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Bi-modular Charge System for Calibre 155 mm I.

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Abstract:

The article provides background information on issues of Bi-modular charge system designed for 155 mm-calibre weapon system. It summarizes the principles of design and knowledge gained during the development stage, and provides information about firing of modules in the testing cannon.

Keywords:

Bi modular charge, interior-ballistics, cartridge chamber, 155mm calibre, propelling charges,

1. Introduction

This is a further development stage of design of charge systems for split ammunition; we can say that these are the modular charges of 2nd generation as presented in the literature [1]. The complete Bi-Modular Charge System (BiMCS) represents in its design substance the solution of charge system by two types of modules: Bottom Charge module (BC-E) and Top Charge module (TC-F). The BC-E module serves for covering of small ranges of fire (it consists of one Zone-1 module and two Zone-2 modules). Type of TC-F module serves for covering of long and maximum ranges of fire (it comprises of three to six modules – Zone – 3, 4, 5, and 6). BiMCS system is designed in such a way that the combination of both types of modules is not presumed.

It would be a great benefit if a uni-modular system of propelling charges were developed. Combination of single type of (propelling charge) module would cover complete range of velocity from 300 to 945 m/s for respective volume of projectile chamber and for respective projectile. The current modules (propelling charges) do not meet these characteristics, as also stated in the literature [2]. Some reports [3, 4] monitor this course; however, there is a long way to the practical application.

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Solution of BiMCS considerably reduces demands on logistic support, and mainly increases the speed of preparation of ammunition for firing on one hand and reduces the risk of errors on the other.

First and foremost BiMCS was designed for the barrel length of 52 calibres and projectile chamber of the volume of 23 litres.

Based on the ballistic tests of these modules we can say that the BiMCS can be used also in weapon systems with the barrel length of 39, 45 and 47 calibres and with the projectile chamber volume from 18 to 25 litres, which cover a wide range of weapon systems being in service. Nevertheless, it must be kept in mind that although the using of BiMCS in weapon systems of various manufacturers with parameters mentioned above is universal, design of modules may not be optimal for given weapon and certain design modifications of charge geometry would have to be made.

A part of work was the design of ballistic solution for large calibre ammunition, combustible ammunition components and other system components (ignition system, phlegmatizer, de-coppering agent, flash reducer, etc.) and the verification of testing in the testing cannon.

BiMCS corresponds to the basic requirements for the muzzle velocity and pressure waveforms under the so-called JBMoU (Joint Ballistic Memorandum of Understanding).

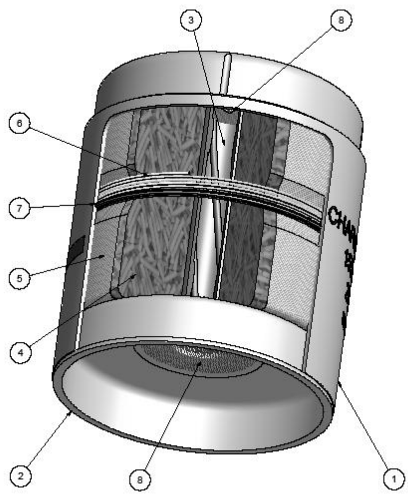

Fig. 1 BC-E module

Modular charge BC-E consists of the following main components:

1. Combustible case
2. Combustible cover
3. Ignition set
4. Powder charge – single-base multi-perforated grain powder
5. Cloth cover
6. De-coppering agent
7. Cord
8. Cover foil for ignition set

Fig. 2 TC-F module

Modular charge TC-F consists of the following main components:

1. Combustible case
2. Ignition set
3. Combustible cover
4. Flash reducer
5. De-coppering agent
6. Powder charge of plastic cover
7. Cover foil for ignition set
8. Powder charge – triple-base multi-perforated grain powder

Both of these modules create the complete BiMCS.

In the framework of development of BiMCS, interior-ballistic project (study) was carried out as the basic theoretical processing of design requirements for single module from the viewpoint of reaching required muzzle velocities and pressures when using individual partial configurations of modules, as well as the full configuration consisting of 6 modules.

