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Software Improvements of the Accuracy in the Air-Electronic Measurement Systems for Geometrical Dimensions

Miroslav H. Hristov, Velizar A. Vassilev, Georgi K. Dukendjiev

***Abstract*—**Due to the constant development of measurement systems and the aim for computerization, unavoidable improvements are made for the main disadvantages of air gauges. With the appearance of the air-electronic measuring devices, some of their disadvantages are solved. The output electrical signal allows them to be included in the modern systems for measuring information processing and process management. Producer efforts are aimed at reducing the influence of supply pressure and measurement system setup errors. Increased accuracy requirements and preventive error measures are due to the main uses of air electronic systems - measurement of geometric dimensions in the automotive industry where they are applied as modules in measuring systems to measure geometric parameters, form, orientation and location of the elements.

***Keywords*—**Air-electronic, geometrical parameters, improvement, measurement systems.

I. Introduction

AIR-ELECTRONIC gauges (AER) are constantly evolving, with manufacturers' efforts aimed at reducing deficiencies and expanding their capabilities.

Permanent targets for improvement include metrological features and calibration methods for AER, measurement uncertainty reduction, and increased reliability.

Despite the existence of various influencing factors on the accuracy of measurement with air gauges, one of the main components of the error is due to the change in supply pressure. This error depends on the pressure regulators, which are one of the most important elements of AER.

II. Exploration of the Characteristics of the IBR ae-1

To determine the influencing factors, it is necessary to study the static characteristics of the measuring system. In this case, a function of transformation of the input magnitude is represented in graphical form - displacement and the value reported by the device (Fig. 1). It shows the change of the instrument reading in relative units vs. the linear displacement in µm. For this purpose, a characterization was performed with three of the most common measuring nozzles - 1.5, 2, and 2.5 mm. The graphical representation is for a 2-mm nozzle.

In the middle part of the graph, a relatively large linear region is observed. This section approximates to linear as the error of non-linearity is below 2%. The non-linearity is 7.14% across the surveyed range [3].

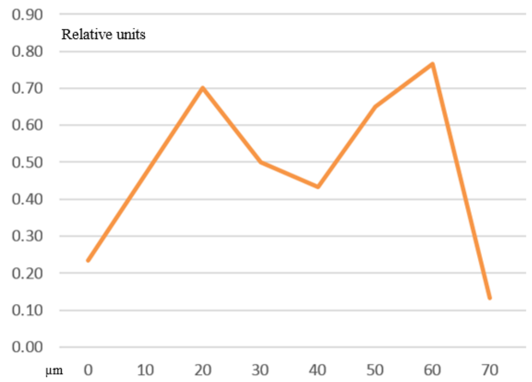

Fig. 1 Change hysteresis of IBR-ae1 in the range 0-70 µm

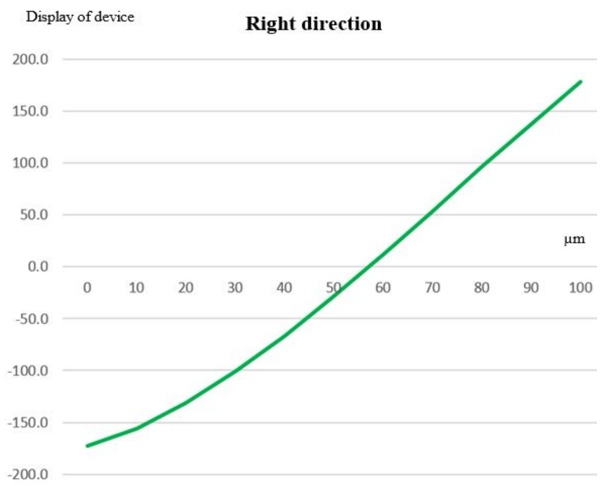

Fig. 2 Conversion function – relative unit to linear displacement in µm – Right direction

Of particular importance is the hysteresis of the regulator (Figs. 2 and 3). It varies between 0.15 and 0.85 relative reading units on the digital display of IBR ae-1. Depending on the operation of the appliance, this may lead to a result error within ± 0.45 µm.

