AN ANALYSIS ON HIGH PRESSURE DYNAMIC CALIBRATORS USED IN THE DEFENSE AREAS

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Abstract

Up to now, there is no the international certified standard calibrator of dynamic pressure because the definition of dynamic pressure is not determined. Even though a few dynamic calibrators were designed, manufactured and used in a variety of industrial areas, they are not traceable to the international standards in practical.

At present, the determination of response characteristics to pressure transducers is routinely limited to static calibration, while using a deadweight pressure standard. The deadweight device is a primary static pressure standard used to generate precise pressure under the assumption that the static and dynamic responses of the transducer in static calibration are equivalent. However, the differences in transducer response between static and dynamic events can lead to serious measurement errors. Dynamic techniques are required to calibrate pressure transducers to meet dynamic events in milliseconds

In this paper, the calibration techniques are surveyed and classified in the area of dynamic pressure and finally analyzed in terms of the waveform, range, transition time and method of dynamic pressure so that its analysis result can be informative and helpful for those who are interested in dynamic pressure for better measurement.

Keywords : dynamic pressure transducer, dynamic calibrator, calibration technique

1. INTRODUCTION

Measurements of pressure inside large caliber weapons are critical for establishing the balance between crew safety and combat effectiveness. A 2 % error in chamber pressure measurement can result in 3 % change in weight, a 4 % change in effective range, and a 6 % change in fatigue life [1]. That is the main reason why the definition of dynamic pressure and the development of dynamic pressure calibrator should be necessary and important, so that it can be used all over the world as an international standard calibrator of dynamic pressure.

In the past, piezoelectric transducers had limited frequency response, and were mainly used for an acoustic and engine combustion applications.

Cornell Aeronautical Labs developed miniature, high-frequency acceleration-compensated quartz pressure transducers with microsecond response time. Other research facilities developed special transducers tailored to specific applications. Aberdeen Proving Ground designed blast pressure transducers for weapons development and a unique, tourmaline-structured, non-resonant pressure bar for reflected shock wave measurements.

Dynamic high pressure measurement is widely applied in industrial and military field. The central issue of high pressure testing technology research is to obtain the dynamic characteristics of transducer under its working pressure to ensure an accurate and reliable test data.

The dynamic technical indicators and the pressure transducer can be determined only by dynamic calibration. The common methods of pressure transducer dynamic calibration are shock tube calibration method, step function pulse pressure calibration method, drop hammer method and relative method. The dynamic calibration of the high-pressure transducer can only be carried through in low pressure. Step pulse pressure calibration method uses the vertical flying-flake strike the liquid surface to produce the narrow pressure-pulse, which of a microsecond pulse width and the pressure up to 700 MPa. Drop hammer method is mainly used for amplitude and waveform consistency of standards [2].

In order to resolve the disadvantage and shortage of existing step pulse pressure calibration method, an improving step calibration method is put forward.

The determination of response characteristics to pressure transducers is routinely limited to static calibration, while using a deadweight pressure standard. The deadweight device is a primary standard used to generate precise pressure under the assumption that the static and dynamic responses of the transducer in static calibration are equivalent. However, differences in transducer response to static and dynamic events can lead to serious measurement errors. Dynamic techniques are required to calibrate pressure transducers to meet dynamic events in milliseconds.

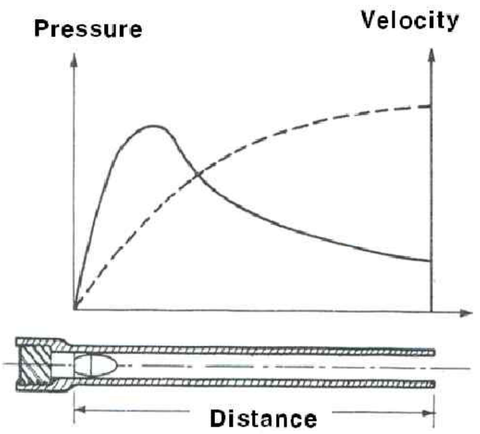

Fig. 1: Pressure and velocity curves in the chamber of gun

2. Calibration Techniques of Dynamic Pressure

Dynamic pressure calibrators have evolved over the years in response to specific need at various laboratories. Calibrators vary widely in the type of pressure source used, and in their amplitude and frequency range. Dynamic pressure transducer makers adapted the best of these technologies for in-house transducer research and dynamic calibration. To help customers understand and evaluate the characteristics of transducers for transient applications, several dynamic pressure calibrators are now offered as standard commercial products.

