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HIGH DYNAMIC PRESSURE STANDARD USING A STEP PRESSURE GENERATOR

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Abstract: This paper describes how to implement a high dynamic pressure instrument using a step pressure generator and standardization based on a medium density equation. The step dynamic pressure without any big vibration due to an impulse caused by a trigger mechanism is generated upto 800 MPa. A basic design concept to eliminate the unnecessary vibration is proposed. In addition, density equations according to pressure are used to establish the high dynamic pressure standard. On the other hand, the effectiveness of conventional sebacate(di-2-ethylhexyl sebacate) oil density equations could be verified by the instrument.

Keywords: Dynamic pressure, Standardization, Resonant frequency, Oil density

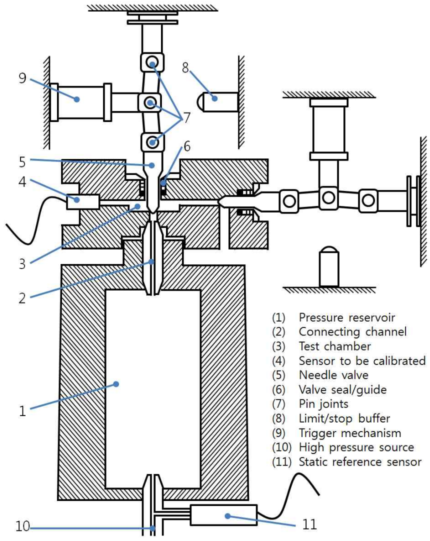
1. INTRODUCTION

A dynamic pressure standard is one of the most important issues in the field of pressure metrology. Most pressure standard covers static pressure in absolute, gauge and differential mode. However, the requirement for the reliable dynamic pressure measurements from the advanced industries is getting increased more and more.

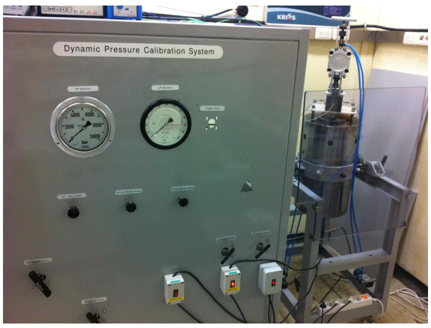
A high dynamic pressure is implemented by a step or an impulse pressure in hydraulic mode. A reference dynamic sensor is compared to the sensors to be calibrated under the fast changing pressure circumstance. The reference sensor should be calibrated by dynamic pressure standards, but well-established dynamic pressure standards such as a shock tube standard based on the properties of diatomic gas molecules cover only low pressure range.[1]-[3]

A conventional high dynamic pressure calibrator uses a fast acting ball valve with a large cross-section area. The big impulse due to the high power trigger mechanism can cause unnecessary vibration in step pressure even though it can generate step pressure within 1 ms of a rise time.

In this paper, the high dynamic pressure system using fast acting needle valves instead of the ball valve is introduced. It has a sufficiently small rise time without any big impulse generation. In addition, the dynamic system has a negative step pressure function beside positive step generation by two dynamic pressure trigger mechanisms. Moreover, we propose the way to calibrate reference dynamic sensors by the estimation of the changing dynamic pressure based on the density change of transmitting medium.



(a)



(b)

Fig.1 Dynamic pressure standard (a) schematic diagram and (b) System picture

2. NEW HIGH DYNAMIC PRESSURE CALIBRATION SYTEM

Dynamic pressure is generated by releasing transmitting medium stored in high pressure reservoir(1) to test chamber(3). If a ball valve with a large cross-section area is used, since the amount of the releasing medium is large, a short rise time can be obtained. However, the pressure drop from the initial pressure of the reservoir is great, and the trigger mechanism generates a great impulse force when it impacts.

Instead of the big ball valve, a needle valve with a small cross-section area can be used in order to avoid big impulse generation and high pressure drop. On the other hand, the rise time may increase due to the small amount of released medium, but the short rise time can be obtained if the volume of the test chamber is designed as small as possible.

Fig.1 shows the schematic design of the high dynamic pressure system using two trigger mechanisms with the needle valve instead of the big ball valve.

