited owing to greater accuracy and reliability of measuring devices [8,9,11,14].

Contemporary measuring devices employ computers with measuring cards and appropriate software for data generation, acquisition, processing as well as for communication with the user [12,15].

2. FUNDAMENTALS OF THE MEASUREMENT CORRELATION METHOD

The correlation method [3] is based on the assumption that a heat wave covering the distance between two sensors X and Y induces two signals at these sensors, the signals being shifted in time. In perfect conditions it is actually the same signal shifted in time. Marking as $x(0,t)$ the sensor X signal and as $y(L,t)$ the sensor Y signal, where L is the distance between the sensors we can write the following:

$$y(L,t) = x(0,t - t_m)$$

or (1)

$$y(L,t + t_m) = x(0,t)$$

The sought time t_m corresponds to the extremum of the correlation function of signals generated in the sensors, being the function of variable t describing time shift of the two signals.

$$\Phi_{xy}(t) = x(t) * y(t) = \lim_{T\to\infty} \frac{1}{T} \int_0^T x(0,t) y(L,t+t) dt \qquad (2)$$

Knowing distance l between the sensors it is possible to calculate velocity.

$$w = \frac{l}{t_m} \qquad (3)$$

For the analysis of flow velocity measurements by means of the correlation method a model was created of the flow phenomena occurring in a pipeline as well as a model of measuring converters.

It is assumed in the former model that a pipeline containing fluid can be considered an object with transmittance *G(s)* and corresponding impulse response *g(t)*. Input signal *x(t)* and output signal *y(t)* are natural or artificial zaburzenia occurring in the flow, which can be of determined or random character. The correlator receives signals $\tilde{x}(t)$ and $\tilde{y}(t)$ converted by the converters. For completeness of description noise $n_1(t)$ and $n_2(t)$ in the converters and interference in the flow *z(t)* are considered [14].

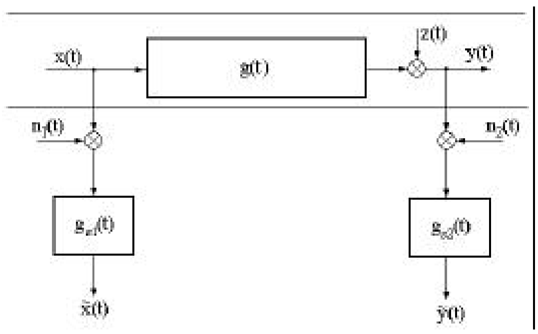

Fig.1. Model of flow including converters.

3. SYSTEM OF SIGNAL GENERATION AND DETECTION

The modified measuring system offered in the present paper consists of a probe containing a sender and two sensors, input-output systems (two measuring bridges and an amplifier), and a PC with software Dasylab including the system for generation and detection of a thermal wave created by a pseudorandom signal PRBS [10,13].

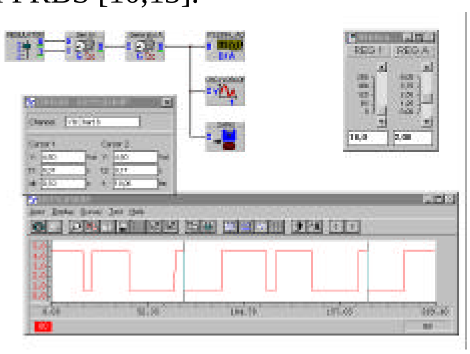

Fig.2. Signal PRBS generation system.

Using units of the software package pseudorandom signal generators were constructed by connecting rectangular signal generators in series.

The system for PRBS generation includes:

- GENERATORS OF RECTANGULAR SIGNALS for generation of pseudorandom signal;
- OSCILLOSCOPE for visual presentation;
- SAVE for data recording;
- measuring card PCL – 818L AO for tranmitting the signal to input/output systems.

Another solution involves a TTL generator system (Fig. 3).

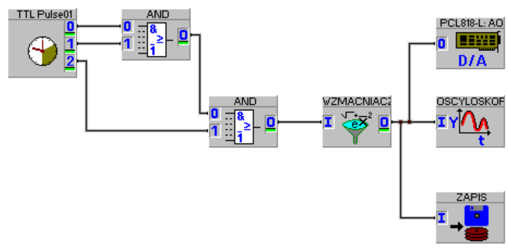

Fig 3. Pseudorandom signal generator with TTL.

