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Effects Of Pit Test Medium On Fragments Formation Using Autodyn Sph Solver

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Abstract
In this work two models were created to verify the possibility of using Autodyn SPH 3D instead of costly pit tests. First model represents fragmenting of OG-7 warhead surrounded by 25 mm of sand to simulate partially a pit test for fragments recovery. The second model represents fragmenting of free OG-7 which was created to find out the effect of sand in fragments formation. The simulation results were compared with an experimental cubic pit test results. The experimental and simulation results were analyzed by Held's formula for fragments mass distribution.

Keywords: Autodyn SPH, fragments mass distribution, mass of fragments, number of fragments, pit test, pit test medium

Nomenclature:

B,λ	Expiremental Constants of Held Formula
M(n)	Mass of Fragments of Number of Fragments Greater Than *n*
M_o	Total Mass Of Fragments
N	Number of Fragments
OG-7	Propelled Grenades (Oskolochnaya Granata)
RDX	Cyclotrimethelenetriamine (Hexogen)
SPH	Smooth Particle Hydrodynamics

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1. Introduction

Natural fragmentation of projectiles or warheads results in wide range of random distributions 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. High explosive warhead performances depend on its geometrical shape and dimensions, mass and type of explosive, and material of the warhead case.
Measurements of warhead performances require very complex measuring equipment in adition to its expensive process. Capability of warheads performances and efficiency assessment is based on complexity of our database of natural fragmentation parameters which should encompass data on number, mass, initial velocity, fragments shape factor and spatial distribution, material characteristics of warhead case and explosive charge.[1]
Parameters of natural fragmentation process can be determined by analytical methods, experimental researches and numerical modeling methods. Number of fragments, their mass, and geometrical shapes are determined experimentally with Pit test method. In Pit test, warhead is detonated in closed space (pitfall), filled with sand fig.1. After the fragmentation of warhead, fragments are obtained from the sand. Mass and shape of fragments are determined, and fragments are classified by their mass groups. After fragments classifying, their mass distribution can be obtained. Prediction of fragments mass distribution is usually performed by application of Mott formula, or Held formula.

2. Autodyn Sph Solver

SPH is a meshfree method that can be applied to nonlinear problems with large deformation and large strains, especially for impact and penetration of solid structures. SPH holds promise to overcome many of the inherent limitations associated with classical Euler and Lagrange approaches.
In an SPH solver, partial differential equations are transformed into integral equations through interpolation functions. Interpolation functions give a “Kernel estimate” of the field variables at each interpolation point by evaluating the integrals as sums over the neighboring interpolation points. These interpolation points are called SPH nodes. Therefore, a physical object is represented by a field of SPH nodes, instead of cells (or elements) as in a traditional Lagrange or Euler solver. By definition, there is no “mesh tangling” or “mesh degeneration” in the SPH solver. Moreover, a numerical erosion model is not needed. AUTODYN is a general finite element/finite difference/finite volume computer code for the nonlinear analysis of solids, fluids, and the interaction between solids and fluids. Lagrange, 1st order Euler, 2nd order Euler, ALE, and Shell solvers have previously been implemented in AUTODYN-2D and 3D. Extensive usage of AUTODYN by users worldwide has borne out that the software is easy to use and accurate enough. More recently, a SPH solver has been implemented in AUTODYN-2D and 3D [2]. A number of research projects have been successfully performed for simulating impact and penetration events for solid structures using the SPH solver in AUTODYN. In this present paper, the SPH processor in AUTODYN was applied to the fragmentation warhead and results were compared with those of experimental pit test.

3. Material Modeling

AUTODYN utilizes the differential equations governing unsteady material dynamic motion that express the local conservation of mass, momentum and energy. In order to obtain a complete solution, in addition to appropriate initial and boundary conditions, it is necessary to define a further relation between the flow variables.

In this work two models were created using SPH solver with particle size equal to 1 mm. The two models consist of a warhead case (steel), base cover, fuze simulater (Al), and high explosive material (phelgmatized RDX). In the first model the parts of the warheads were surrounded by 25mm of sand to simulate partially a pit test for fragments recovery. The second model represents fragmenting of free OG-7 which was created to find out the effect of sand in fragments formation.
Material modeling of metallic, and high explosive material were typical to that done by M. A. Abdalla [3]. Table 1 shows the material modeling of sand. Fig. 2 represnt the graphics of the two model.