Double trigger mechanisms can make not only a positive going step pressure generation, but a negative step pressure generation as shown in Fig.2. The negative pressure method has shorter rise time and no viscos behaviour.

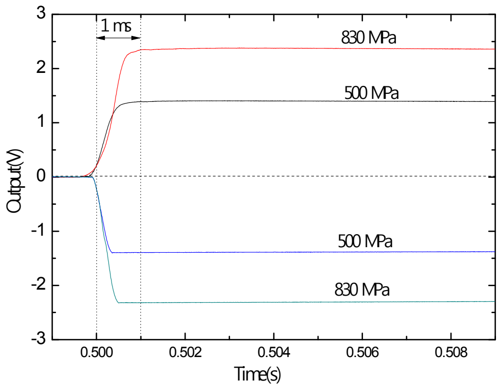


Fig.2 Positive and negative step pressure signal

The procedure of the working principle is as follows. First, the pressure is generated and stored in pressure reservoir while two trigger mechanisms are close. If the primary trigger mechanism moves forward, then the needle valve retreats and the pressurized medium will be transmitted to the test chamber. After completing the data acquisition of positive going step signals, if the primary trigger mechanism moves backward, then the needle valve is closed and two chambers are separated by the valve. In test chamber, there is still the pressurized medium, but the accurate pressure is not known. Then, if the secondary trigger mechanism moves forward, the small amount of the pressurized medium in test chamber will be released quickly to an ambient reservoir. If the pressure drop is small enough, the pressure in reservoir is still available and the dynamic pressure at specific pressure measurement points can be generated repeatedly.

Fig.3 shows the calibration results by both of the positive and negative going step pressure generation with the high dynamic pressure system. The results by the negative going step pressure has small output values in high pressure range because a small leak in test chamber can cause high pressure drop due to the small volume, compared to the pressure reservoir. It means the sensor to be calibrated by the negative going step pressure method should be compared with the reference dynamic pressure sensor calibrated by the positive going step pressure method. However, even in the positive going method, the reference dynamic pressure should be estimated carefully as explained in section 3.

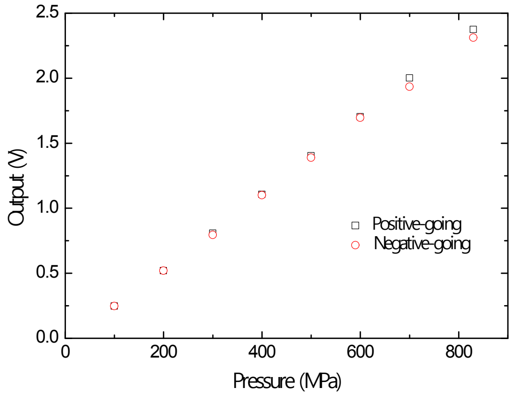


Fig.3 Calibration results by positive and negative going step pressure

3. STANDARDIZATION OF DYNAMIC PRESSURE

If the medium stored in pressure reservoir is transmitted to the test chamber, there will be a pressure drop. If the volume ratio of the pressure reservoir to the test chamber is small, the pressure drop will be decreased. If the initial pressure in reservoir is measured by a calibrated static pressure sensor and the pressure drop is negligible, the value of the pressure sensor before releasing the medium could be used as a dynamic pressure standard with negligible uncertainty. On the other hand, the pressure drop is not negligible compared with the uncertainty of the dynamic pressure system, it should be estimated accurately to improve the uncertainty of the dynamic pressure.

In order to obtain the pressure drop theoretically, the volume ratio can be used as follows.

$$\gamma = \frac{V}{V+\Delta V} = \frac{\rho(P-\Delta P)}{\rho(P)} \cong 1 - \frac{\rho'(P)}{\rho(P)}\Delta P \qquad (1)$$

where V is the volume of the pressure reservoir, ΔV is the volume change, γ is the volume ratio of the transmitting medium before and after releasing medium. P is the pressure measured by the static pressure sensor before releasing medium, respectively. ΔP is the pressure drop after releasing medium.

