

Retraction Notice

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Retraction initiative (multiple responses allowed; mark with **X**):

- All authors
 Some of the authors:
 Editor with hints from Journal owner (publisher)
 Institution:
 Reader:
 Other:

Date initiative is launched: 2017-07-24

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 Lab error Inconsistent data Analytical error Biased interpretation
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- honest error
 academic misconduct
 none (not applicable in this case – e.g. in case of editorial reasons)

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History

Expression of Concern:

yes, date: yyyy-mm-dd

no

Correction:

yes, date: yyyy-mm-dd

no

Comment:

The paper does not meet the standards of "Open Journal of Fluid Dynamics".

This article has been retracted to straighten the academic record. In making this decision the Editorial Board follows [COPE's Retraction Guidelines](#). Aim is to promote the circulation of scientific research by offering an ideal research publication platform with due consideration of internationally accepted standards on publication ethics. The Editorial Board would like to extend its sincere apologies for any inconvenience this retraction may have caused.

Editor guiding this retraction: Prof. Heuy Dong Kim (EiC, OJFD)

Simple Prediction Formula of Delay Time of Measurement Pressure

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Abstract

An experimental and analytical study on estimating delay time and time variation of measurement pressure was conducted to design favorable difference pressure measurement system. This paper reports the construction of prediction formula to achieve a simple and quick approach to estimating the delay time and time variation in pressure, including the effects of the internal diameter and the length of pressure guide tube, based on Hagen-Poiseuille flow, adiabatic change and experimental results.

Keywords

Delay Time, Pressure Response, Pressure Measurement System, Wind Tunnel Test

1. Introduction

Pressure measurement is generally used for investigating details of flow fields quantitatively in fluids measurement experiments. It is necessary for the pressure measurement to make a preparation of making a hole in an object surface, tubing pressure guide tubes, the other pressure tube connecting to a location to measure the reference static pressure of main flow or an atmospheric pressure as a reference, and connecting them to the pressure sensors.

From past studies, points of attention to evaluate difference pressure were reported that evaluable frequency was limited by Helmholtz resonance or the phase change of the pressure due to pressure-measurement-hole dimensions, the length and the volume of the pressure guide tube [1] [2]. Therefore, for unsteady pressure evaluation, it is needed to design favorable pressure measurement system depending on evaluation frequency of the pressure, and put the pressure sensor into the object as close to the object surface as possible, if possible, the measurement surface of the pressure sensor is

preferable to put on the object surface in parallel and in no small step. On the other hand, for steady state pressure measurement in averaged evaluation, it is necessary to wait a time to reach a constant measurement pressure [3] because the pressure guide tube from measurement holes to pressure sensor is long in terms of experiment efficiency.

The difference pressure measurement is usually conducted in wind tunnel. The wind tunnel originally has characteristics of static pressure fluctuation, called pulsation, due to resonance of tunnel mode in wind tunnel duct and resonance of edge-tone mode in open test section, which is very low frequency up to about 3 Hz, by all means, depending on wind tunnel configuration, dimension and so on [4]-[7]. In recent years, in motor vehicle industry, wind tunnels which can generate gustiness of incoming flow in low frequency turbulence were constructed to investigate the aerodynamic effect of the vehicle body in simulated natural environment [8] [9]. That is, it is increasing the necessity to measure the difference pressure around the object in the pressure fields with low frequency fluctuation. When the difference pressure measurement is conducted by such wind tunnel with low frequency fluctuation, it is concerned about the possibility of causing an error of difference pressure due to the difference of delay time between pressure sensor side and reference pressure side, which results from the difference of the tube length and the internal diameter.

Therefore, the purposes of this study were to achieve a simple and quick approach to estimating the delay time and time variation of measurement pressure, due to the length and internal diameter of pressure guide tube, for favorable design of pressure measurement system. Past studies reported an estimated equation which could calculate the delay time and the time variation [1] [10], but was different from author's experiment result, so this study started from basic equation introduction. In this paper, we report the comparison of delay time between estimation and experimental results for the validity of the prediction equation.