M. H. Hristov is with the Mechanical Engineering Department, Technical University of Sofia, Sofia, Bulgaria (phone: +359 87 86 16 331; e-mail: miro.hr@abv.bg).

V. A. Vassilev is with the Mechanical Engineering Department, Technical University of Sofia, Sofia, Bulgaria (phone: +359 2 965 28 96; e-mail: vassilev_v@tu-sofia.bg).

G. K. Dukendjiev is with the Mechanical Engineering Department, Technical University of Sofia, Sofia, Bulgaria (phone: +359 2 965 26 88; e-mail: duken@tu-sofia.bg).

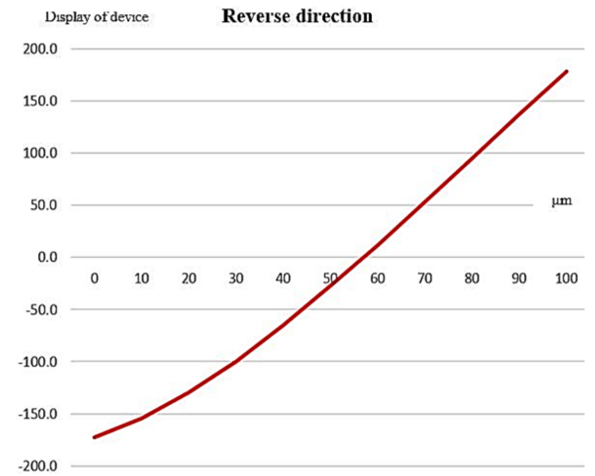

Fig. 3 Conversion function – relative unit to linear displacement in µm – Reverse direction

III. Pressure Regulators

The correct choice of a pressure regulator is important in a metrological aspect when developing an air gauge. The solution requires familiarization with the operating conditions and principles of the regulator's operation [1].

A. Types of Pressure Regulators

There are two types of pressure regulators non-amplifying pressure regulator and regulators with an amplification. The magnitude and stability of the working pressure is a function of several variables. The output of the analytical expression for H is based on the equation equilibrium force acting on the moving parts.

Therefore, the ability of regulators without amplification in terms of accuracy is too limited in terms of principle and construction. In this respect, regulators with an amplification are significantly superior [1]. The errors of this type of regulator caused by network pressure fluctuations and air consumption are significantly lower than those of the other type without an amplification, and a shift of the working pressure is practically not obtained [1].

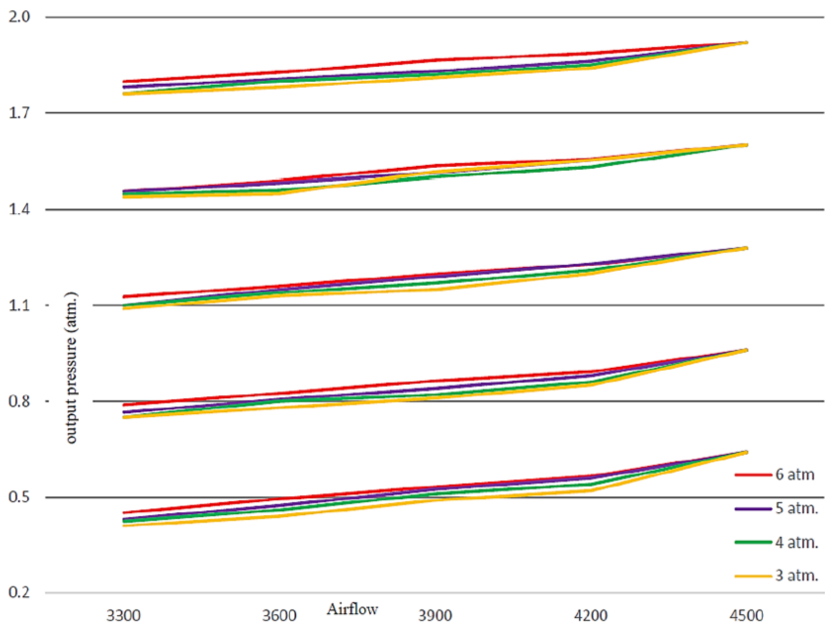

Fig. 4 Graph of change in output pressure as a function of airflow at regulator SMC AR 20