Dynamic pressure calibrators are of two general types, periodic and aperiodic [3].

The full line of piezoelectric pressure transducers are used for a variety of dynamic pressure measurements. Some examples include: compression, pulsations, surges, hydraulic and pneumatic pressure fluctuations, high-intensity sound, fluid borne noise detection, shock and blast waves, ballistics, explosive component testing, closed bomb combustion studies, and other dynamic.

A. Step Pressure Calibrator

Normally, step pressure waveform tends to be used for dynamic pressure calibration, because it can include all kinds of frequency components and has a little easier repeatability. The step pressure calibrators designed and manufactured by transducer makers or army proving grounds are classified into a few categories based on the difference of quick opening apparatus and pressure reference. Quick opening apparatus is used to be very important core component to convert static pressure into dynamic pressure in the dynamic pressure calibrators.

- **hydraulic step pressure calibrator (PCB 905C) [4]**

PCB 905C calibrator indicated in Fig. 4 is designed to calibrate piezoelectric pressure transducers with built-in electronics and charge type transducers.

A high-pressure pump exposes the unit under test to graduated pressure steps with dump valve for rapid, pressure release. Strain gage pressure transducer is used as a reference. This pressure calibrator covers up to 700 MPa .

The hydraulic step pressure calibrator shown in Fig. 3 are composed of pressure reservoir, pump intensifier, reference standard gage, mounting transducer adaptor and dump valve which transforms static pressure into dynamic pressure. In addition, all necessary cables, seals and other accessories are supplied.

To prolong the life of the reference pressure transducer, a stop valve is provided at the side of the pump enclosure to shut off the transducer from the hydraulic pressure circuit when only pressure-cycling test transducers. The reference pressure system consists of a calibrated, 700 MPa strain gage reference pressure transducer, a digital panel meter, and cabling. A momentary push button is provided on the rear of the calibrator for internal calibration of the reference pressure transducer and meter.

Be sure to check the reservoir to be certain that it is filled. A gallon of hydraulic fluid is supplied with the pump. Only the supplied fluid should be used to replenish the reservoir.

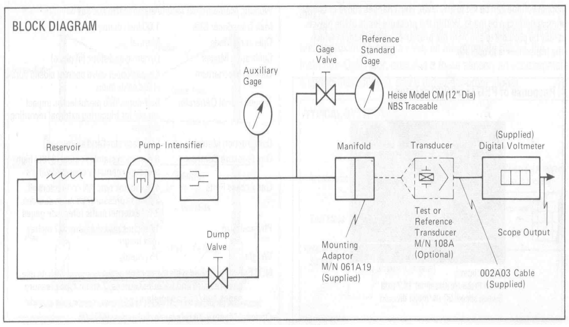

Fig. 3: Block diagram of hydraulic step pressure calibrator (PCB 905C)

Fig. 4: Hydraulic step pressure calibrator (PCB 905C)

- **Negative step pressure calibrator (Yuma Test Center: YPG) [5]**

Yuma negative step pressure calibrator shown in Fig. 5 and 6 is designed to calibrate piezoelectric pressure transducers to improve the shortcoming of existent step pressure calibrators. The step pressure calibrator consists of pressure reservoir, pump intensifier, deadweight piston gage, mounting transducer adaptor and needle quick opening apparatus, which transforms static pressure into dynamic pressure. In addition, all necessary cables, seals and other accessories are supplied

Firstly, deadweight piston gage can take the place of strain gage pressure transducer used as a reference so that this calibrator can provide better accurate uncertainty and reliability. In the area of static pressure, deadweight piston gage is now used as a standard calibrator in order to maintain and supply the standard of static pressure to industries and research institutes.

Secondly, the needle quick opening apparatus is utilized instead of release valve operated by manual, so that rising time can be a little faster than that of the old calibrator. Falling time is about less than 2.5 ms. Rising time seems to be variable depending on the pressure applied to the pressure transducers.

Thirdly, Yuma negative pressure calibrator is fully operated and manipulated by program to improve calibration efficiency and reduce human errors.

Finally, the calibrator is designed to range up to 700 MPa. But in practical, it is a bit unstable around the maximum pressure. The negative step pressure waveform shown in Fig. 7 generated by step pressure calibrator indicates falling transition that eliminate shock damage to transducers to be calibrated while applying calibration pressure using quick opening valve.