This configuration includes:

- GENERATOR TTL and logical operators AND for psudorandom signal generation;
- OSCILLOSCOPE for visual presentation;
- SAVE for data recording;
- measuring card PCL – 818L AO for tranmitting the signal to input/output systems .

Examples of signal waveforms are presented in Fig.4.

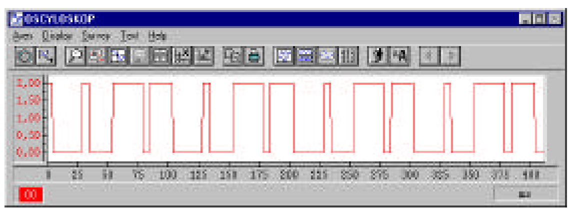

Fig.4. PRBS waveform

Signal generation and detection is performed by means of measuring card PCL

818L and software developed on the basis of DasyLab package containing systems for signal generation and analysis.

The use of the measuring card increases the speed and accuracy of measurements. The card applied is equipped with 12-bit a/d converters, and , according to the producer, the accuracy of measurements performed by means of the card is described as ± 0.01 % (of the measuring interval voltage) with ± 1 significant bit. It follows that the value of the basic error of the measuring card is influenced by both its class error and discretization component of the measurement by means of the 12-bit a/d converter.

The measurements were performed with the use of a forcing pseudorandom signal PRBS. Besides, a three- or two-wire converter was employed for measurements and correlation method was applied in the analyses.

The object of the study was thus the operation of a wave thermoanemometer with a pseudorandom forcing signal generated in the sender wire of the Wave Thermoanemometer sensor. Fig. 5 shows the system for signal generation and analysis with a two-wire converter. The system performs the following functions:

- modelling the forcing signal (modules Regulator, Generators);
- generating the electric signal (module PCL818L AO);
- reading the value of the electric signal from the measuring card (module PCL818L AI);
- filtering the signal by means of a filter (module FILTER);
- finding the value of the similarity function between the registered signal and the set generated deterministic signal (modules, CORRELATION, SUM CALCULATEt, INDICATORt);
- finding the value of measured gas flow velocity (modules CALCULATE W, INDICATOR W);
- visual presentation – OSCILLOSCOPE;
- recording data – SAVE, REGISTER.

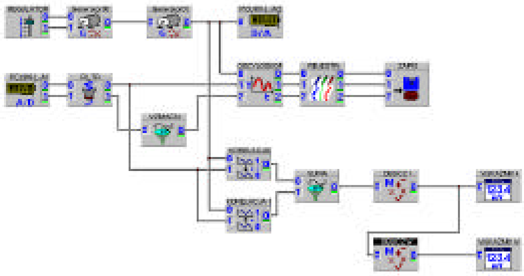

Fig.5. System for signal generation and analysis with a two-wire converter, PRBS forcing

4. RESULTS

Below are presented examples of results of signal measurements in the three-wire converter of a wave thermoanemometer (Fig. 6).

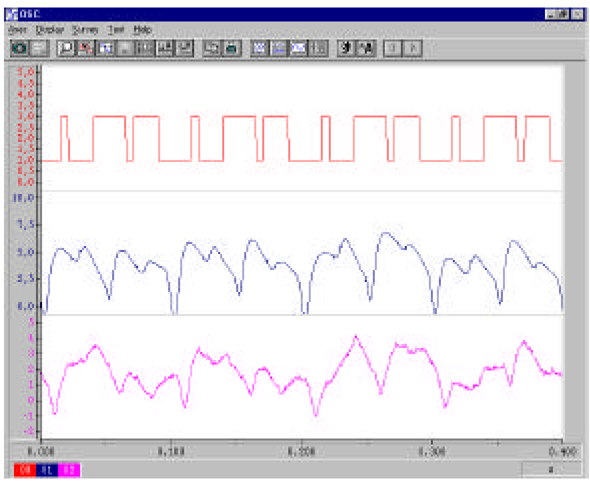

Fig.6. Signals in the sender and sensors; PRBS forcing

The values of absolute and relative errors were calculated on-line in a subroutine of the DasyLab package.

