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INFLUENCE OF WARHEAD CASE MATERIAL ON NATURAL FRAGMENTATION PERFORMANCES

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Abstract: *At warheads natural fragmentation, fragments geometry, their mass and spatial distribution are functions of designed shape of the warhead case (shell), mechanical performances of case material (tensile strength and toughness) and performances of explosive (physical and energetic). It is essential to have a capability to make warhead performance predictions in the earliest phases of ammunition or warheads preliminary design.*

Key words: *warhead, natural fragmentation, fragment velocity, case material, fragment size.*

1. INTRODUCTION

HE warhead performances depend on its geometrical shape and dimensions, mass of explosive charge and explosive type, material of warhead case, initiation way and initiation point position, fuze type, round-to-round variations etc. Geometrical shape of natural fragments, their mass and spatial distribution are functions of geometrical forms of internal and external warhead case surfaces, mechanical properties of warhead case material (tensile strength and toughness) and performances of explosive (physical and energetic). It is essential to have a capability to make warhead performance prediction in the earliest phases of HE ammunition or warheads preliminary design. Ability for warhead performances prediction depends on comprehensive data base of warheads natural fragmentation features, including data on numbers, initial fragment velocities, warhead case material performances, fragment shape features and spatial fragment distributions etc.

2. EXPERIMENTAL RESEARHES OF FRAGMENT SIZE DISTRIBUTION

Artillery projectiles and rocket warheads are usually two-dimensional axial symmetric. Natural fragmentation of projectiles or warheads results in a wide range of random distribution of fragment sizes (masses and geometries). Expansion of warhead case caused by detonation products of explosive charge brings about a warhead structure being split into various sized fragments (Garland, 1997).

The fragments spatial distribution around a detonated cylindrical warhead is not uniform. Naturally fragmented cylindrical warhead typically splits into initial long axially oriented strings. Splitting effect of warhead case radial fracture depends on toughness, brittleness and material structure grain size, explosive power (magnitude of the detonation impulse). Further, these strings are broken up into ultimate fragments in both ways, radially and longitudinally, during subsequent detonation products expansion, whose fragments size distribution, can be described approximately by the Mott formula. Detonation products solicit expansion of the warhead case greater than twice the warhead initial radius. For cylindrical steel warhead cases, initial elastic-plastic expansion of the case occurs when it is extended from the original volume to about 1,44 times. When the current case volume being risen to about 2,56 to 3,24 times of the initial warhead volume, the detonation products are released through cracks and subsequently an expanding detonation products cloud is developed beyond the fractured warhead case (Pearson, 1991).

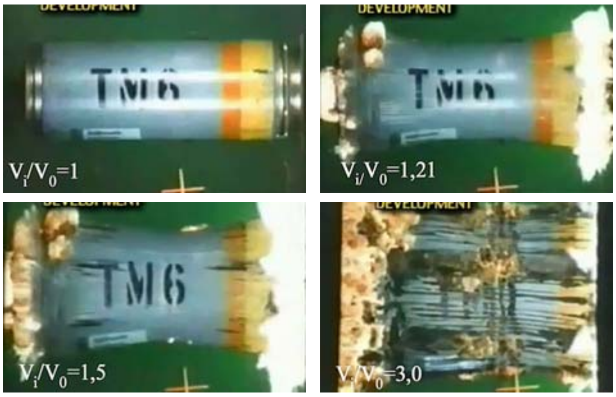

Fig. 1 Sequences of a HE warhead natural fragmentation (www.nawcwpns.navy.mil/mov/energet/seg/WB.mov)

Researches performed in USA were aimed on development of simulation methods for prediction of fragmentation characteristics of HE ammunition (Gold et al., 2001). The recent attainment is development of CALE computer simulation program, which is able to simulate fragmentation performances of two and three - dimensional axial symmetric warheads and HE ammunition.

Authors classified all available experimental data from fragmentation tests conducted in Bosnia and Herzegovina, which were processed in accordance with new improved methodology applying in U.S.A. and Europe.

Experimental researches performed by authors were undertaken in order to estimate all relevant performances of warhead natural fragmentation (number, mass and fragments shape) when the material of the warhead case is changed (three types of steel with different mechanical properties). Number, mass and fragments shape of each mass group are determined using the Pit test, and relative estimation of spatial fragments efficiency was done by arena test. The main point of the research described in this paper was directed to an influence of warhead metal case material properties on warhead natural fragmentation performances (number, mass and fragments geometrical shape). Dimensionless thickness of the warhead shell W1 was $t/d=0,058$, and ratio of metal warhead shell and explosive charge mass was $C/m = 0,32$. Tested warhead cases were made of following steels 45Cr2 (ratio of tensile strength and yield strength $R_m/R_v=1,09$), C70D ($R_m/R_v=1,59$) and steel AB or 9180VP ($R_m/R_v=1,41$) marked according to JAS standard.

Prediction of fragments mass distribution is usually performed by application the Mott formula, or the Held formula. Each of mentioned formulas has certain limitations. These empirical formulas are based on experimental data gained from many fragmentations Pit and arena tests.

