MARIND' 2001

PROCEEDINGS

OF THE THIRD INTERNATIONAL CONFERENCE ON MARINE INDUSTRY

Edited by Peter A. Bogdanov

VOLUME II

04 - 08 June 2001
VARNA, BULGARIA

EXPERIMENTAL ASSESSMENT OF ACCURACY PARAMETERS OF COMPUTERIZED POLYMETRIC SYSTEMS

B.N. Gordeev, O.A. Zimina, Yu.D. Zhukov, P.A. Shamiloff
Advanced Measuring Instruments Company,
No.1, Spaska St., Nikolaev, UKRAINE

ABSTRACT

Computerized polymetric systems (PMS) for measuring storage parameters of liquid and loose media are based on the principle of time domain reflectometry. Thus the media under control is probed with video pulses of picosecond duration and the signals reflected from discontinuities are analyzed. One of the more frequently used representatives of such systems is automated remote control system of SADCO series, which is described in [1].

Certain factors and parameters, which affect the quality of measuring channel calibration and accuracy of measurements themselves, are considered. These factors are as follows:

- different cable length between the base electronic block and sensors;
- mechanical defects in sensor waveguide;
- quality of power supplies.

1. ASSESSMENT OF THE INFLUENCE OF CABLE LENGTH ON ACCURACY PARAMETERS OF PMS

Calibration of measuring channel of a PMS in field conditions at the site of exploitation is a complex and expensive task, therefore the calibration is usually performed in the laboratory environment. The length of cable lines between the base block and the measuring transformers (sensors) in case of calibration in laboratory may differ from the actual length by up to one hundred meters, and it can significantly affect the form of calibration function of the measuring channel.

This problem was investigated and a number of experiments has been made in the laboratory of polymetric systems (LPS) at the scientific and technical center of energy-efficient and environment-friendly technologies, which was established basing upon research-and-production company *AMICO Ltd.* The LPS is accredited and certified by Ukrainian State Committee of standardization, metrology, and certification, stating the technical competency of metrological provision of liquid and loose media parameters measuring and of measuring equipment calibration. The LPS is equipped with exemplary polymetric systems: basic reference standard of level and temperature acquisition (permissible error range 0.64 mm and 0.1°C respectively) and working measure standard (permissible error range 1.08 mm and 0.15°C respectively).

To explore the problem the following experiment was made. The calibration of several level measuring channels of *SADCO* polymetric system was performed with various flowline (cable) lengths with an equal step of 30 meters (10, 40, 70 and 100 meters).

As result of the research linear regression dependencies were built according to the least-squares method for each of the obtained calibration functions. Certainty evaluation was performed according to Pirson criteria [3], which equals in this case to $\chi^2 = 0{,}9999$.

Regression equation is linear:

$$f(x) = kx + b$$

A set of curves was obtained accomplishing the variation of k and b coefficients of linear regression dependencies with respective lengths of flowline (see Appendix A, Fig.1.).

These relations were approximated with 3[rd] order polynomials. Certainty evaluation was performed according to Pirson criteria, which equals in these cases to $\chi^2 = 1$. For this set of curves polynomial equations with averaged coefficients are as follows:

$$k = -0{,}0076l^3 + 0{,}055l^2 - 0{,}1131l + 6{,}5218$$

and for b coefficient:

$$b = 0{,}1305l^3 - 0{,}8147l^2 + 1{,}3518l + 62{,}068$$

As it can be derived from the above relations, k and b regression coefficients may be equal at different flowline length. Thus, this set of flowline lengths can be recommended, since the calibration functions do not variate considerably. As an example, dashed line shows equal values of the coefficients for the 1[st] measuring channel (position 1 on fig.1).

2. INFLUENCE OF MECHANICAL DEFECTS INTRODUCED DURING WAVEGUIDE PRODUCTION

It is reasonable to use one waveguide for all measuring channels during their calibration and testing their metrological characteristics in laboratory environment. At the same time, the following mechanical defects could have an influence on precision of calibration function determination:

- non-parallel axis sensor tubes;
- bend and torsion in flats, which are perpendicular and parallel to sensor flat;
- deviation of sensor axis from normal.