Fig. 5: Negative step pressure calibrator (Yuma Test Center) with deadweight piston gage

Fig. 6: Needle quick opening apparatus (Yuma Test

Center)

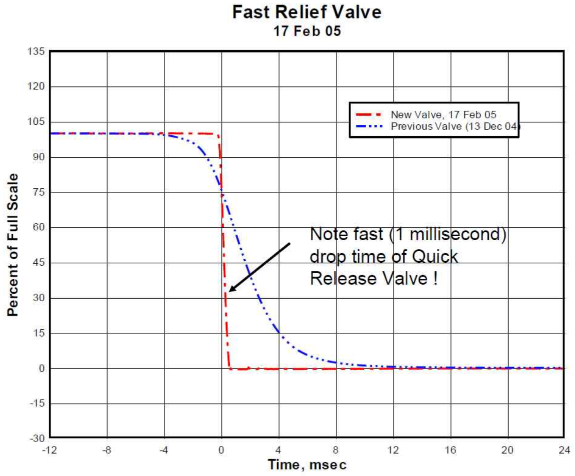

Fig. 7: Negative step waveform of pressure transducer when activating quick opening apparatus

- **Positive step pressure calibrator (Yuma Test Center) [5]**

On the site in test proving grounds, the rising time of the positive waveform of dynamic pressure is a meaningful and important factor in measuring the chamber pressure of weapon systems. If possible, dynamic pressure calibration should conform to the same pattern of waveform of gun chamber.

Yuma positive step pressure calibrator shown in Fig. 8 is designed to modify negative step pressure calibrator to supply positive step waveform and expand calibration range indicated in Fig. 9. The step pressure calibrator consists of pressure reservoir, pump intensifier, strain gage pressure transducer traceable to national standards, mounting transducer adaptor and needle quick opening apparatus, which converts static pressure into dynamic pressure. In addition, all necessary cables, seals and other accessories are supplied.

The new needle quick opening apparatus can provide a little fast rising time and expend the pressure range of calibration as well. Rising time is about less than 2.2 ms. Rising time seems to be variable depending on the pressure applied to the pressure transducers.

Positive step pressure calibrator is fully operated and manipulated by program to improve calibration efficiency and reduce human errors. The calibrator is designed to range up to 800 MPa. But in practical, it is a bit unstable around the maximum pressure. The step pressure waveform generated by step pressure calibrator shown in Fig. 9 indicates rising transition that reduce dead volume in the chamber of transducer adaptor while applying calibration pressure using quick opening valve.

Fig. 8: Positive step pressure calibrator (Yuma Test Center) with strain gage pressure transducer

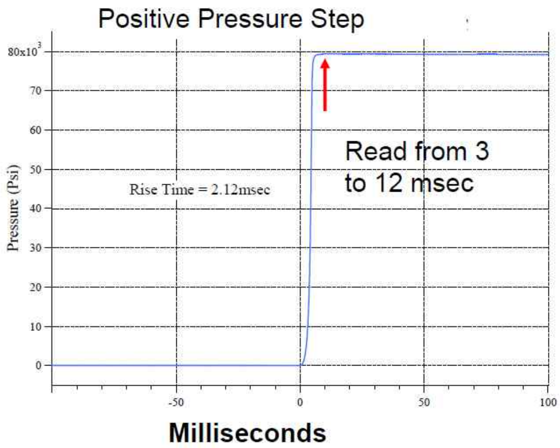

Fig. 9: Positive step waveform of pressure transducer when activating quick opening apparatus

B. Parabola Pressure Calibrator

The pressure waveform of gun chamber is kind of similar to parabola pattern shown in Fig. 1 in the test of weapon systems.

Normally, parabola pressure waveform tends to be used for dynamic pressure calibration, because it can closely produce pressure patterns similar to that of gun chamber. There remains lot of error components in the calibration system because the system should require three phases of energy transitions such as position energy, kinetic energy and compression energy at the same time, while mass hits the measuring head of transducers.

- **Parabola pressure calibrator (AVL B620) [6]**

AVL calibrator indicated in Fig. 10 was designed to calibrate piezoelectric pressure transducers using the absolute calibration without built-in reference pressure transducers on the basis of experimental theory in the beginning stage of development. Due to various errors of aging, abrasion and damage, the system could no longer be used in the absolute calibration. In the end, it should require another pressure transducer with excellent stability and linearity as a reference.