4. Fragmentation Analysis

Held has developed an experimental approach to represent the fragment mass distribution as a function of a number of fragments. The method of analyzing mass distributions by means of Held's formula is explained as follow. [4]

$$M(n) = M_o\left(1 - e^{-Bn^{\lambda}}\right). \tag{1}$$

Where:
M(n) - mass of fragments of number of fragments greater than *n*
M_o - total mass of fragments
B,λ - expiremental constants
To determine the values of B and λ it is convenient to take a logarithm of equation (1) so that in a logarithmic representation the point of intersection n=1, or log n=0, will give constant B directly on the ordinate axis, and exponent λ can be determined from the slope of straight line:

$$\log\left[\ln\left[\frac{M_o}{M_o - M(n)}\right]\right] = \log B + \lambda \log n. \tag{2}$$

5. Resluts And Disscution

The simulation rsulets show similar expansion behavior up to 52 µs for the two models, after that the sand in the first model appear to affect fragmentation process. The shape of fragments in fig. 3 at 80 µs becomes cylindrical against elliptical shape with sand free model.
The simulation results were compared with an experimental cubic pit test results by M. Sideeg [5] that filled by 1 m^3 of sand. The experimental and simulation results were analyzed by Held’s formula as shown in figures 4 and 5. From figure 5 λ values are found to be 0.656, 0.782, and 0.811 for Autodyn SPH with sand, snad free, and the experiment respectively. The B values for the same situation respectively are 0.0552 (log -1.258), 0.037 (log -1.432) and 0.0134 (log -1.872).
Figures show the same behavior of the results and verify that there is a good tendency for Autodyn SPH 3D to be used in comparison with pit test results.
Fig. 3 and 4 show clearly the effect of sand in experimental and simulated pit test in which small fragments weight decreased. The variation on results, between experimental pit test, and Autodyn SPH 3D simulation can be explained by the thickness of sand that used in simulation which less than the real case by about 1/20.
The conduct of pit test with the procedure used by M. Sideeg [5], needed to be modifed in order to minimize the effect of sand in fragments formation phase. This can be done by

increasing the space between the warhead and the sand, and if so, the amount of sand must be increased to absorb the increament in blast effect due to the empty space around the warhead.

6. Conclusion

In conclusion, the two models that created using Autodyn SPH 3D for OG-7 warhead, represent the effect of sand on fragments formation, shapes, number of fragments, and mass distribution. These models may reduce the highly cost of the pit tests. On the other hand, redesign of the pit test need to be revised to get more perfect results that similar to the real situation on land.

References

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Table 1 Sand Material Modeling Input Data

Equation of State	**Compaction**
Reference density [g/cm^3]	2.64100
Density No. 1 [g/cm^3]	1.67400
Density No. 2 [g/cm^3]	1.73950
Density No. 3 [g/cm^3]	1.87380
Density No. 4 [g/cm^3]	1.99700
Density No. 5 [g/cm^3]	2.14380
Density No. 6 [g/cm^3]	2.25000
Density No. 7 [g/cm^3]	2.38000
Density No. 8 [g/cm^3]	2.48500
Density No. 9 [g/cm^3]	2.58500

Density No. 10 [g/cm^3]	2.67130
Pressure No. 1 [kPa]	0.00000
Pressure No. 2 [kPa]	4.57700E+03
Pressure No. 3 [kPa]	1.49800E+04
Pressure No. 4 [kPa]	2.91510E+04
Pressure No. 5 [kPa]	5.91750E+04
Pressure No. 6 [kPa]	9.80980E+04
Pressure No. 7 [kPa]	1.79443E+05
Pressure No. 8 [kPa]	2.89443E+05
Pressure No. 9 [kPa]	4.50198E+05
Pressure No. 10 [kPa]	6.50660E+05