Due to economical aspects, it was effective to carry out the tests in the testing cannon which was 125 mm-calibre gun modified to the calibre of 100 mm, and only after reaching satisfactory results the selected variants of BC-E and BC-F modules were tested in the 155 mm-calibre weapon.

2. Theoretical Part

Interior-ballistic verification of design of modules was carried out in the testing cannon 100mm TK V20.

Testing cannon 100mm TK V20 enables the testing of complete configuration of modular charge in quantities of 1, 2, 3 and 4 pieces (TC-F modules in the quantities of 3, 4, 5, and 6 pieces are used in 155 mm-calibre weapon with volume of projectile chamber of 23 litres). Pressures are measured with three piezoelectric sensors placed at the bottom of the cartridge chamber and near the bottom of the projectile.

If the pressure at the bottom of the projectile overtakes the pressure at the bottom of the cartridge chamber in the initial phase of the round development, it is a demonstration of wave action.

Trials with the testing cannon were designed so that the number of necessary tests of BiMCS in the particular weapon system was minimized.

The tests were performed in accordance with established methodology of ballistic tests of smokeless powders and charges. The barrel must be of ballistic category, i.e. the velocity loss of the particular round must be max. up to 2%. Acceptance test assessment of the weight of module is carried out at three weight levels, variance of muzzle velocities serves for checking of "homogeneity" of charges being tested and it was defined as follows:

Variance in the group of rounds with several levels of powder charge weight:

When the weight of the powder charge of the rounds being tested in one group is the same, then the probable deviance is calculated according to the following formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(v_{0i} - v_{0\text{mean}}\right)^2}{n-1}}$$

$$Uv_0 = 0.6745\,\sigma \qquad (1)$$

When considering firing with different weights of charges and different number of rounds, then we calculate a linear regression function of v_0 depending on the weight of the charge

$$v_0 = a + b\omega \qquad (2)$$

where *a* and *b* are determined regression coefficients.

For compliance of "calculated determined mean" values with those of gained after the firing, we can calculate an equivalent to the probable deviation mentioned above as follows:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(v_{0i} - v_{0i\text{REG}}\right)^2}{n-1}}$$

$$Uv_{0\text{REG}} = 0.6745\,\sigma_{\text{REG}} \qquad (3)$$

where $v_{0i\text{REG}}$ are values of velocity determined from linear regression relationship (2) for *i*th level of weight ω_i, of the powder charge tested by firing

$$v_{0i\text{REG}} = a + b\omega_i \qquad (4)$$

For one weight of charge being tested, this relationship is equivalent to formula (1).

Ballistic tests of TC-F in the testing cannon include checking of individual components, preliminary acceptance test assessment of the powder charge, check of round development and check of wave progress of pressures. The tests were performed with the configuration of powder charges 4 × TC-F and 2 × TC-F.

Definitive acceptance test assessment of the weight of TC-F charge was done by full number of modules – 5 × TC-F in a 155mm/ 39 cal. gun, and 6 × TC-F in both 155mm/45 cal. and 155mm/52 cal. gun.

Acceptance test assessment was carried out by firing of two valid three-round groups with two different weights of the powder charge with full number of modules. Weight of the charge was preliminarily defined by firing from the testing cannon 100mm TK V20; wave characteristics of the powder charge were verified at the same time. In addition, another three-round group with three modules with estimated weight of the powder charge was fired; thus there were fired in total 9 valid rounds.

Verification of complete TC-F by firing can be carried out either with particular 155mm gun or with 100mm TK V20 testing cannon.

In this manner, it is possible to check performance – muzzle velocity and to compare it with preliminary acceptance test assessment of the weight of powder charge.

3. Experimental Section

For illustration, let me present:

a) Test results of module charge TC-F with 100mm TK V20 testing cannon, whose purpose was to verify the performance and wave processes.

The following table shows the main input and the measured values.