B. Pressure Regulators Offered by Leading Manufacturers

One of the leading manufacturers of pressure regulators is SMC (Japan). For the purpose of the study, we used two of their regulators [5]:

- Simple (no amplification) - SMC AR20 F02H
- Precision (with amplification) - SMC IR 1000

The manufacturer presents the characteristics as graphs representing the relationship between inlet and outlet pressure, consumption and hysteresis.

For the SMC AR20 F02H pressure regulators, according to the manufacturer's technical parameters, a change in the outlet pressure is observed when the flow rate changes in a relatively small range [2], [4].

Standard AERs work with inlet pressure ranging from 2-4 atm. Here, a group of curves with the closest characteristics is observed. A major problem in the application of AER in industrial conditions is that there are too many air consumers and there is a large change in the pressure to the pressure regulator. This leads to an additional stabilization error caused by the change in the rise and pressure reduction - hysteresis of the regulator. This error is around 0.1 atm.

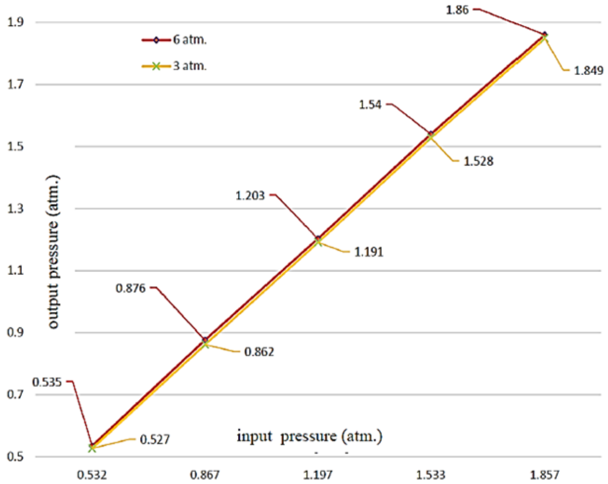

Fig. 5 Graph of change of output pressure as a function of input at regulator SMC IR1000

Precision (with amplification) regulators have significantly improved performance. Again, the main influential factors here are related to the variable inlet pressure and the variable flow in industrial conditions. Here, the errors that are observed are one order smaller than the non-amplified regulators.

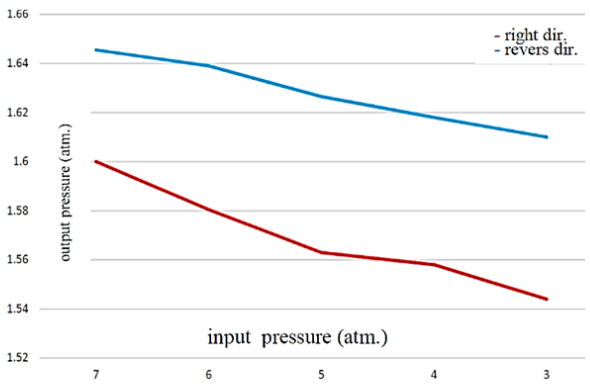

Fig. 6 Hysteresis when changing the supply pressure of pressure regulator SMC AR20

IV. Influence of SMC AR20 F02H and SMC IR 1000 on the Accuracy of Pneumatic-Electron Measuring Instrument IBR-ae1

From the research done, the influence of the pressure regulator on the pneumatic system IBR ae-1 is observed. The main parameters of the study are related to changes in the supply pressure and the influence that it exerts on the outlet pressure of the regulators [6].