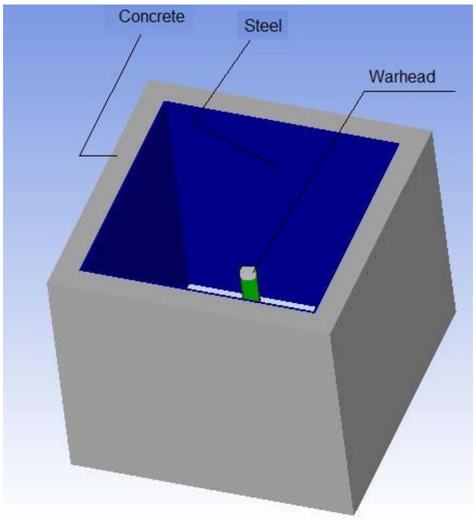


Fig. 1 Schematic Drawing of the Pit Test

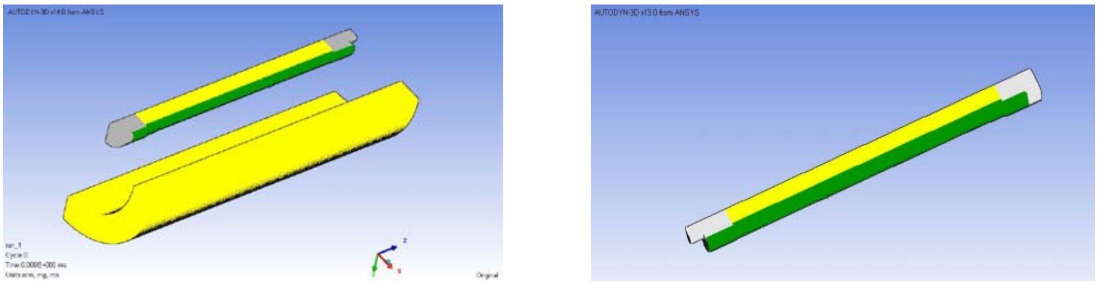
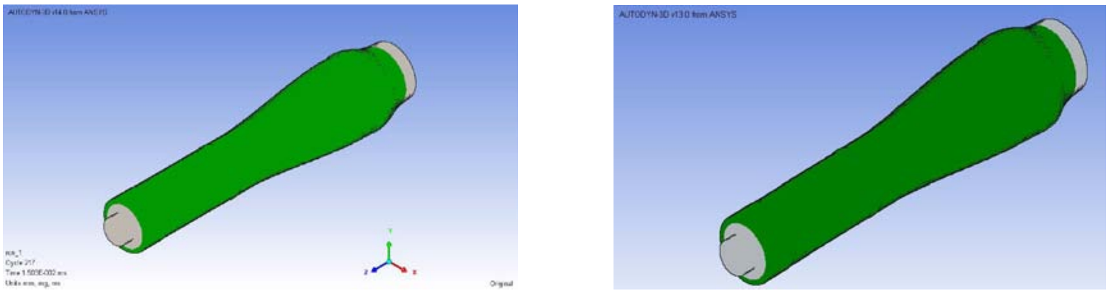
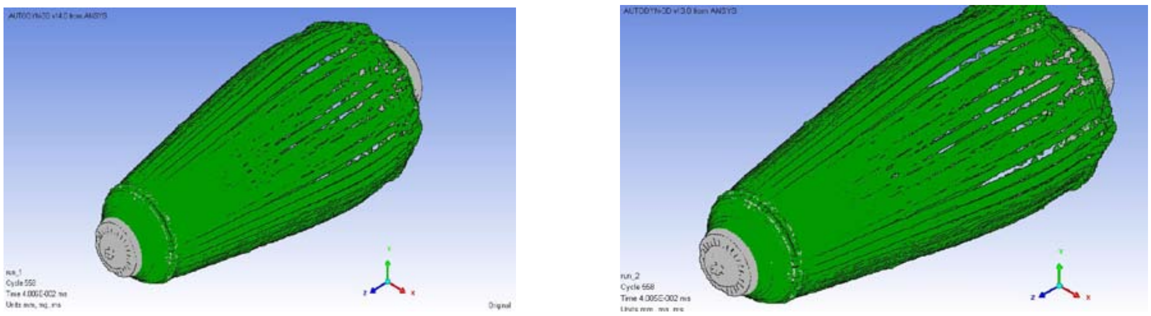


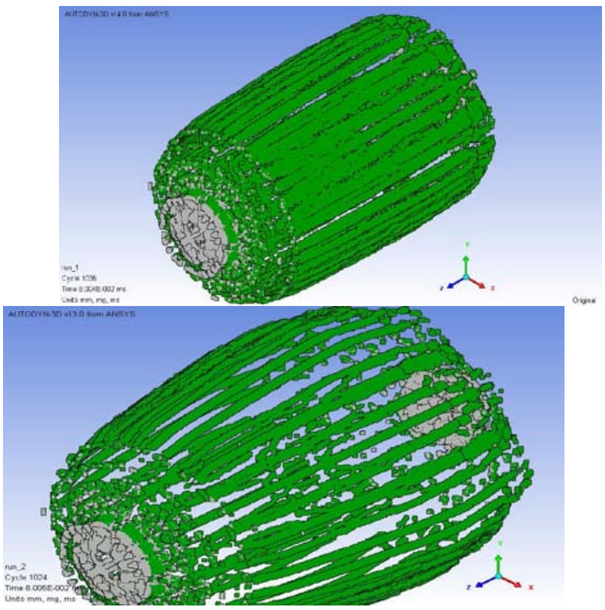
Fig. 2 Simulation Model For OG-7 Surounded By Sand to Left and Free of Sand to Right



15 µs



40µs



80µs

Fig. 3 Expantion and Fragment Formation Processes in AUTODYN SPH Solver at Different time,
Left Figures for Process with sand, and Right Figures for Sand Free Process