2. Experimental Apparatus and Procedures

2.1. Measurement of Delay Time

Figure 1 shows schematic view of pressure measurement system. The difference pressure instrument is DSA3200, made by Scanivalve Corp., which is the precision of $\pm 0.05\%$ F.S. The full scale is 2.5 kPa. The sampling rate is used 20 Hz. The digital pressure controller is PPC4, made by Fluke Calibration which the precision of the pressure

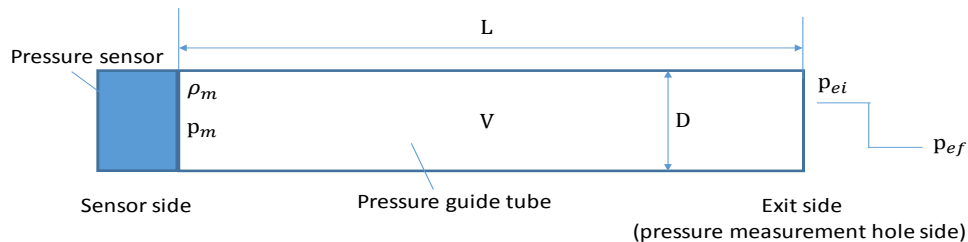


Figure 1. Schematic view of pressure measurement system.

control is +/- 0.002% reading. The delay time and time variation in pressure was measured in accordance with following procedure; The targeted pressure was applied to the pressure guide tube from pressure controller, the time series pressure data was started to measure, the pressure of measurement-hole side was suddenly released (initial pressure p_{ei} and released pressure p_{ef} at exit side) and continue to measure until the difference pressure to zero.

2.2. Test Cases

Table 1 shows test cases and test conditions. It can be evaluated the effect of the magnitude of applied pressure, the length and the internal diameter. In our wind tunnel testing, three types of tube shown in Table 1 are used conventionally. Therefore the tubes are chosen for this study, in spite of difference of the material.

3. Approach to Constructing a Prediction Formula of Delay Time of Measurement Pressure

Figure 1 shows schematic view of supposed pressure measurement system. How to determine the prediction formula calculating the time variation in pressure is considered when the pressure of measurement-hole side was suddenly released (initial pressure p_{ei} and released pressure p_{ef} at exit side). The mass change $Vd\rho$ due to the density change in the pressure guide tube is equaled to mass flow rate \dot{m}_e in a time at tube exit, then the relationship is indicated by Equation (1).

$$-Vd\rho = \dot{m}_e dt \tag{1}$$

Here, V is volume of pressure guide tube, ρ is fluid density in pressure guide tube, \dot{m}_e is mass flow rate at exit of pressure guide tube. t is time. It is presumed that the flow in pressure guide tube is laminar flow, therefore the mass flow rate \dot{m}_e can be expressed by Equation (2) based on Hagen-Poiseuille equation.

$$\dot{m}_e = \rho_{ef} \pi D^4 (P_m - P_{ef}) / (128 \mu L) \tag{2}$$

Here, ρ_{ef} is fluid density at exit of pressure guide tube after pressure suddenly released. D is internal diameter of pressure guide tube. P_m is pressure of sensor side. P_{ef} is pressure at exit of pressure guide tube after the pressure suddenly released. μ is viscosity of fluid, L is length of pressure guide tube. Assuming isentropic change in pressure guide tube, Equations (3) and (4) expresses the relationship between pressure and density at sensor side and exit side.

Table 1. Test cases and test conditions.

Case	Pressure	Tube		
		Length	Diameter	Material
1	1,500 Pa, 1,000 Pa, 500 Pa, 300 Pa, 100 Pa	15 m	0.001 m	Rubber
2	Same as above	15 m	0.003 m	Nylon
3	Same as above	9 m	0.002 m	Polyurethane

$$p_m / \rho_m^\kappa = p_{ef} / \rho_{ef}^\kappa, p_m = (p_{ef} / \rho_{ef}^\kappa) \rho_m^\kappa \quad (3)$$

$$dp_m = \kappa (p_{ef} / \rho_{ef}^\kappa) d\rho_m \quad (4)$$

Here, the density ρ in Equation (1) assumed uniform density distribution in pressure guide tube. Therefore, the density ρ_m of the sensor side differs from the density ρ in Equation (1). Considering the pressure gradient being a constant through the tube from the sensor side to exit side and assuming the isentropic change, using the density of sensor side ρ_m and the density of the exit side ρ_{ef} , the density ρ in Equation (1) and the differential form can be expressed by Equation (5) in the averaged expression and Equation (6), respectively.