From the graphically obtained results, for the SMC AR20 regulator, it can be concluded that when the supply pressure changes by 1 atm. In a normal range for industrial conditions of 3 to 6 atm, a change of the outlet pressure was observed by 0.02 atm. This change caused a ~ 1 µm error in the investigated IBR ae-1 (Fig. 4).

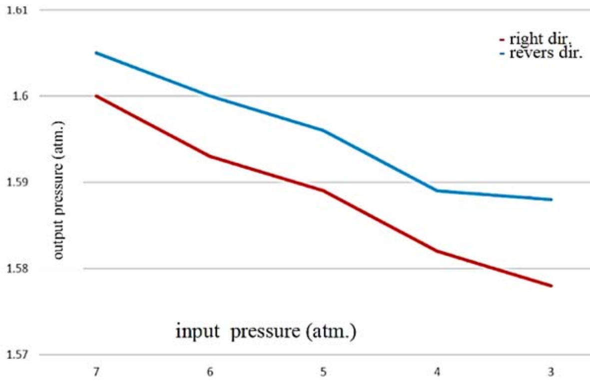

Fig. 7 Hysteresis when changing the supply pressure of pressure regulator IR 1000

For the precision pressure regulator SMC IR 1000, the error of the input pressure fluctuation of 0.3 MPa causes an error in the IPR to be tested ~ 0.9 ÷ 1,3 µm (Fig. 5) [5].

Under real conditions, the oscillating pressure in the feed system rarely exceeds 1 atm, which may result in an error of ~ 0.3 µm [6].

The main source of error in the pressure regulators is the hysteresis error at the supply pressure fluctuations (Figs. 6 and 7). With simple regulators, this error results in ~0.02 atm., and with the precision regulators of 0.004 to 0.008 atm. The reported results in a change in IBR ae-1 score of 1 µm in simple regulators (SMC AR20) and up to 0.5 µm in precision (SMC IR 1000).

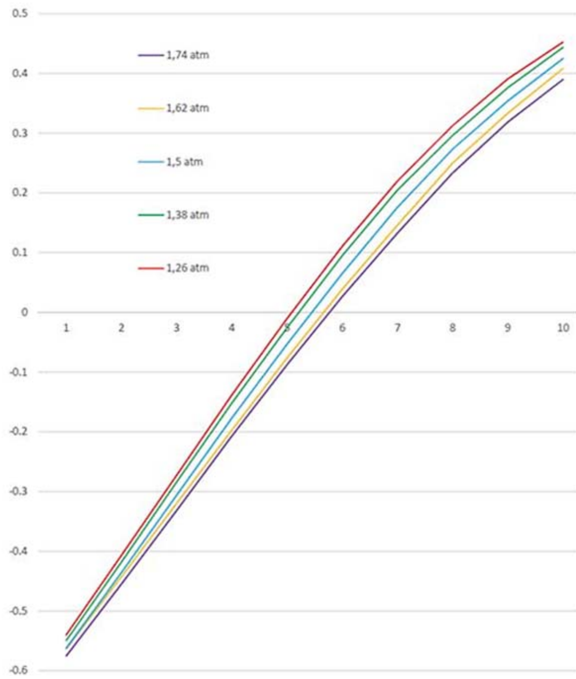

Fig. 8 Family curves as a function of the relative value of IBR ae-1 to linear displacement at charge of inlet pressure