If the pressure drop(ΔP) is small, the volume ratio can be expressed with density properties as in equation (1). That is, the pressure drop can be given as in equation (2).

$$\Delta P \cong (1-\gamma)\frac{\rho(P)}{\rho'(P)} \qquad (2)$$

The sebacate oil was used in the experiment, which density equations according to pressure are known well. The volume ratio, γ, can be determined by a single pressure drop experiment, but if it is repeated according to pressure, the uncertainty will be improved.

In the analysis, Vergne and Molinar density equation were used. In addition, Dowson equation could be applied to the equation (2) in order to obtain the volume ratio.

The density equation by Vergne is usually used up to 400 MPa, and on the other hand, the density equation by Molinar is used over 500 MPa. Dowson could be used up to tested pressure range. If the ratio is constant according to the pressure in the result, it can be concluded that the equation is more reliable under the assumption of no big pressure reservoir deformation by high pressure. The volume change was small enough since the volume ratio was only 0.013% as shown in Fig.4

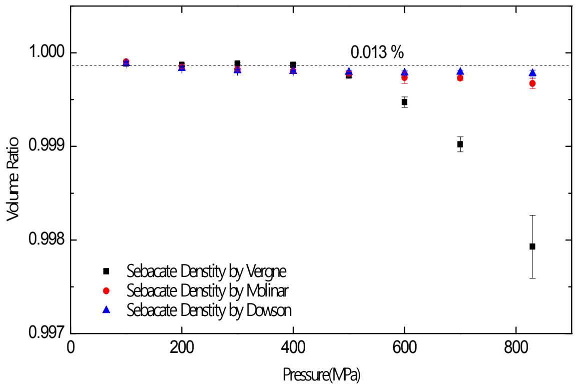


Fig.4 The volume ratio change according to the density equations

Fig.5 shows the comparison results of pressure drop estimation using Dowson density equation with the experimental pressure drop. Even if the pressure drop is not considered in the dynamic pressure generation, only 0.3 % of F.S. could be different from the initial pressure. This small difference results from the small volume ratio between the pressure reservoir and the test chamber. The conventional system using a quick opening ball valve has the pressure drop over 1 % of F.S. If the estimation results are applied, it could be reduced to less than 0.05 % of F.S. All the uncertainty sources should be considered to obtain the total uncertainty of the dynamic pressure system in the future.

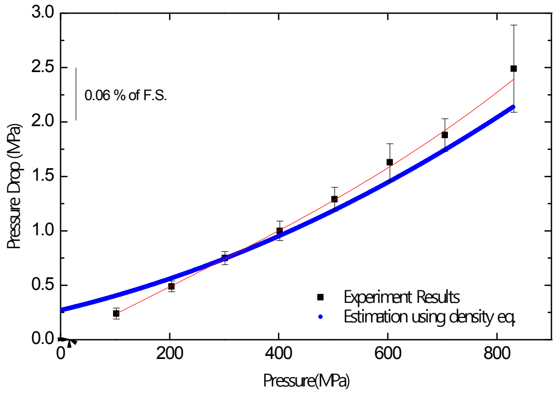


Fig.5 Pressure drop in dynamic pressure system

4. CONCLUSIONS

The dynamic pressure standard system was built using fast acting needle valves. The dynamic pressure sensor was calibrated by a positive-going step pressure and a negative-going step pressure. Both of the methods have a short rise time within 1 ms while not generating big impulse. In addition, the dynamic pressure estimation by static pressure measurement was proposed by the calculation of the pressure drop based on the density change of the transmitting medium. The pressure drop estimation was verified with experimental results.

5. REFERENCES

[1] V.E.Bean, "Dynamic Pressure Metrology," Metrologia, vol. 30, pp. 737-741, 1993/94.

[2] J.P Damion, " Means of Dynamic Calibration for Pressure Transducers", Metrologia, vol.30, pp743-746, 1993/94

[3] Jim Lally and Dan Cummiskey, "Dynamic Pressure Calibration", Technical Note (TN-15), PCB electronics

[4] Alberto C. G. C. Diniz, Alessandro B. S. Oliveira, João Nildo de Souza Vianna , Fernando J.R. Neves, "A Guide for the Dynamic Calibration of Pressure Transducers," in Proc. of XVIII IMEKO World Congress, Rio de Janeiro, Brazil, 2006.

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