$$\rho = (\rho_m + \rho_{ef}) / 2 \quad (5)$$

$$d\rho = 1/2 d\rho_m \quad (6)$$

Separable equation expressed by Equation (7) can be derived from Equations (1), (2), (4) and (6). Resolving Equation (7) provides Equation (8) which expresses the time variation of the measurement pressure.

$$dp_m / (p_m - p_{ef}) = -2\kappa \cdot p_{ef} \rho_{ef}^{1-\kappa} \pi D^4 / 128 \mu L V dt \quad (7)$$

$$p_m - p_{ef} / (p_{ei} - p_{ef}) = \exp(-At), p_m = (p_{ei} - p_{ef}) \cdot \exp(-At) + p_{ef} \quad (8)$$

$$\text{Here, } A = 2\kappa \cdot p_{ef} \rho_{ef}^{1-\kappa} \pi D^4 / 128 \mu L V$$

4. Results and Discussion

4.1. Effect of Applied Pressure Magnitude

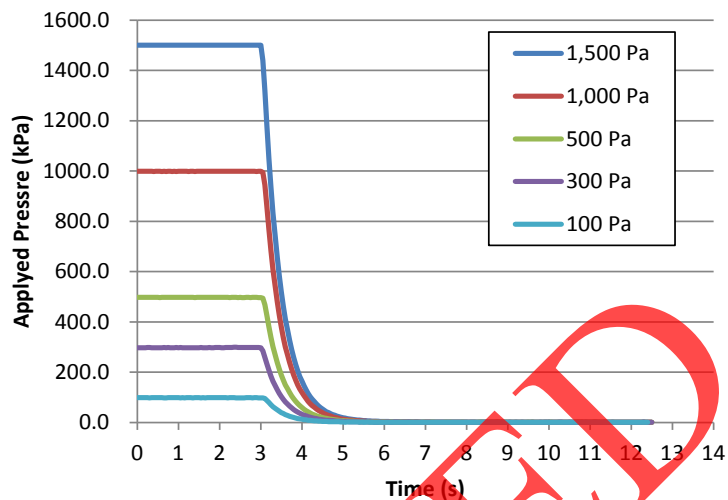
Figure 2 shows experimental results examining the effect of applied pressure magnitude in the case 1 of the tube length 15 m and internal diameter 0.001 m. From these results, the percentage of the pressure change is not depending on the applied pressure magnitude. These results can be evaluated by Equation (8) because the expression in Equation (8) for the ratio of the pressure change is not depending on the pressure magnitude.

4.2. Comparison of Time Variation in Pressure between Prediction and Experimental Result

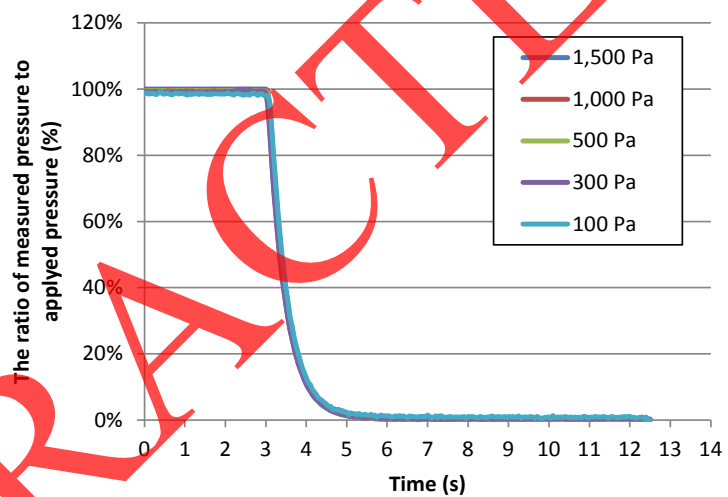
Figure 3 shows comparison of time variation in pressure between prediction and experimental results. The results show the case of applied pressure magnitude 1,000 Pa only because the magnitude of applied pressure is not depending on the ratio of the pressure. In all cases, the empirical results have been confirmed to essentially match the prediction results.

