SOME ASPECTS REGARDING THE USE OF PIEZOELECTRIC TRANSDUCERS FOR MEASUREMENT OF PROPELLANT GAS PRESSURE DURING WEAPON'S FIRING

Sorin GHEORGHIAN*, Nicolae JULA*, Marian PEARSICĂ, Ciprian RĂCUCIU***

*Military Technical Academy
**"Henri Coandă" Air Force Academy, Braşov

Abstract: *The measurement of propellant gas pressure during weapon's firing is vitally important for the correct functioning of the weapon and for the safety of the crew. The paper presents three different schemes for accurate measurement of propellant gas pressure, using a piezoelectric measuring system, according to the weapon's caliber and experiment's goal. For each scheme, the position of the piezoelectric high pressure transducer and typical pressure vs. time curves are presented.*

Keywords: *piezoelectric transducers, weapon, piezoelectric measuring system.*

1. INTRODUCTION

Nowadays, the piezoelectric measuring system is the most used system for pressure measurements in weapon interior ballistic tests.

Piezoelectric high pressure transducer transform the propellant gas pressure inside the weapon's barrel into a charge signal, which is convert into a voltage signal by means of a charge amplifier (Fig. 1). Further on, the electrical tension is measured, stored and displayed.

Electric measuring circuit for piezoelectric transducers poses several difficulties starting with the electric connecting cable.

Special measures must be taken in order to prevent the tribo-electric effect, which consist in electric charges generation due to the frictions between metal and isolator. The isolation resistance and the parasite capacitance of this cable appear to be in parallel with the piezoelectric transducer. The equivalent scheme of the piezoelectric transducer connected to the measuring circuit is depicted in Figure 2. Rc and Cc are the resistance and capacitance of the electrical cable, R and C are the input resistance and capacitance of the amplifier, and Rp and C0 are the piezoelectric transducer resistance and capacitance.

The output electrical tension of the amplifier is

$$\underline{U} = \frac{Q}{Ce} \cdot \frac{j\omega CeRe}{1 + j\omega CeRe} \qquad (1)$$

where: $Re \approx R$ and $Ce \approx C0 + Cc + C$.

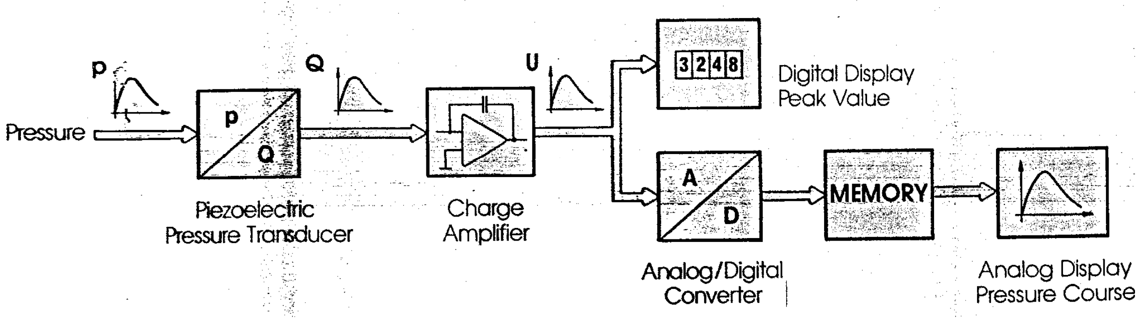

Fig. 1 Schematic of a piezoelectric measuring chain for pressure measurements [1]

From (1) results that the scheme has some restrictions for low frequencies measurements and it must be adjusted for each cable [1].

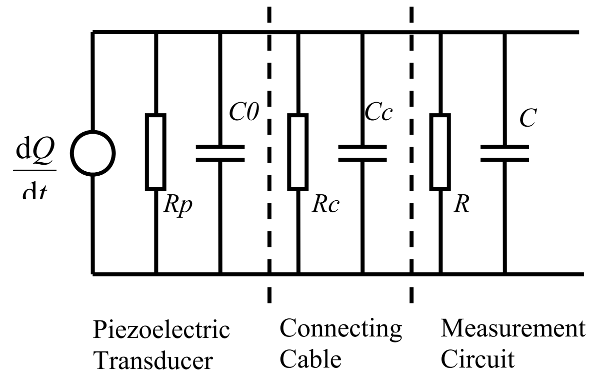

Fig. 2 The equivalent scheme of the piezoelectric transducer connected to the measuring circuit [2]

The base component of the piezoelectric measuring chain is the high pressure transducer. The aspect and the overall dimensions of two typical transducers are presented in Figure 3.