V. Opportunities to Improve Metrological and Operational Performance of AERS with Software Compensation of Errors

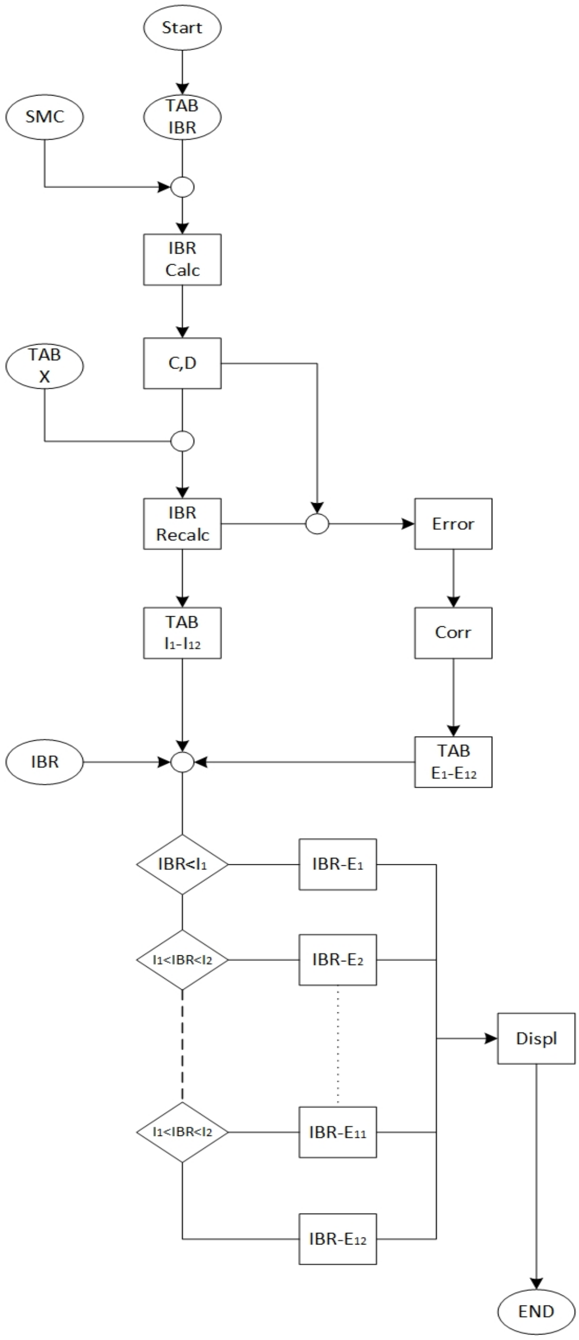

Fig. 9 Block diagram for regression compensation

In order to determine the dependence of the influence factors on the AER transformation function, a regression analysis is required. The conversion function is nonlinear, but there is a linear dependence between the change in the supply pressure and the change in the output parameter.

When changing the inlet pressure of the system, a family of curves and a relatively large linear region can be observed in the middle of the measuring range (Fig. 8). Based on these curves, a regression model can be calculated.

A. Reducing the Non-Linearity of the AER Conversion Function

The use of a regression model to calculate the conversion function introduces an error relative to the real transformation characteristic, but significantly reduces the error of the change in the input pressure. For the determination of the regression model, we use an average value obtained after experimental dropping of the characteristic for different input value (linear displacement) in different tooling (output nozzle) and different supply pressure values.

In the regression model, a coefficient of coverage between the real characteristic and the calculated Sm ~ 4% for the different curves is obtained. After correction of each value, a maximum error shall not exceed 0.5%.

Fig. 9 is a block diagram of the realization of software compensation. To do this, we use a SMC digital press unit to read the pressure and enter the actual value in the data processing computer. We explore a characteristic of the device beforehand and entered as software output data. Based on these, the values obtained from the IBR-ae1 meter are recalculated. LabVIEW calculations of regression model coefficients are performed. Using these coefficients and based on the change of the input quantity X, the value of the IBR is recalculated. The error of the regression model and the correction that must be entered into the final result are calculated after the first. The measurement range is divided into seven equal parts, with a different correction taking into account the model's non-linearity. Based on the data from the instrument, the operating range is selected and the result is adjusted accordingly.

Because of the nonlinear nature of the conversion function, we have a fault of nonlinearity that can be compensated by importing a "fault map" in which correction values for different cases to construct approximation rights to be entered. These actions help to directly increase the measuring range as the system can operate close to both ends of the transformation characteristic.

B. Compensation of Supply Pressure Oscillation by Introduction of „Error Map“

The AER characteristics of the pressure regulator used are pre-recorded. With the data thus obtained, a database is created - "error map". For correction, it is necessary to monitor the inlet pressure change in operating mode. The resulting current value "subtracts" from the result correction database. Thus, the error of the AER indication is reduced by up to 5% depending on the working pressure and the used tooling.