Tab. 1 Results of selected rounds

Shot number	Type of charge	Time Act. [ms]	Velocity V40 [m/s]	M1 [bar]	Piezo M3 [bar]	- Δ Piezo M1-M3 [bar]
1	4 × TC-F V20D2	101	819.3	2288	2151	20
2	4 × TC-F V20D2	113	815.7	2254	2132	60
3	4 × TC-F V24A	73	822.0	2311	2184	10
4	4 × TC-F V24A	120	824.1	2331	2216	90
5	4 × TC-F V25A	88	828.4	2349	2215	15
6	4 × TC-F s.4/06	118	839.8	2397	2270	100
7	4 × TC-F s.4/06	64	840.6	2403	2264	15
8	4 × TC-F s.4/06	149	834.3	2376	2249	140
9	4 × TC-F s.4/06	101	839.2	2393	2268	50

Figs 3 and 4 presented below show examples of measured pressure waveforms and pressure differences of rounds fired from the testing cannon 100mm TK V20.

b) Test results of module charge TC- F with 155mm ShKH "ZUZANA" gun.

Projectiles 155mm OFd-MK (hollow base) were used for firing from 155mm ShKH "ZUZANA" gun. Weight of the projectiles was 43.55 kg. Firing test was carried out from a 155mm weapon system with the barrel length of 45 calibres with piezoelectric pressure measuring points. Velocity was measured by two pairs of electromagnetic frames. Pressure was measured with a pair of pressure crusher gauges with copper cylindrical crushers 8/13, a pair of pressure crusher gauges with copper ball crushers and two piezoelectric sensors. Temperature of powder charges before firing was 21 °C, 50 °C and 62.5 °C.

Figs 5 to 7 present examples of measured pressure waveform and pressure differences for modules 3 × TC-F, 4 × TC-F and 6 × TC-F.