The main technical characteristic of the piezoelectric high pressure transducer is the sensitivity. It states the correlation between de input quantity (pressure P) and the output quantity (electrical charge Q):

$$S_Q = \frac{Q}{P} \text{ [pC/bar]} \qquad (2)$$

The sensitivity of the pressure transducer should be periodically checked. The mean value of the sensitivity of the KISTLER type 6215 transducer is 1,4 pC/bar while the AVL type 4 QP 6000 transducer has 2 pC/bar.

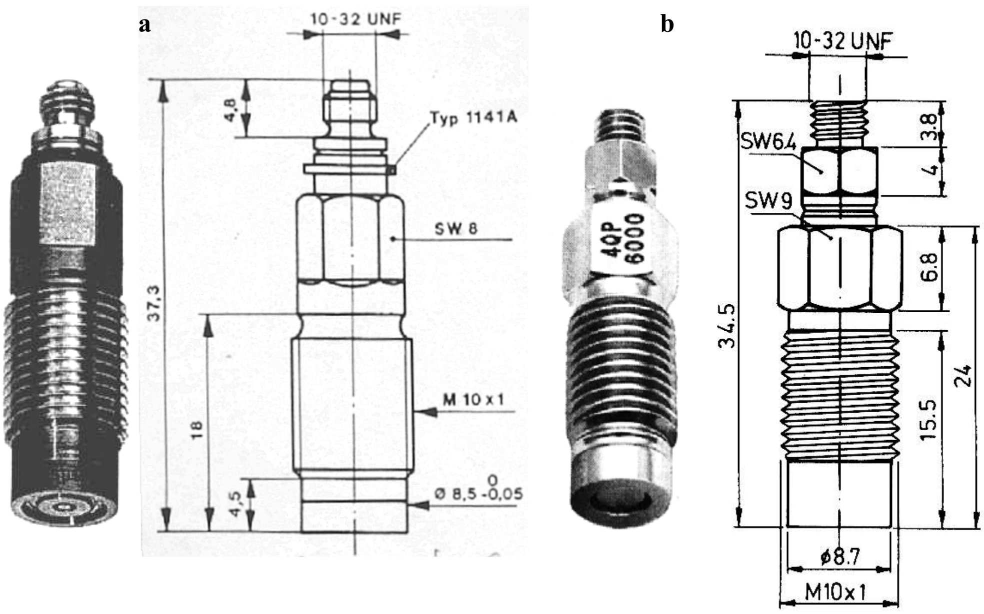

Fig. 3 The aspect and the overall dimensions of two typical transducers [1], [3]
a - KISTLER type 6215; b - AVL type 4 QP 6000

2. PRESSURE MEASUREMENT INSIDE THE CARTRIDGE CASE

This scheme is used for pressure measurements within the small and medium caliber weapons. The piezoelectric pressure transducer is screwed into the weapon's barrel, perpendicular to its axis, in the chamber zone (Fig. 4).

The measured pressure corresponds to the period between percussion of the primer device and projectile's exit through the barrel's mouth. From the pressure vs. time curve, the following quantities can be determined: maximum pressure, delay of the igniter device, rise time of the pressure up to 10 % of the maximum pressure and action time [4]. Before the measurement of the pressure it is necessary to make a hole through the cartridge case and a small cut into the base of the cartridge case in order to fix the cartridge case in the proper position inside the barrel.

These operations must be done with the help of a special protective device, because the cartridge case is fully loaded with propellant. In order to prevent the loss of propellant through the hole, this must be covered with a small piece of adhesive strip. Figure 5 shows a typical measured pressure vs. time curve with the experimental setup from Figure 4.

