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APPLICATION OF 0-A-0 PRESSURIZATION TO PRESSURE GAUGE CALIBRATIONS

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Abstract – A new calibration method is proposed and examined to improve the pressure calibration using pressure gauges as the reference device. In the method, the reference gauge is pressurized with the 0-A-0 procedure, while the test gauge can be pressurized with various procedures. The calibration results with this method were found to be consistent with those calibrated against a pressure balance. The method is expected to help develop more precise and low-cost pressure calibration systems.

Keywords: calibration, pressure gauge, hysteresis

1. INTRODUCTION

In the field of pressure calibration, pressure balances are commonly used as the reference device. Although the pressure balance is one of the most stable apparatus for pressure measurement, expertise and skills are necessary for appropriate and efficient operations. Recently, electromechanical pressure gauges are also used as the reference pressure devices in various industries, owing to considerable improvements in quality. Among them, gauges with digital outputs are commonly used to efficiently calibrate pressure gauges, due to its usability and versatility.

When pressure gauges are used as the reference device, several characteristics should be evaluated in advance and on-site, including repeatability, hysteresis, long-term shift, and the effects of the surrounding conditions. Among them, the time-dependent behaviour and the effect of pressurization on the outputs have been focused in this study. The effects of the pressurization procedures on the calibration results are quantitatively evaluated with a stepwise pressurization [1], as schematically shown in Fig. 1(a), and with a 0-A-0 pressurization [2], as shown in Fig. 1(b).

Calibrations of pressure gauges are conducted typically with a stepwise pressurization [3,4]. However, even with nominally the similar stepwise procedure, the difference in the pressurization procedures, such as time intervals and presence or absence of the preliminary pressurization, can affect the outputs of the gauges used as the reference, and then, ultimately affects the calibration results of the test gauge.

In this study, a new calibration method is proposed [5] and examined to make the calibration using the pressure gauge as the reference more precise and useful. In the new method, applying the 0-A-0 pressurization to the reference pressure gauge highly eliminates the effect of pressurization procedure on the reference gauge, and then, enables us to precisely calibrate test pressure gauges with various pressurization procedures.

In this paper, first, the advantages of applying the 0-A-0 pressurization in pressure gauge calibrations are summarized in section 2. Keys to obtaining reproducible results are also mentioned. Then, a new calibration method using the 0-A-0 pressurization is explained in section 3. Demonstration experiments are conducted to confirm the effectiveness of the new method. The scheme and results of the experiment are shown in section 4, followed by discussions about the advantages and applications of the new method. The findings are summarized in section 5.

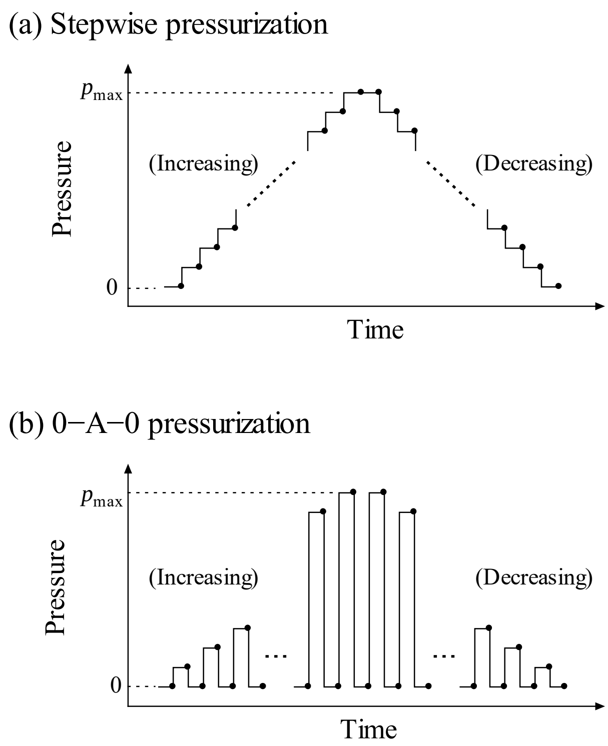

Fig. 1. Pressurization procedure for pressure gauge calibrations. (a) Stepwise pressurization, (b) 0-A-0 pressurization.

2. ADVANTAGES IN 0-A-0 PRESSURIZATION

A distinctive advantage in applying the 0-A-0 pressurization is a high reproducibility of calibration results irrespective of pressurizing history: order of calibration pressure, interval between the calibration cycles, waiting time at each calibration pressure, preliminary pressurization and so forth [2].

Fig. 2 shows calibration results for a clamped thin film pressure sensor, a commercial pressure gauge, with the stepwise (Fig.1(a)) and 0-A-0 (Fig.1(b)) pressurizations. For the both procedures, the maximum pressure in a cycle was set 100 MPa, 70 MPa, and 50 MPa. Relative deviation of the gauge's output from the standard pressure applied from a pressure balance is shown in the figure. As obviously shown in the figure, the hysteresis, which is the difference between the results for pressure increasing and decreasing processes, was much smaller with the 0-A-0 pressurization than the stepwise pressurization. The results with 0-A-0 pressurization almost fell in one calibration curve, although the data scattering was slightly larger at lower pressures. Even when the pressure point is changed in a random sequence instead of the sequential order, the calibration results also fell on the same calibration curve with the sequential order. The similar results are shown for quartz Bourdon-type pressure transducers [2], with which the data variation was relatively less than a few parts per million.