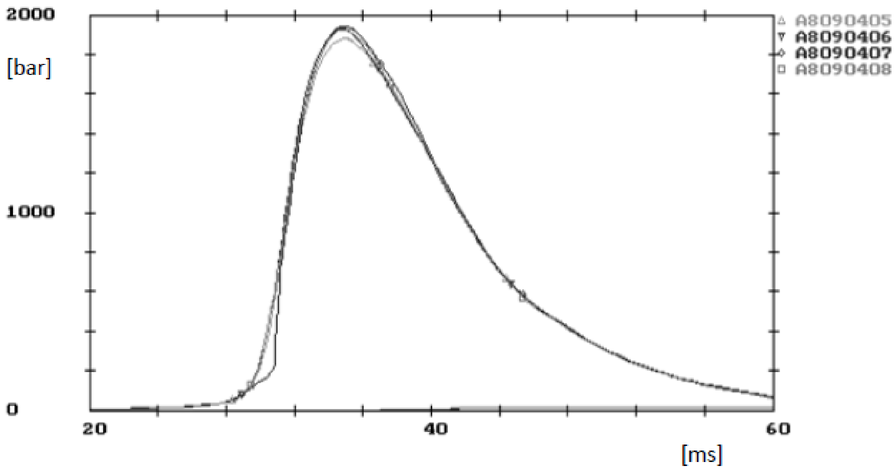

Fig. 3 Dependency of the pressure on time

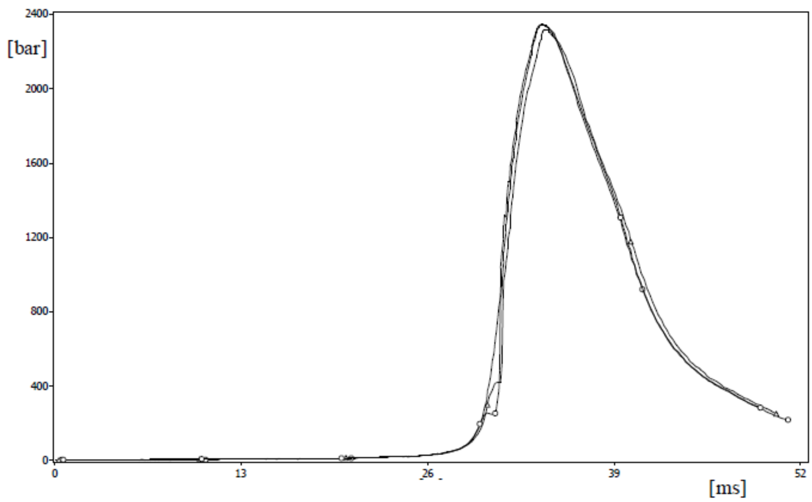

Fig. 4 Dependency of the pressure on time

4. Discussion of Results and Conclusion

When comparing the results obtained from the testing cannon and the real 155mm weapon system we can say that the testing cannon is a sufficient substitute for getting the first elementary interior-ballistic data necessary for development of modules of

BiMCS and gaining the knowledge from the point of performance characteristics of modules, possibility to find out forming of waves during the firing, and other relevant parameters regarding to development of modules of BiMCS.

Table 2 Test Results - TC-F (155mm/45 cal. weapon system, Projectile OFd-Mk 43.55kg)

No. of rounds	Charge	Temperature [°C]	v_0 [m/s]	Pcu roll 8/13 [MPa]	Pcu ball [MPa]	Piezo [MPa]	- Δ press. [MPa]
2	3 × TC-F	+21	547.3	93.5	107.9	102.9	1.0
2	3 × TC-F	+62	556.1	94.5	108.3	103.8	2.5
2	3 × TC-F	+21	680.1	143.8	173.0	168.8	2.7
2	5 × TC-F	+21	807.8	227.7	264.8	255.8	1.7
2	6 × TC-F	+21	935.4	320.8	388.1	370.1	0.0
2	6 × TC-F	+50	948.5	335.9	398.4	389.9	0.9
2	6 × TC-F	+62	958.2	343.6	415.9	404.5	7.5

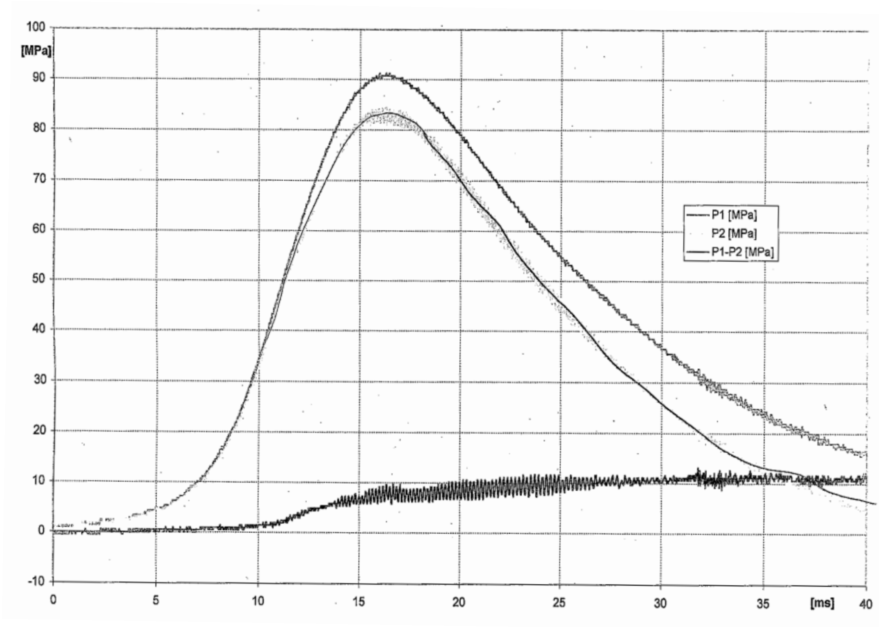

Fig. 5 Dependency of the pressure on time-charge 3 × TC-F

With assistance of the testing cannon, it is possible to verify interior ballistics of designed modular charges and their configurations, for example, from the point of ignition spreading and interior-ballistic parameters (dispersion, meeting of requirements of so called "ballistic memorandum" that defines all required interior-ballistic data).