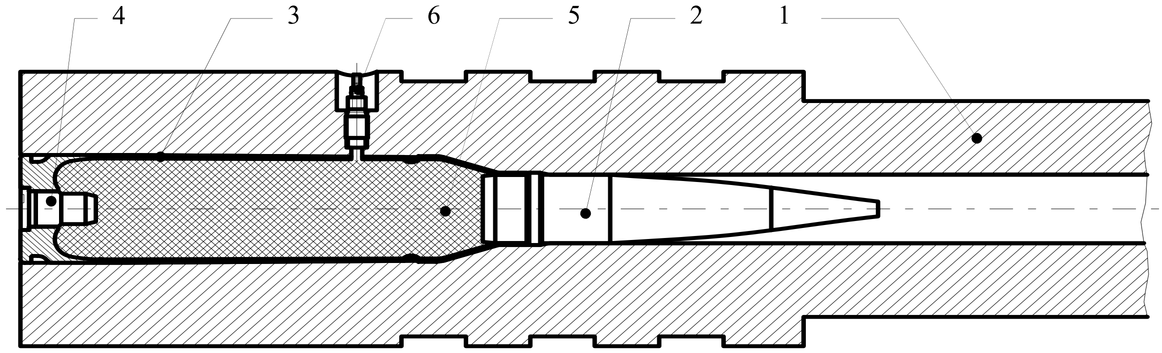

Fig. 4 Experimental setup for pressure measurement inside the 35 mm cartridge case
1 - barrel; 2 - projectile; 3 - cartridge case; 4 - primer; 5 - propellant; 6 - transducer

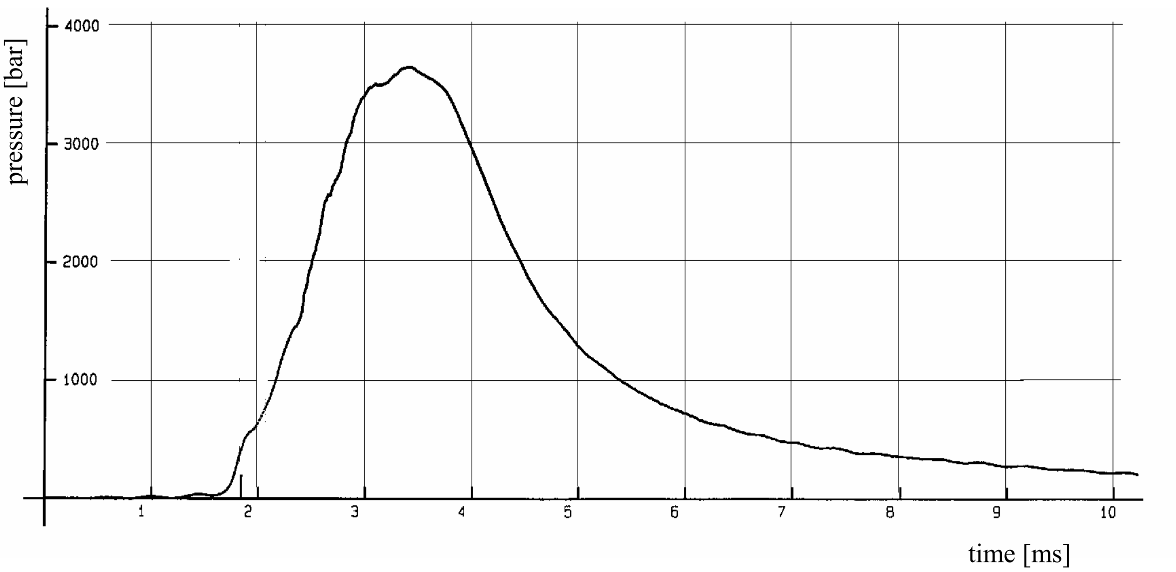

Fig. 5 Pressure vs. time curve measured inside the 35 mm cartridge case

If the pressure transducer is arranged near the cartridge case's mouth, the measurement of the pressure begins from the moment when the pressure overtakes the shot-start pressure, the first portion of the pressure-time curve being loosed. However, the measurement of the pressure at the cartridge case's mouth is often used because it allows the measurement of the maximum pressure without the drilling of the cartridge case.