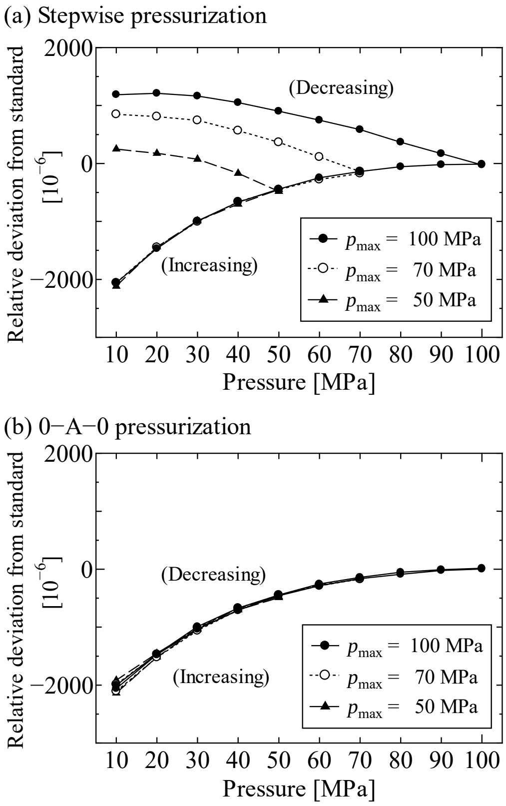

Fig. 2. Examples of calibration results for an electromechanical pressure gauge with the three maximum pressures, 50 MPa, 70 MPa, and 100 MPa. (a) Stepwise pressurization, (b) 0-A-0 pressurization.

It is worth nothing that the offset correction using the measurement data at the atmospheric pressure right after the measurement at a target pressure is a key to achieving the high reproducibility. In addition, the operations and time intervals between the measurements at the target pressure and at the atmospheric pressure need to be precisely fixed. Using a fully-automated calibration system in unattended environment reduced changes in ambient conditions and also reduced random errors of the data, to obtain reproducible results for respective pressurization procedures.

3. NEW CALIBRATION METHOD APPLYING 0-A-0 PRESSURIZATION TO REFERENCE GAUGE

To explain the new calibration method, a calibration of a test gauge against a reference gauge with a stepwise pressurization is supposed in this section. Fig. 3 schematically illustrates pressures applied to the reference and test pressure gauges. In a conventional method shown in Fig.3(a), the same pressure is always applied to both the reference and test gauges. In the proposed method in Fig.3(b), on the other hand, the two gauges are pressurized with different procedures: the test gauge is pressurized with the stepwise procedure, same as Fig.3(a), while the reference gauge is pressurized with the 0-A-0 procedure. The pressure lines for the two gauges are connected to each other when the measurement data is obtained at the target pressure, as shown by open and filled circles in the figure.

The new calibration method explained above is easily implemented by using a pressure controller and by switching the opening and closing of the valves located between the two gauges. Moreover, this method is applicable to other pressurization procedures for test gauges, other than the stepwise pressurization.

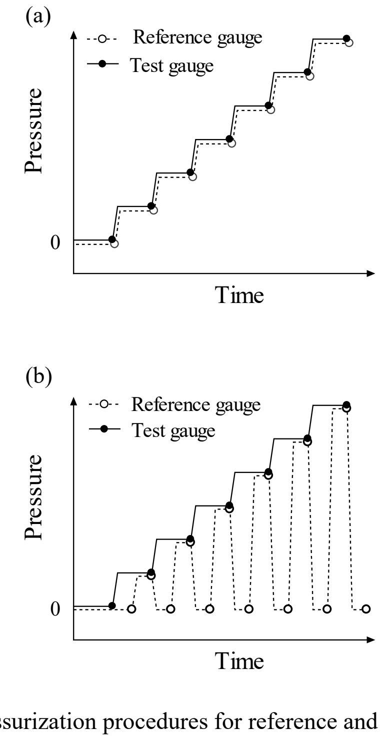

Fig. 3. Pressurization procedures for reference and test gauges during calibration: conventional method (a), and proposed method (b). For both procedures, the test gauge is calibrated with a stepwise pressurization.

4. ADVANTAGES IN 0-A-0 PRESSURIZATION

A demonstration experiment is conducted to check that the correct calibration results are obtained with the new method. The scheme of the experiment is shown in Fig.4.

The pressure gauge A, used as the reference gauge in Method II, is the clamped thin film sensor, whose calibration results were shown in Fig. 2. The pressure gauge B is a foil strain gauge from another manufacturer. The calibrations of the test gauge B were conducted with the stepwise pressurization with the two different maximum pressures pmax: 70 MPa and 100 MPa. It is naturally expected that the results in pressure decreasing process differ depending on the maximum pressure. The gauge B was calibrated with the two methods as the following. In Method I, the gauge B was calibrated against a pressure balance with a conventional method. In Method II, on the other hand, the gauge was calibrated against the gauge A with the new method. The gauge A, the reference gauge for the gauge B in Method II, had been calibrated against the pressure balance with the 0-A-0 procedure in advance.