4.3. Effect of Length and Internal Diameter of the Tubes

Figure 4(a) and Figure 4(b) show calculated results of time variation in pressure by

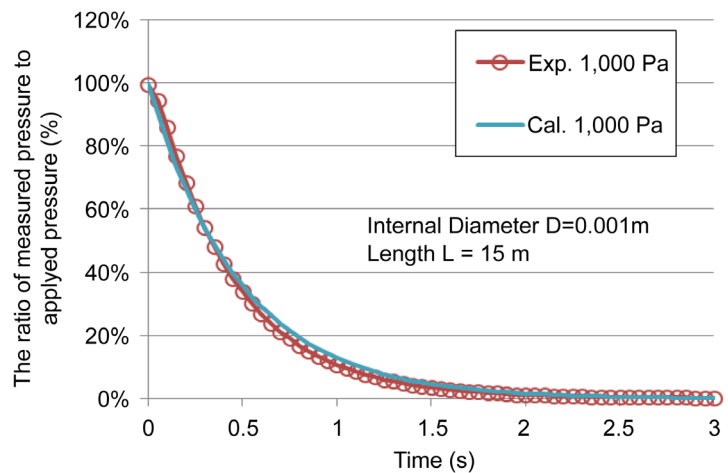


(a)



(b)

Figure 2. Experimental results of time variation in pressure in the case of the tube length 15 m and internal diameter 0.001 m. (a) Vertical axis: Pressure; (b) Vertical axis: Percentage.



(a)

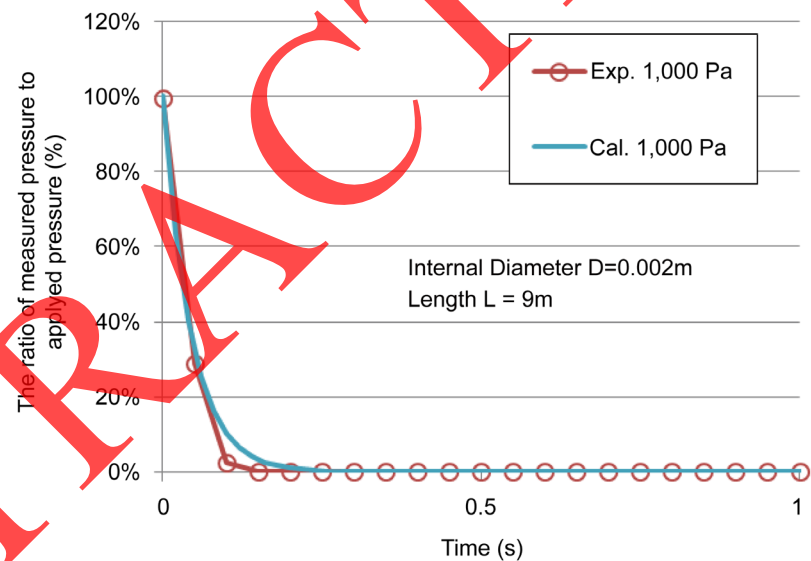
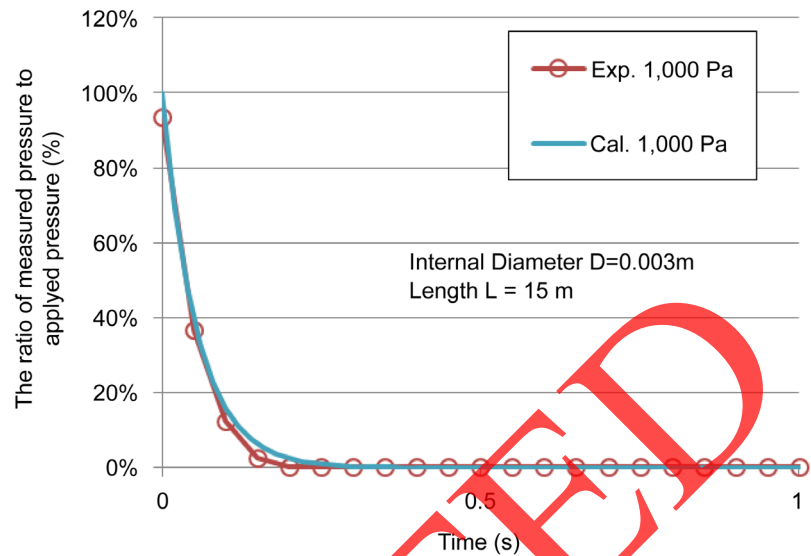


Figure 3. Comparison of time variation in pressure between prediction and experimental result. (a) Internal diameter 0.001 m, length 15 m; (b) Internal diameter 0.003 m, length 15 m; (c) Internal diameter 0.002 m, length 9 m.