3. DIFFERENTIAL PRESSURE MEASUREMENT INSIDE THE CARTRIDGE CASE

The differential pressure measurement is required for the safety assessment of a medium and big caliber weapons to the ignition induced pressure waves.

In order to do this type of measurement, two piezoelectric transducers are needed as shown in Figure 6.

The first transducer is screwed into the barrel, near the mouth of the cartridge case, and second is mounted at the base of the cartridge case, into a special socket.

Figure 7 shows the pressure vs. time curves measured by the pressure transducers as well as the resulted differential pressure vs. time curve.

In practice, it is necessary for safety reasons that the maximum differential pressure not to overtake a certain value, specific for each weapon [5].

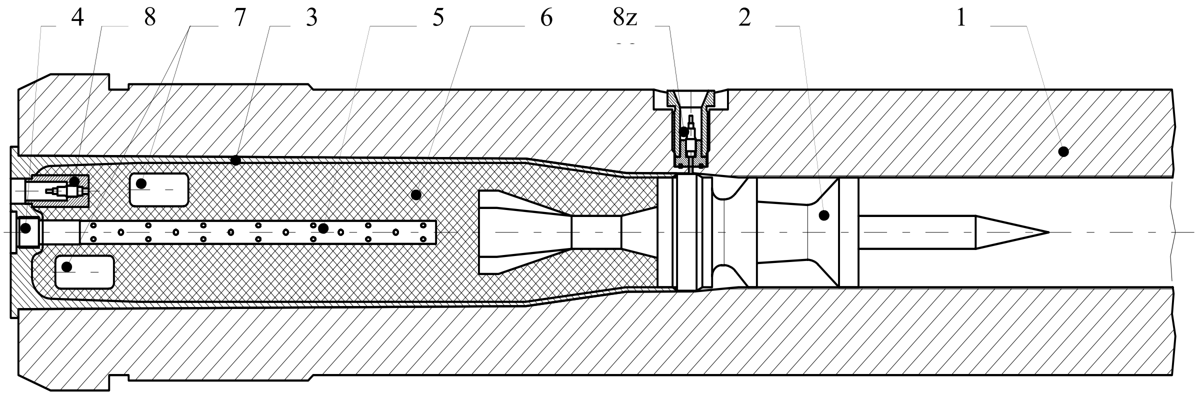

Fig. 6 Experimental setup for pressure measurement inside the 100 mm cartridge case
1 - barrel; 2 - projectile; 3 - cartridge case; 4 - primer; 5 - igniter tube;
6-propellant;7-crusher gauge; 8-pressure transducer