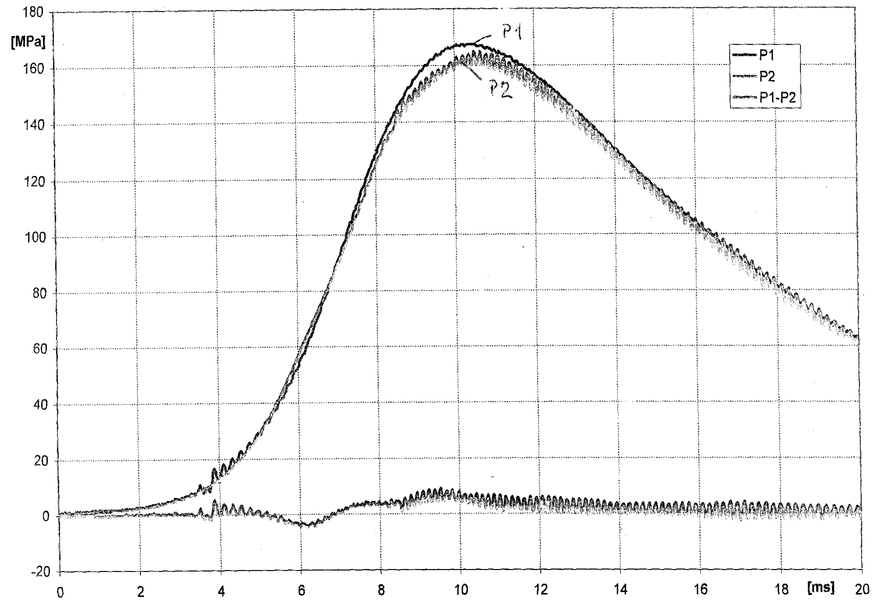

Fig. 6 Dependency of the pressure on time-charge 4 × TC-F

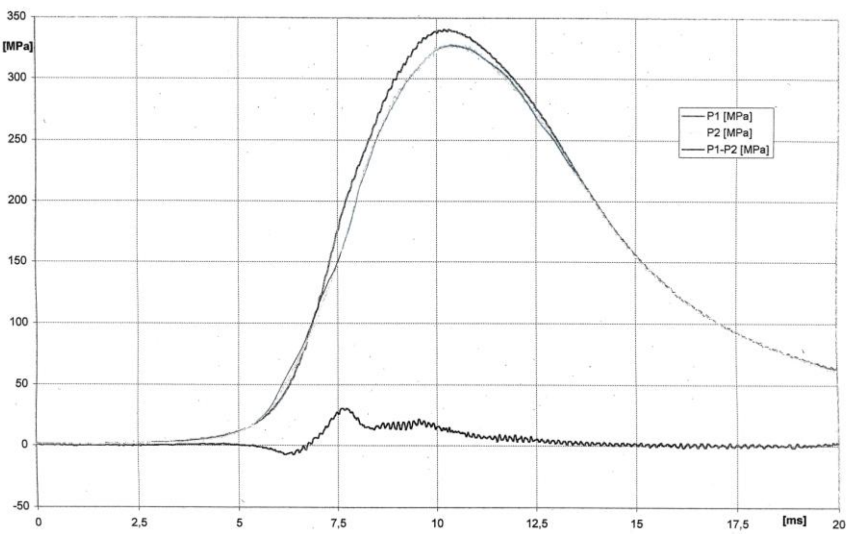

Fig. 7 Dependency of the pressure on time-charge 6 × TC-F

In addition, it will be possible to assess numeric criterion for "quality" of wave processes, as well as to monitor quantity of unburned residues during firing of the round from the testing cannon.

When contemplating about the future, we can say that the testing cannon will be able to replace the real gun system from the viewpoint of acceptance test assessment of the weight of powder charge for individual modules. However, it is necessary to stress that this assumption must be supported with greater number of comparative firing tests to get real conversion coefficients. Regardless the knowledge gained, we have to emphasize that the final acceptance tests of the complete BiMCS must be carried out by firing from the real gun.

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