Equation (8) to discuss the effects of the length and internal diameter of tubes. **Figure 4(a)** shows the calculated results when the internal diameter varies from 0.001 m to 0.004 m and the tube length is a constant, 30 m. While, **Figure 4(b)** shows the calculated results when the tube length varies from 10 m to 40 m and the internal diameter is a constant, 0.002 m.

From **Figure 4(a)**, larger internal diameter of the tube decreased the delay time of the measurement pressure. The larger internal diameter results in increase the flow volume at the tube exit, although the volume of the tube is increased, because the flow

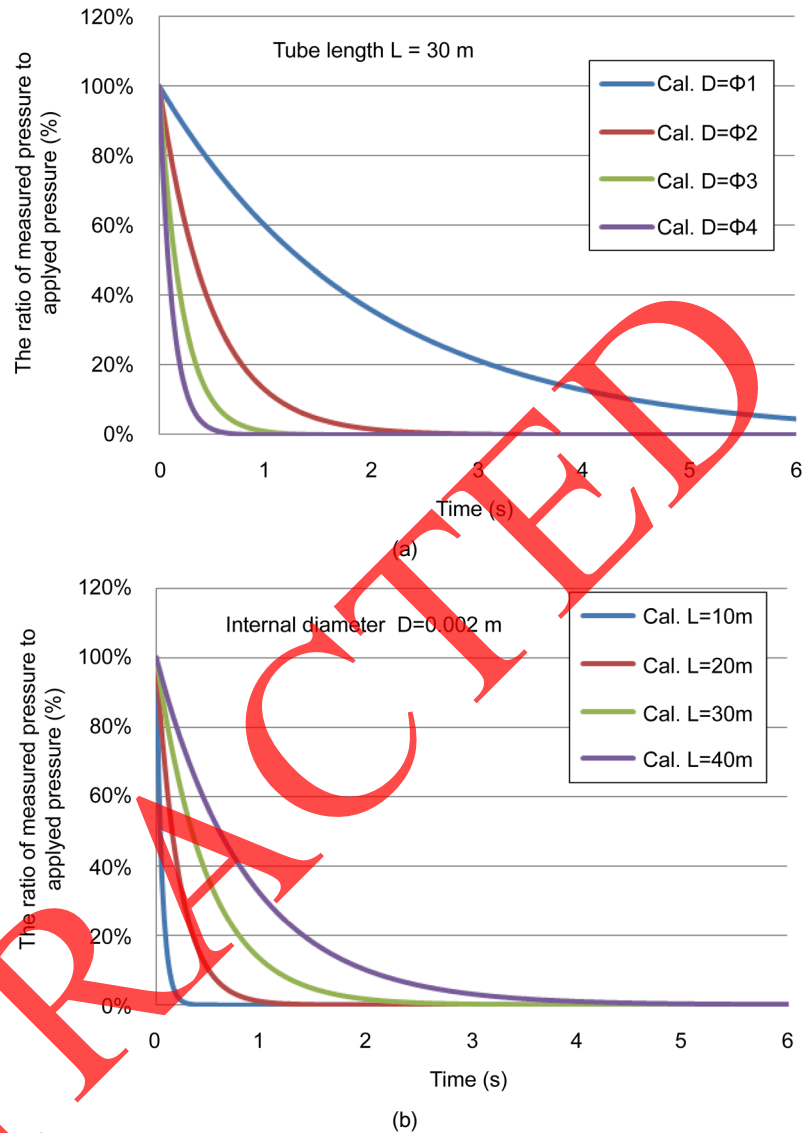


Figure 4. Calculated results of time variation in pressure by Equation (8). (a) Effect of internal diameter; (b) Effect of tube length.

volume is increased in proportion to the fourth power of the internal diameter while the volume of the tube increases with the square of the internal diameter, based on Equation (2) and Equation (8).

From **Figure 4(b)**, shorter length of the tube decreased the delay time of the measurement pressure, because the shorter length of the tube makes it possible to decrease the volume of pressure guide tube and the friction drag in tube flow.

5. Conclusion

An experimental and analytical study on estimating delay time and the time variation of measurement pressure was conducted to design favorable difference pressure measurement system. The construction of prediction formula to achieve a simple and quick

approach to estimating the delay time and time variation in pressure includes the effect of the length and the internal diameter of pressure guide tube, based on assumption of Hagen-Poiseuille flow, isentropic change and experimental results. From the comparison of time variation in pressure between the prediction and experimental results, the empirical results have been confirmed to essentially match the prediction results.

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