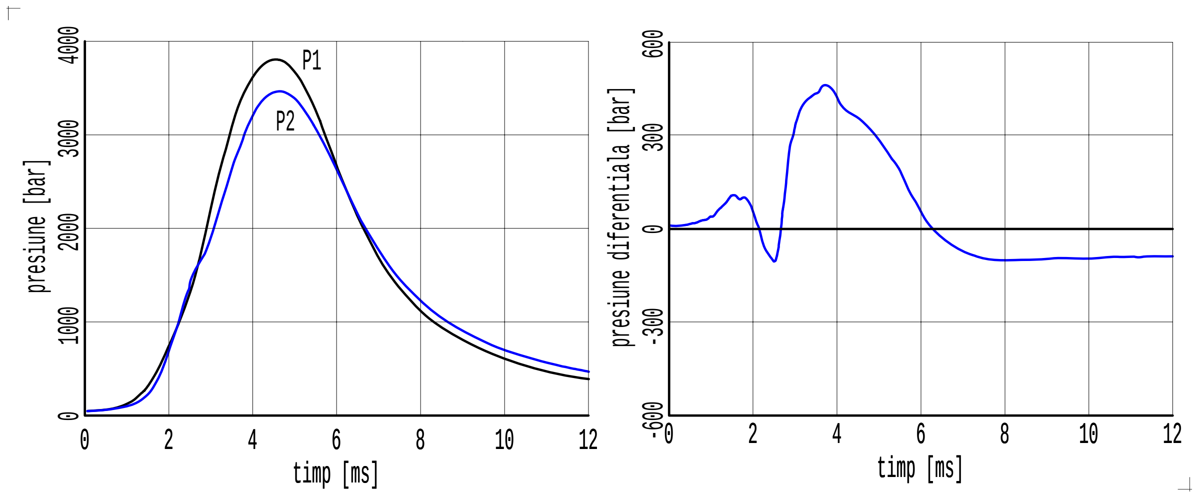

Fig. 7 Pressure vs. time curves measured inside the 100 mm cartridge case
P1 – pressure at the base of the cartridge case; P2 - pressure at the mouth of the cartridge case;
P1-P2 - differential pressure

4. MEASURING OF THE PRESSURE WITH THE PIEZOELECTRIC GAUGE

The piezoelectric gauge allows for the measuring of the entire pressure-time curve inside the barrel of the big caliber guns. The piezoelectric gauge has a miniaturized design, is air tight and contains all the components of a piezoelectric measuring chain for pressure measurements.

In addition, the gauge is completed with a transducer for environment temperature measurement before and after firing.

Figure 8 shows the B250 AVL piezoelectric pressure gauge [6].

In order to do the measurement, the piezoelectric gauge is paced at the bottom of the cartridge case of the round, as it is shown in Figure 9.

The input of the measuring parameter and the output of the measured date are done by the means of PC through specialized software. This measuring scheme has, compared with the others schemes, the advantage that no special preparations of the ammunition or barrel is needed.

An example of measuring of the pressure by piezoelectric gauge during 152 mm howitzer firing is presented in Figure 10.

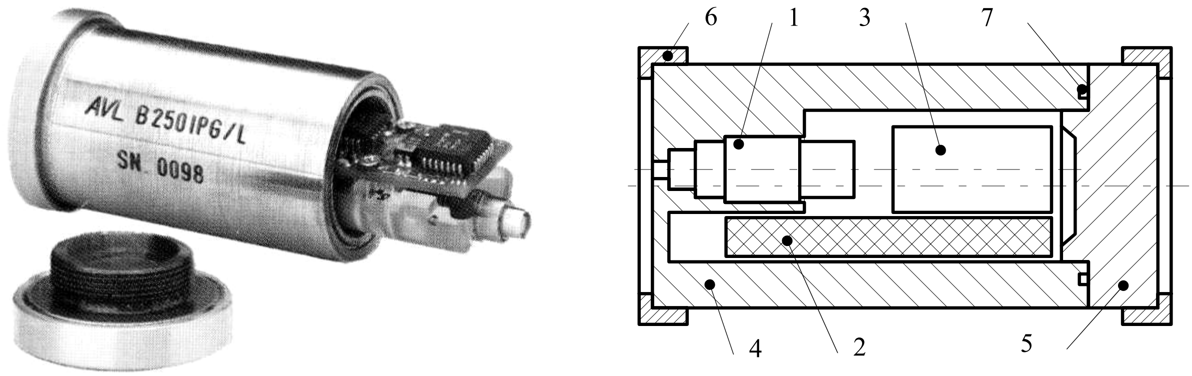

Fig. 8 The B250 AVL piezoelectric gauge: 1-pressure transducer; 2-electronic module; 3-battery; 4-body; 5-closure; 6-prottective ring; 7-sealing ring