5. CONCLUSIONS

The results obtained and their analysis lead to the following conclusions:

- the measuring converter discussed in the paper unifies two methods of measuring flow velocity: the correlation method and the thermoanemometric method;

- the method of generating forcing signals by means of a computer is fast and effective and provides the possibility of the initial testing of the system operation;
- the value of the measured velocity is determined with an error not exceeding 1 % (the frequency of the forcing signal is 40 Hz, the signal amplitude is 1,2 V);
- the accuracy and stability of signal parameters depends mainly on the input/output systems collaborating with the measuring card;
- the design of the measuring stand allows for the possibility of increasing measuring points. It also enables measurements and control of other important parameters of industrial processes;
- in the system described gives high accuracy of measurements and wide possibility of their pocessing and analysis.

REFERENCES

[1] Bendat S. J., Piersol A. G.: Metody analizy i pomiaru sygna³ów losowych *(Methods of analysis and measurements of random signals).* PWN, Warszawa 1976.

[2] Biernacki Z.: Sensory i systemy termoanemometryczne. *(Sensors and thermoanemometric systems)* WKi£, Warszawa 1997 r.

[3] Izydorczyk J., P³onka G., Tyma G.: Teoria sygna³ów – wstêp, *(Theory of signals - introduction)* wyd. Helion, Gliwice 1999.

[4] Jaworski J.: Matematyczne podstawy metrologii *(Mathematical foundations of metrology),* WNT, Warszawa 1979.

[5] Kielbasa J.: Pomiar wolnych przep³ywów *(Measurements of free flow)*. Materia³y XXVIII Miêdzyuczelnianej Konferencji Metrologów MKM'96, t.1 s. 392-399, Czêstochowa 1996.

[6] Kurkowski M.: Badania i analiza sygna³ów w aspekcie wykorzystania w termoanemometrii falowej. *(Signal analysis and its application in wave thermoanemometry. PhD dissertation)* Praca doktorska Czêstochowa 2001.

[7] Kurkowski M.: Analiza sygna³ów przy u¿yciu pakietu DasyLab *(Signal analysis by means of the DasyLab package),* XXXII Miêdzyuczelniana Konferencja Metrologów MKM’2000, Rzeszów 2000.

[8] Kurkowski M., Rakus P.: Generatory sygna³ów zdeterminowanych i losowych *(Generators of random and determined signals),* XXXII Miêdzyuczelniana Konferencja Metrologów MKM’2000, Rzeszów 2000.

[9] Lal-Jadziak J.: Metody korelacyjne i ich dok³adnoœæ *(Correlation methods and their accuracy).* Wyd. Politechniki Zielonogórskiej 1996.

[10] Lyons R. G.: Wprowadzenie do cyfrowego przetwarzania sygna³ów *(Introduction to digital processing of signals),* WKi£, Warszawa 1999.

[11] Mi³ek M.: Pomiary wielkoœci nieelektrycznych metodami elektrycznymi.*(Measurements of non-electric quantities by means of electric methods)* Zielona Góra 1998.

[12] Morawski R.Z.: Metody odtwarzania sygna³ów pomiarowych *(Methods of representing measuring signals),* seria: Metrologia i Systemy Pomiarowe, Monografia, wyd. PAN, 1989.

[13] Sankowski D.: Zastosowanie pseudolosowych ci¹gów binarnych do identyfikacji w³asnoœci dynamicznych wybranych elektrotermicznych obiektów sterowania. Praca doktorska *(Application of pseudorandom binary sequences for the identification of dynamic properties of selected eletrothermal control objects, PhD dissertation)* £ódŸ 1979.

[14] Zator S.: Analiza b³êdów przep³ywomierzy korelacyjnych *(Error analysis of correlation flow meters),* Materia³y XXVIII Miêdzyuczelnianej Konferencji Metrologów MKM’96, Tom 2, str. 338 - 344 Czêstochowa 1996.

[15] Winiecki W.: Organizacja komputerowych systemów pomiarowych *(Organization of computer measuring systems).* Wyd. P.W. 1998.