Fig. 2 Warhead W1

The Mott equation has been using for years for prediction the fragments size distribution of naturally fragmented warheads and ammunition, and this method is only one, which is used in U.S.A. (Victor, 1996):

$$N(m)=\left[M_0/\left(2\cdot M_k^2\right)\right]\cdot e^{-\left(m^{0,5}/M_k\right)} \tag{1}$$

where: N*(m)* is the fragments number with a mass greater than *m*, M_0 is the total fragments mass and M_k is parameter which characterizes the fragments mass distribution. The parameter M_k is a function of warhead case thickness t_i, internal diameter of the warhead d_i and explosive charge. In the parameter M_k, constant *B* depends on the explosive charge and casing material.

$$M_k = B\cdot t_i^{\frac{5}{6}}\cdot d_i^{\frac{1}{3}}\cdot\left(1+t_i/d_i\right) \tag{2}$$

For a mild steel case, the constant B obviously decreases with increasing of detonation pressure (yielding smaller fragments); but it also decreases with increasing case hardness (Lloyd, 1999).

Four warheads fragmentation tests were performed for each casing material of the warhead and obtained data were processed according to Mott methodology (Fig.3).

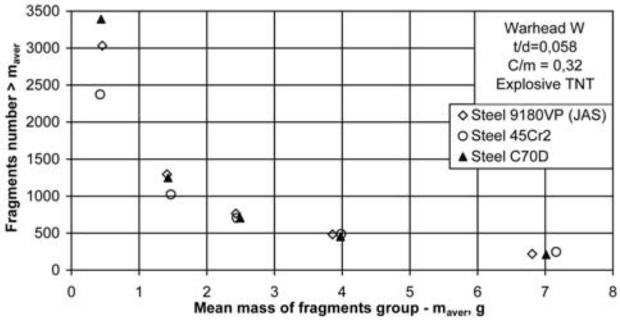

Fig.3 Dependency of fragments number variation greater than m from the mean fragments mass

3. EXPERIMENTAL RESEARCH RESULTS ANALYSIS

The warhead with case made of the steel C70D has greatest fragments number, while the warhead with case made of the steel 45Cr2 has a minimal fragments number and this ratio is valid for fragments $m_{aver}<2,5g$. At risen mean fragments mass this order is changed, so the warhead with the case made of 45Cr2 steel has a maximum fragments number, which is followed by warheads of 9180 steel and C70D steel but both with minimal mutual variations. Authors noted a strong dependency of fragments number and their mass from the ratio R_m/R_v. Steels with higher ratios R_m/R_v generated considerable higher fragments number (steels C70D and 9180). However, it was not possible to conclude from Fig.3 which material would be the most favourable. Because of that, authors presented their results in a different way (fig. 4). The mean fragments mass of each particular group was taken as a variable. Relationship between fragments mass groups' number, whose mean masses are less than the mean mass of the total fragments number, or between fragments mass of each group and the total warhead fragments mass were established. Warhead with case made of the steel with larger ratio of R_m/R_v generates greater number of fragments but with less mean mass and greater fragments mass participation. Authors explained this phenomenon as a consequence of warhead case ability to expand into more considerable volume with thinner case walls under detonation products pressure before fragmentation (warhead body mass conservation condition). Experimental researches have shown that initial volume of a warhead can be increased several times before fragmentation of warhead case material has been occurred (Fig.1). Authors also found the relationship $t_i/t_0=(V_i/V_0)^{-0,5}$ between relative volume rise and relative wall thickness during the warhead case expansion. At 4 times increase of warhead volume, new corresponding warhead case thickness decreases at 0,52 of initial case thickness. When the ratio of R_m/R_v rises, the ratio V_i/V_0 increases as well and t_i/t_0 decreases, what result in greater fragments number but with less mass.

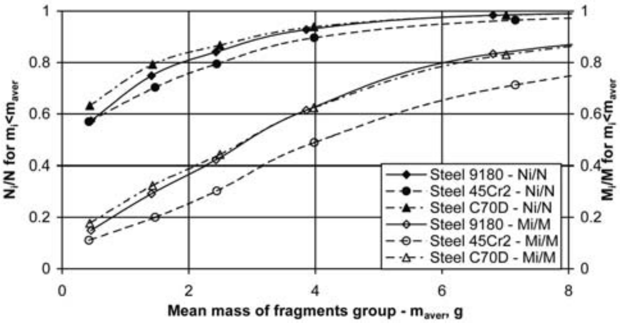

Fig. 4 Fragments number or mass participation as a function of mean fragments mass

4. CONCLUSION

Mott formula cannot provide a clear influence of warhead metal case variation on natural fragmentation performances.

Authors gave a different approach to presentation of fragmentation experimental data, which enables selection of an optimal warhead case material.

Authors also established relationship between t_i/t_0 and V_i/V_0 and connected it with the ratio R_m/R_v in order to find how above parameters affect fragment number and their mass. Warhead with steel case, which has higher ratio R_m/R_v generates simultaneously greater fragments number but with less mean fragments mass and with greater fragments mass participation.

Authors also concluded that it was necessary a further development of empirical relationship between R_m/R_v, and V_i/V_0.

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