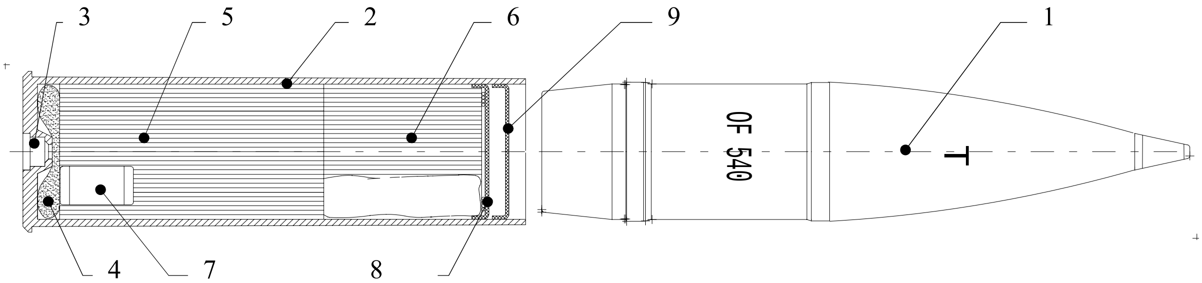

Fig. 9 Positioning of the piezoelectric gauge inside the 152 mm cartridge case
1-projectil; 2- cartridge case; 3-primer; 4- igniter; 5-bottom charge; 6-upper charge; 7-piezoelectric gauge; 8-cover; 9-base cover

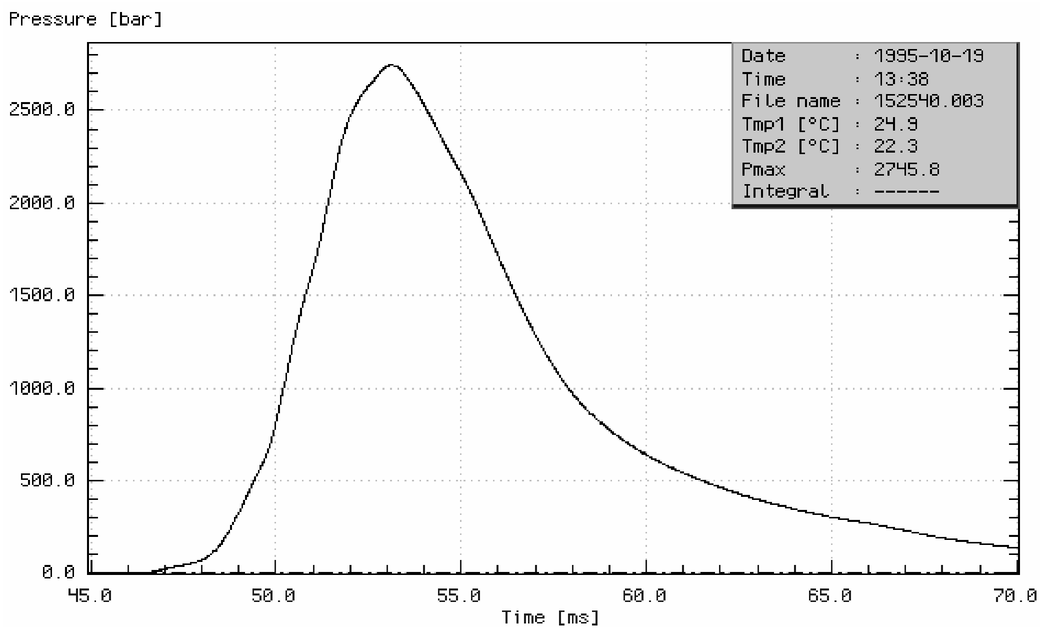

Fig. 10 Pressure vs. time curve measured inside the 152 mm cartridge case

4. CONCLUSIONS

Metrology characteristics of the piezoelectric high pressure transducers correlated with the possibility of miniaturization of their construction, recommend the use of this transducers for propellant gas measurements in ballistic tests.

For the measurement of the pressure inside the weapon's barrel, several methods can be used, according to the goals of the test.

The piezoelectric method for propellant gas pressure measurements can be used both in R&D of new weapons systems and in acceptance of the existing ones.

REFERENCES

1. * * * *AVL Piezoelectric High Pressure Transducers*, 1994;
2. Cepişcă, C., Jula N., *Traductoare şi senzori*, Editura ICPE, Bucureşti, 1998;
3. * * * *Piezo-instrumentation KISTLER*, Kistler Instrumente AG, Schweiz, 1994;
4. * * * Oerlikon pocket-book, Oerlikon-Buhrle AG, Zurich, revised edition 1981;
5. Stiefel, L., *Progress in Astronautics and Aeronautics: Gun Propulsion Technology*, Vol. 109, AIAA, Washington, DC, 1988, pp. 75-80;
6. * * * *B250 IPG Internal Piezo Gage*, Operating Manual, AVL List GmbH, Gratz, Austria, 1992.