Fig. 10 is a block diagram of the realization of software compensation. We explore a characteristic of the device beforehand and used as the source information for the software. We use the SMC digital block to report the pressure and enter the current value in the data processing computer. The result obtained with a compensated error is displayed on the computer's data processing display.

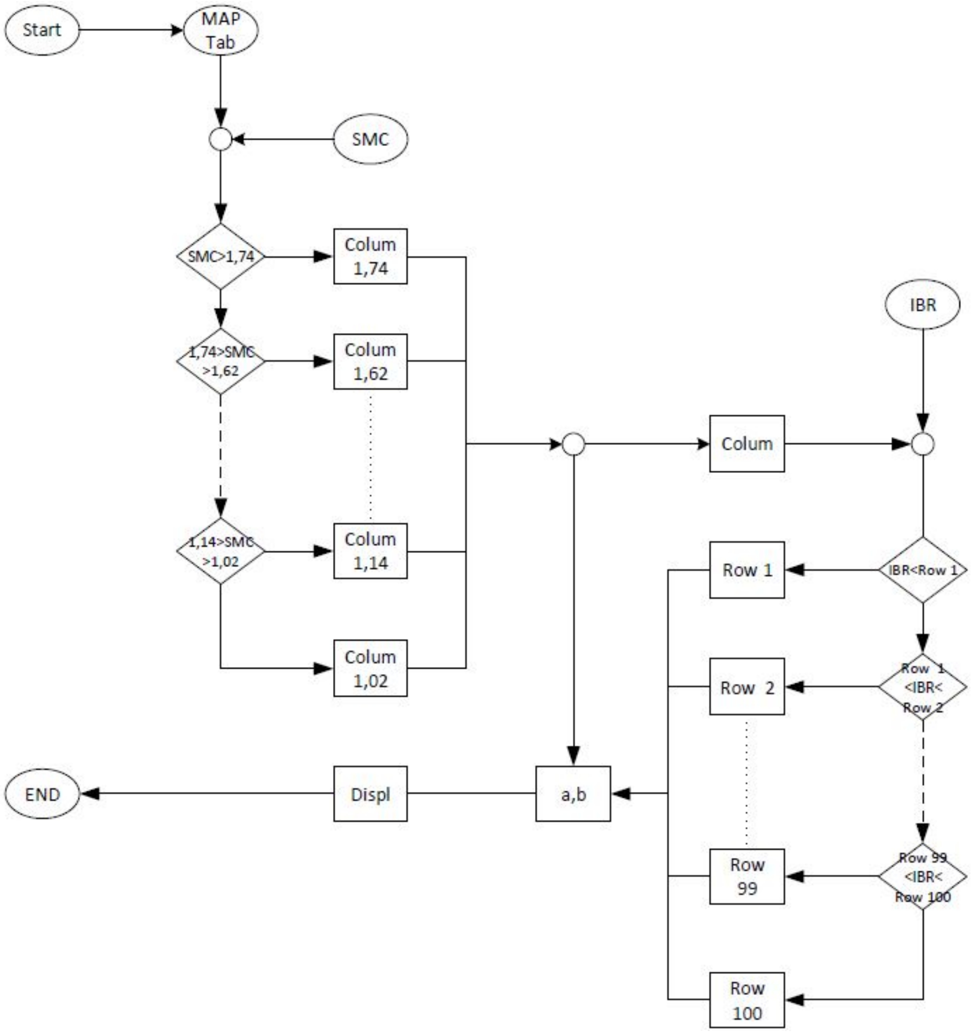

Fig. 10 Block diagram for "Error map" compensation

VI. Conclusion

The influence of input pressure on the accuracy of AER was studied. It is proposed to introduce into the measuring system a converter for input pressure reading and direct correction on the result by means of software compensation. This improves the metrological characteristics of AER and simplifies the setup methodology.

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