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EXPERIMENTAL RESEARCH ON INFLUENCE OF EXPLOSIVE CHARGE TO NATURAL FRAGMENT SIZE DISTRIBUTION

Zecevic, B.; Terzić, J. & Catovic, A.

Abstract: *At natural fragmentation of warheads, replacement of explosive charge with greater detonation rate considerable affects geometry of natural fragments as well as their mass and spatial distribution, and particularly changes of fragments velocities.* Authors proposed a new approach to presentation of experimental results, which enables selection of an optimal warhead explosive charge.

Key words: *warhead, natural fragmentation, explosive charge, fragment velocity, fragment size.*

1. INTRODUCTION

Measurements of warhead performances require very complex measuring equipment and measuring process itself is expensive as well. HE warhead efficiency at natural fragmentation depends on fragments space distribution, mass, shape and velocity of each fragment and projectile impact conditions. Fragment velocity depends directly on warhead metal shell and explosive charge mass ratio, detonation rate and density of explosive charge. Geometric shape of natural fragments, their mass and spatial distribution are functions of designed warhead shell geometry, mechanical properties of warhead shell material (tensile strength and toughness) as well as performances of explosive (physical and energetic). It is essential to have a capability to make warhead performance prediction in the earliest phases of ammunition preliminary design. This warhead performances prediction capability is based on comprehensive database of warheads natural fragmentation performances (Gold at al., 2001).

Artillery projectiles or rocket warheads are usually two-dimensional axial symmetric. Natural fragmentation of projectiles or warheads results in wide range random distributions of fragment sizes (masses and geometries). Expansion of warhead shell caused by detonation products of explosive charge brings about a body being split into various sized fragments. Detonation products cause expansion of warhead case greater than about twice the warhead initial radius. The maximum fragment velocity (95 to 100% of the Gurney velocity) is achieved at the end of fragment acceleration at a radius of about 1.6 to 1.8 times the initial warhead radius (Lloyd, 1999).

2. EXPERIMENTAL RESEARCH ON INFLUENCE OF EXPLOSIVE CHARGE TO FRAGMENT SIZE DISTRIBUTION

Experimental researches performed by the authors were aimed at estimation of natural fragmentation performances (number, mass and fragments shape) of warhead when the explosive charge is changed (comparison of two explosive charges with different detonation rates and densities). Number, mass and fragments shape at natural fragmentation of warheads have been determined by Pit test. The point of research was an estimation of influence of detonation rate on natural warhead fragmentation performances (number, mass, geometrical shape and velocity of fragments). Warhead cases were made of the steel C70D, and warhead masses were kept the same, but only types of explosive charge were varied (TNT and Composition B). Ratios of explosive charge mass and warhead metal case mass were $C_{TNT}/m = 0,565$ and $C_{Comp\ B}/m = 0,587$. Dimensionless thickness of the warhead shell W2 was $t/d = 0,08237$. Four fragmentation tests were carried out for each type of explosive charge.

Fig. 1 Warhead W2

For prediction of size distribution of natural fragmented warhead, the Held formula with two parameters and the total mass M_0 or the best fit of total mass M_{0Best} as inputs, gives an excellent description of the experimentally found mass distributions of a natural fragmented warhead (Held, 1993). An improved fit to natural-fragmentation data can be obtained using equation:

$$M(n) = M_0 \cdot \left(1 - e^{-B \cdot n^{\lambda}}\right) \tag{1}$$

where; B and λ are both empirically determined constants, with $B = const. \cdot \sqrt{d/t}$ and of order 10^{-2} and λ of order 2/3. In the Held equation M_0 is the total mass of all fragments, $M(n)$ and n are the cumulative fragments mass and cumulative fragments number beginning with the heaviest fragment. Held frequently found that it was necessary to discard a few of the heaviest fragments in order to obtain a curve fit to data over the rest of the range. The constants B and λ are determined from above equation by mathematical transformation:

$$\left[M_0 - M(n)\right]/M_0 = e^{-B \cdot n^{\lambda}} \tag{2}$$

and the natural logarithm of the above equation is:

$$\ln\left[\left(M_0 - M(n)\right)/M_0\right] = -B \cdot n^{\lambda} \tag{3}$$

If the logarithm of above equation is performed again, it is possible to determine the constants B and in the log-log plot. By differentiating of the equation, Held $M(n)$ gave the approximate mass of the n-th fragment:

$$m(n) = dM(n)/dn = M_0 \cdot B \cdot \lambda \cdot n^{\lambda - 1} \cdot e^{-B \cdot n^{\lambda}} \tag{4}$$

From the fragment mass distribution (FMD) log-log diagram, constant B and exponent λ with correlation coefficient r^2 are obtained. If in the log-log diagram, the straight line does not fit the measuring data very well, given total mass Mo is not an optimum mass for such fragments mass distribution. Now, an optimum mass (or best mass) M_{0Best} is calculated:

$$M_{0_{Best}} = M(n) / \left(1 - e^{-B \cdot n^{\lambda}}\right) \tag{5}$$

The constants B and λ are originally determined. The new constants B_B and λ_B are determined with the total mass M_{0Best}

$$M(n) = M_{0_{Best}} \cdot \left(1 - e^{-B_B \cdot n^{\lambda_B}}\right) \tag{6}$$

This procedure is repeated until a satisfactory correlation coefficient is obtained ($r^2 \geq 0{,}99$).