Following experiments were conducted to examine the influence of these mechanical defects on the accuracy parameters of the system. Several sensors with the same design were chosen in a random way. Calibration equations were obtained for each of the sensors on the same measuring channel [1]. Then pairwise differences were evaluated of measured values in units of analog-digital converter for all points calibration function and for different sensors.

$$\Delta_i^m = x_i'^m - x_i^m, \; i = C_n^2$$

where: n – quantity of sensors;

$x_i'^m, x_i^m$ – system reading in the same point of different waveguides;

m – quantity of calibration function points;

C_n^2 – quantity of combinations of sensor pairs.

Diagrams of these differences are represented on fig.2, appendix A.

Evidently, average of distribution of calibration function deviations is

$$M(\Delta) = \frac{1}{n}\sum_{i=1}^{n} M_i(\Delta^m),$$

where $M_i(\Delta^m)$ – average of distribution of deviation within i-th sensor pair.

Experimental value equals for $M(\Delta) = 0{,}303$ units of analog-digital converter or $1{,}5mm$. Standard deviation equals to $\sigma(\Delta) = 0{,}179$ or $0{,}9mm$. This deviation is too considerable.

At the same time, diagrams of calibration function deviation of the sensors, being produced with higher accuracy class of form tolerance and surface layout tolerance, lay near zero (see appendix A, fig.2).

These researches enable us to conclude that calibration and metrological performance verification are allowed for all measuring channels using one waveguide, on conditions that manufacturing and assembling methods are kept to the appropriate quality class for the form and surface layout tolerances.

3. INFLUENCE OF POWER SUPPLY

The following experiments were conducted to examine the influence of power supply quality on measurements accuracy. Set of readings were collected in a fixed point with supply voltage 170, 180, 190, 200, 210, 220, 230, 240, & 250 volts. This test applied to several points chosen equally spaced on the length of sensor.

Analysis has shown that influence of power supply variation U on system error Δl is not constant along the sensor length. Thus, for range beginning, system is more negative edge sensitive $\Delta l \approx 6mm$ (see appendix A, fig.3) than positive-going edge $\Delta l \approx -0{,}5mm$.

The opposite result is observed in the end of range. So, error equals $\Delta l \approx 5mm$ for the positive-going edge of supply voltage and $\Delta l = -1mm$ for the negative edge of it. In the middle of range (about 80 % of all sensor length), the power supply changing has inessential influence on system error.

Dependencies data have been approximated with 4th exponent polynomial.

In general, we may describe these all dependencies with the help of some surface (see appendix A, fig.4), plotted in co-ordinates $\Delta l - U -" zone\_of\_range"$.

Therefore, conducted experiments enable us to derive a total error dependence:

$$\Delta l = f(U)\mathrm{sgn}(\Delta U) + f(x)\mathrm{sgn}(\Delta x)$$

where $f(U)$ – dependence of system error on the power supply;

$\mathrm{sgn}(\Delta U)$ – sign of the supply voltage deviation;

$f(x)$ – system error, depends on calibration function nonlinearity;

$\mathrm{sgn}(\Delta x)$ – sign of the deviation, depends on calibration function nonlinearity.

4. CONCLUSIONS

1. Dependency of calibration function parameters and the flowline (cable) length has been acquired. The practical benefit is the possibility to utilize interchangeable cable (flowline) lengths for calibration in laboratory environment and for direct exploitations of measuring channel.

2. Experimental researches of sensor defect influence allows to recommend the class of accuracy for the form and surface positioning while production, when those defects do not considerably affect the quality of measurements by different measuring channel of polymetric system.

3. Relationship between the system's accuracy and power supply quality permits to recommend extreme deviations of voltage 200V±10% to provide the accuracy of measuring channel ±1mm. This is the reason to use stabilizing units for power supply of serial monitoring systems of SADCO type in operation.

4. If optimal proportion of the factors is observed the accuracy of the basic reference standard of level measurement can reach 0.64 mm. This accuracy can be achieved also for the serial systems of SADCO type using the above recommendations.

5. REFERENCES

1. Zhukov Y.D., Gordeev B.N. Logvinenko Y.I., Prischepov Y.O. – Computerized maritime polymetric systems – Proc. of the 2-th International Conf. on Marine Industry (MARIND'98) – Vol. III.–Varna (Bulgaria)– 1998. – p. 245-252.

2. Глебович Г.В., Андриянов А.В, Веденский Ю.В. и др. – Исследование объектов с помощью пикосекундных импульсов/под ред. Г.В. Глебовича. – М.: Радио и связь, 1984.

3. Пустыльник Е.И. Статистические методы анализа и обработки наблюдений. - М., «Наука», 1968.