The parabola pressure calibrator are composed of pressure reservoir, impact mass, measuring head, guide rod, supporting arm, safety catch and system controller. Measuring head is a core component including measuring bores, piston, piston guidance, pressure chamber, filling coupling, bleeding coupling and gage for the projecting length of piston.

The new needle quick opening apparatus can provide a little fast rising time and expend the pressure range of calibration as well. Rising time is about less than 2.5 ms. Parabola pressure calibrator is fully operated and manipulated by program to improve calibration efficiency and reduce human errors. The calibrator is designed to range up to 116,000 MPa.

Fig. 10: Parabola pressure calibrator (AVL) with piezoelectric reference transducer

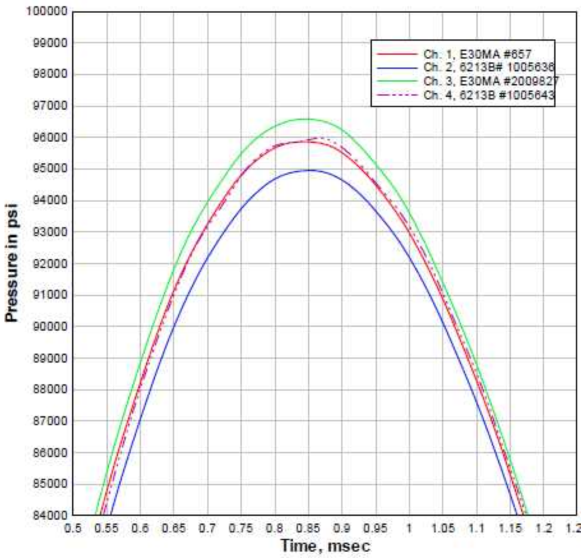

Fig. 11: Parabola waveform of pressure transducer when mass hits measuring head of transducer

3. Analysis of Dynamic Pressure calibrators

According to the introduction of various kinds of dynamic pressure calibrators described in the previous chapter, users who have a strong interest in dynamic pressure calibrator need to know the general information of dynamic pressure calibrators available in the world by analyzing calibrators based on the criteria of analysis.

The items of the analysis of dynamic pressure calibrators are established as product name, maker/model, calibration range, pressure conversion type and merit/defect for the comparison analysis of available dynamic pressure calibrators shown in Table 1.

Table 1: Comparison analysis of dynamic pressure calibrators available in the world

Product Name	Make-r/ Mod-el	Calibratio-n Range (MPa)	Conversi-on Type/ Time	Remark (Merit/Defect)
Positiv-e Step Pressur-e Calibra-tor	PCB / 905C	Less than 700	Positive step / Rising time: a few ms	. Source: hydraulic energy . Reference: strain gage pressure transducer . Valve response: a little slow . Waveform: a bit close from the gun chamber pressure pattern . Operation: manual . Uncertainty: good
Negativ-e Step Pressur-e Calibra-tor	YPG	Less than 700	Negative step / Falling time: < 2.5 ms	. Source: hydraulic energy . Reference: deadweight piston gage . Valve response: fast . Waveform: a bit far from the gun chamber pressure pattern . Operation: automatic . Uncertainty: excellent
Positiv-e Step Pressur-e Calibra-tor	YPG	800	Positive step / Rising time: < 2.2 ms	. Source: hydraulic energy . Reference: strain gage pressure transducer . Valve response: fast . Waveform: a bit close from the gun chamber pressure pattern . Operation: automatic . Uncertainty: excellent
Parabol-a Pressur-e Calibra-tor	AVL / B620	800	Parabola / Rising time / < 1.5 ms	. Source: position energy →kinetic energy → compression equation . Reference: experimental equation . Valve response: a little fast . Waveform: a bit similar to the gun chamber pressure pattern . Operation: automatic . Uncertainty: bad (Due to many error components)

4. Conclusions

Normally, step pressure waveform tends to be used for dynamic pressure calibration, because it can include all kinds of frequency components and has a little easier repeatability. The step pressure calibrators designed and manufactured by transducer makers or army proving grounds are classified into a few categories based on the difference of quick opening apparatus and pressure reference. Quick opening apparatus is used to be very important core component to convert static pressure into dynamic pressure in the dynamic pressure calibrators.

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5. References

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