Fragments were classified by mass groups and experimental data were processed using Held methodology (Fig.2).

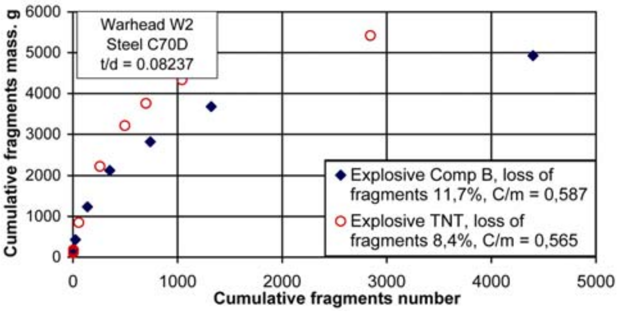

Fig. 2 Cumulative fragments mass dependency on cumulative fragments number

Fragment velocities are measured using different techniques as electronic, optical or x-ray. If these techniques are not available, initial velocity of fragments released from explosion of a warhead is approximated by the Gurney formula. The simplest expression of the Gurney formula for symmetrical configurations is:

$$v_{Gurney} = \sqrt{2 \cdot E} \cdot \sqrt{1/(0{,}5 + M/C)} \qquad (7)$$

where $\sqrt{2 \cdot E}$ is Gurney constant, M-metal mass of warhead case and C - mass of explosive charge (Karp, 1975). The Gurney constant can be approximated by the simple expression $\sqrt{2 \cdot E} = 0{,}338 \cdot D$, where D is the detonation velocity (depending on explosive type and its density).

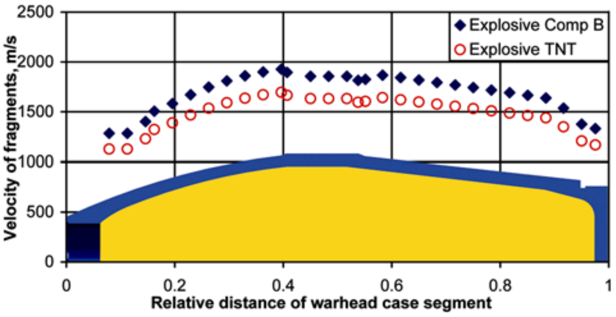

Fig.3 Variation of fragment velocity as a function of explosive type

3. EXPERIMENTAL RESULTS ANALYSIS

Warhead with the case made of steel C70D and Comp B produces larger number of fragments compared to the warhead with TNT explosive charge. At the same time, at the first variant of warheads a larger loss of the fragments mass was registered (metal part of the warhead was transformed to very small fragments), 11,7 % compared to 8,7 % for another one. However, it is not possible to conclude from Fig.3 which warhead has better fragmentation performances. Because of that, authors presented their results in a different way (Fig. 4). The mean mass of particular groups was taken as a variable. Correlation between fragments number of mass groups, whose mean masses are less than mean fragments mass related to total fragments number, or between fragments mass of these mass groups and total fragments mass of the warhead were established. The warhead with explosive charge of Comp. B generates more fragments but with less mean mass and with more fragment mass contribution. Authors explained such results as consequence of more intensive influence of detonation products generated by more powerful explosive. When more powerful explosive is used, initial warhead volume is increased more intensive and warhead case thickness is decreased (condition of mass conservation). Explosive Comp B has 40% greater detonation pressure and 12% greater detonation rate. Experimental researches showed that warhead volume can be risen more considerable before fragmentation process has been started (Zecevic and al., 2004). Increase of the ratio V_i/V_0 causes decrease of the ratio t_i/t_0, that result in a greater fragments number with less mean fragments mass.

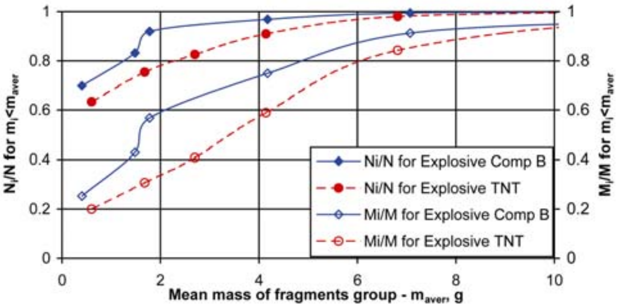

Fig. 4 Fragments number contribution, or fragment mass contribution as a function of the mean fragments mass

The warhead with explosive charge of Comp B has in 4% greater metal mass loss compared to the warhead with TNT explosive charge. Explosive Comp B has 12% greater detonation rate and 3,8% greater density related to TNT. Increased detonation rate and greater explosive density affect increase of fragments velocity in 13,8 %, so fragments with less mean masses have considerable greater kinetic energy and lethality as well.

4. CONCLUSION

It was not possible to be clear defined an influence of explosive type on natural fragmentation performances by using Held method.

Authors proposed a new approach to presentation of experimental results, which enables selection of an optimal warhead explosive charge.

The warhead with Comp B explosive charge generates more fragments (57%) with greater fragments kinetic energy and increased fragments spatial distribution density, which considerable increase lethal zone of such filled warheads.

5. REFERENCES

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