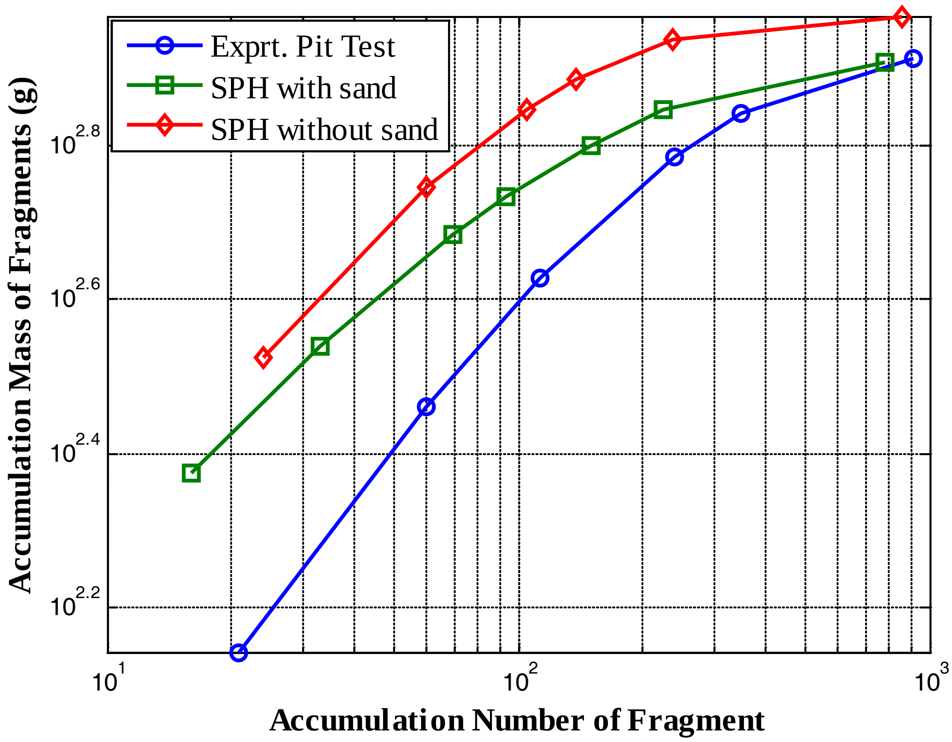


Fig. 4 A Logarithmic Number and Mass of Fragments Distribution

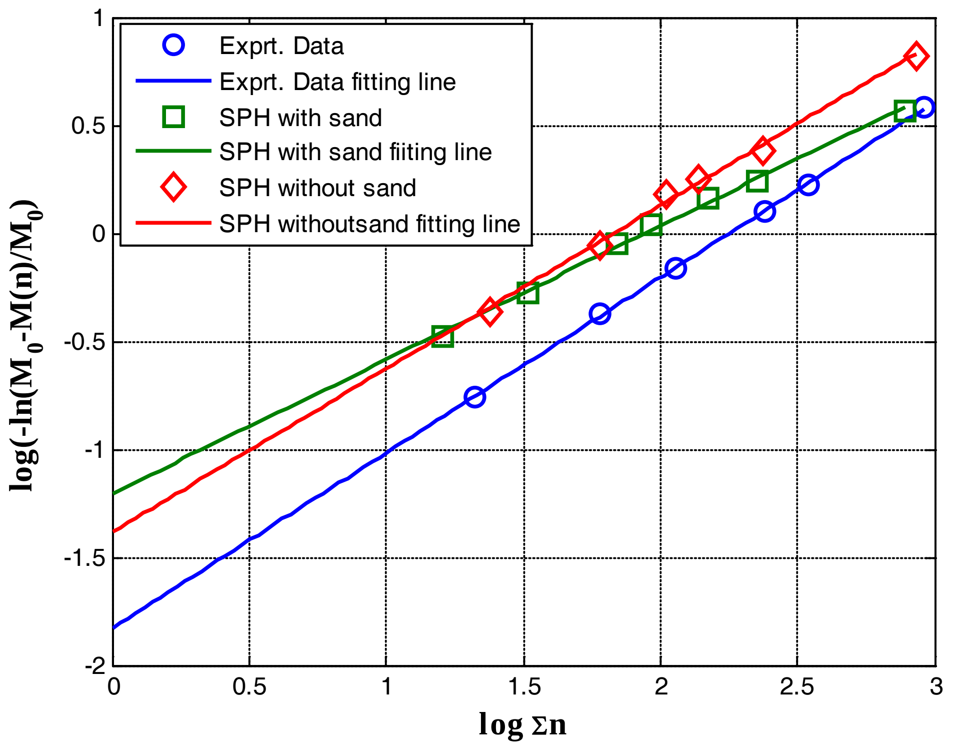


Fig. 5 A Logarithmic Relation to Find Constants B and λ