Results of the gauge B with the two methods are compared in Fig.5. For both the conditions in terms of the maximum pressure, the results with the two methods are in good agreement with each other, showing that the new calibration method and calibration system appropriately work and that the effects of the maximum calibration pressure on the gauge B results were correctly evaluated without using pressure balance.

In a normal calibration method using the gauge A as the reference, the gauge A was calibrated with stepwise pressurization against the pressure balance in advance, and the gauge B is calibrated against the gauge A with the similar stepwise procedure as illustrated in Fig. 3(a). In that case, the gauge A should be calibrated with the two maximum pressures in advance, to obtain correct calibration results. Otherwise, the results of the gauge B in the pressure decreasing process would deviate from the correct values due to the hysteresis of the reference gauge A. With the new method, in contrast, it is not necessary to take into account the effects of the pressurization conditions, such as the change in the maximum pressure and pressurization procedure, on the reference gauge A. When a high-end pressure gauge is used as the reference gauge, the magnitude of the pressurization effects on the results is relatively at most a few parts per million, which is comparable to the reproducibility of the pressure balance.

The new method is also applicable to calibrations using other types of pressure gauges as the reference. Using the new method can help reducing the cost of the pressure gauges used as the reference, leading a precise and low-cost calibration devices for pressure gauges.

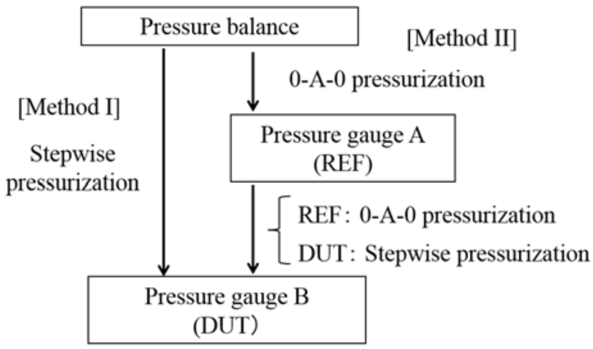

Fig. 4. Scheme of the demonstration experiment for the new calibration method. Method I is a conventional method using a pressure balance as the reference. Method II is the newly proposed calibration method using a pressure sensor as the reference.

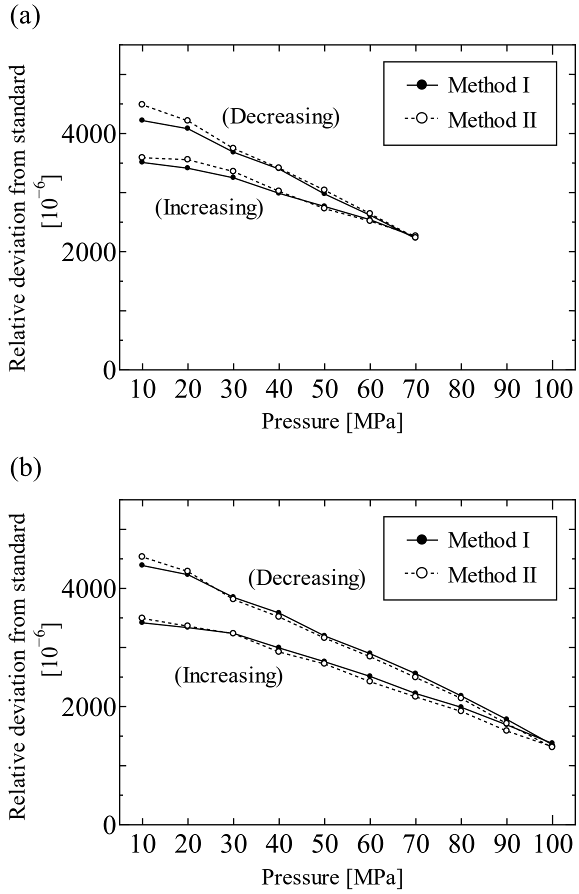

Fig. 5. Calibration results for the gauge B in demonstration experiment with (a) p_{max} = 70 MPa and (b) p_{max} = 100 MPa.

5. CONCLUSIONS

A new calibration method is proposed and examined to make the calibration using the pressure gauge as the reference more precise and useful. In the new method, the reference gauge is pressurized with the 0-A-0 pressurization procedure, while the test gauge can be pressurized with various procedures according to the measurement conditions and client's requests. The 0-A-0 pressurization to the reference gauge highly reduces the effect of the pressurization history on the outputs of the reference gauge, and then yields highly reproducible results. In a demonstration experiment, the calibration results with this method were found to be consistent with those calibrated against a pressure balance. The new method is of wide application in terms of the kind of pressure gauges used as the reference and pressurization procedures applied to the test gauge. The method is expected to help develop more precise and low-cost calibration systems.

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