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# Simulation of FRP Composite Warhead Case Using Ansys- Autodyne SPH

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**Abstract**

*In this paper an 80 mm missile warhead metal case was replaced with composite material, based on fiberglass and carbon fiber as a reinforcement, and epoxy resin as a matrix material. A layer of 6.35 mm steel ball was used as preformed fragment. A numerical simulation using Autodyn SPH solver was created to find the killing range for both cases, fiberglass and carbon fiber. The simulation results were confirmed using experimental arena test. Killing range simulation result for fiberglass and carbon fiber were found to be 24 m, and 25 m respectively, while experimental arena was 19 m, and 25 m which consider as a good agreement.*

**Keywords:** Autodyne SPH, carbon fiber, fiberglass, killing range, MATLAB**,** 80 mm warhead**,** FRP

## 1. INTRODUCTION

The purpose of ammunition is to generate damage to kill target. Traditional ammunition has a steel casing which turns into dangerous fragments. These steel fragments may kill innocent bystanders outside of the target, which will bring political pressure to the government. In order to adapt the need of fighting in an urban environment without hurting innocent bystanders in the process, designers made a lot of researches on explosives, casing materials and configurations. [1]

The experimental design of “multi as one” warhead was provided by U.S. Army Ordnance Research. The effect of combined hollow charge, penetration and fragmentation charge/blast fragmentation charge together were studied by the foreign scholars, the domestic reports remain in the designed and optimized the structure of liner in armor warhead. The experimental studied on prefabricated fragments warhead and simulation studied on the molding effect and fragment velocity of anti-armor composite warhead. [2] For instance Zhang Jun et al. study on the capability of wounding of composite warhead which influenced by the thickness, liner size and diameter of spherical fragment through simulation [3]; Tan Duowang et al. studied on the decay rule of spherical fragment flight speed through experiment [4]. Lu Haitao studied on a large caliber anti-armor composite warhead which with prefabricated fragments surrounding it, through simulated on the different forms of prefabricated fragments, different shell structure and different liner's effect on the EFP and fragment formation and damaging capacity, found an assemble structure of the warhead which has better damaging capacity.[2]

Reducing collateral damage of the ammunition at target can be accomplished primarily by one of three methods. The first method requires that the ammunition explodes over target, continue downrange and impact in a zone assumed to be safe. The second is to use large parachutes to slowly bring down the ammunition just to the target. The third method is to fragment the ammunition into nonlethal pieces either during or after the payload is ejected. Among these methods the third method of fragmentation is the most attractive. [5]

### 1.1 Autodyne SPH Solver:

AUTODYN is a general finite element, finite difference, finite volume computer code for the non-linear analysis of solids, fluids and the interaction between the solid and fluids. [6]

SPH is a mesh-free 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. [7]

In an SPH solver, these partial differential equations are transformed into integral equations through the use of 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. 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. [8, 9] A sum of research projects has been well executed for simulating impact and penetration proceedings for solid structures using AUTODYN SPH solver. In this present paper, the SPH processor in AUTODYN is applied to the fragmentation warhead and compare with experimental arena test. [8, 9]

## 2. MATERIAL MODELING AND METHOD:

Two models of fiber glass epoxy and carbon fiber epoxy of 80 mm warhead case in this work were created using SPH solver with particle size of 1 mm. The model consists of base cover, simulated fuze (Al), and high explosive material (Comp-B). Figure 1 represent the model in SPH 3D.

The material modeling of metallic, fiber epoxy resin, and high explosive materials are shown in tables 1, 2, 3 respectively. The gauges (Gauge#1, Gauge#2, Gauge#3, Gauge#4) for calculating velocity of fragments were put in 60, 137, 235, and 255mm along the length of the model, as shown in figure 2.

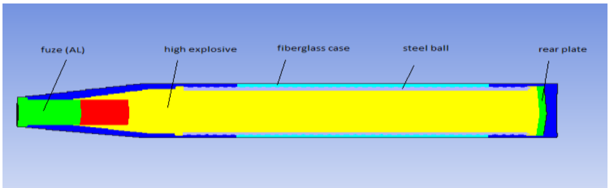


**Figure 1. Simulation model for 80 mm warhead with composite case parts illustration**

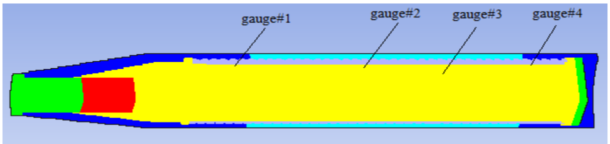


**Figure 2 The Iput Gauges**

**Table 1:** Material modeling for metals

| **Material** | **Steel 1006** | **AL 7039** |
|---|---|---|
| **Equation of State** | **Shock** | **Shock** |
| Reference density [g/cm3] | 7.896 | 2.785 |
| Gruneisen coefficient [none] | 2.17 | 2.00 |
| Parameter C1 [m/s] | 4569 | 5328 |
| Parameter S1 [none] | 1.49 | 1.338 |
| Reference Temperature [K] | 300 | 300 |
| Specific Heat [J/kg.K] | 452 | 875 |
| **Strength** | **Johnson Cook** | **Johnson Cook** |
| Shear Modulus [kPa] | 8.18E+07 | 2.76E+07 |
| Yield Stress [kPa | 3.50E+05 | 2.65E+05 |
| Hardening Constant [kPa] | 2.75E+05 | 3.37E+05 |
| Hardening Exponent [none] | 3.60E-01 | 4.1E-01 |
| Strain Rate Constant [none] | 2.20E-02 | 1.0E-02 |
| Thermal Softening Exponent [none] | 1 | 1 |
| Melting Temperature [K] | 1811 | 877 |
| Ref. Strain Rate [/s] | 1 | 1 |
| **Failure** | **Plastic Strain** | **Plastic Strain** |
| Plastic Strain [none] | 25 | 25 |

**Table 2 :** Material modeling for Fiber epoxy risen

| **Material** | **GLASS-EPOXY** | **GRAPH-EPOXY** |
|---|---|---|
| **Equation of State** | Puff | Puff |
| Reference density [g/cm3] | 1.84 | 1.568 |
| Parameter A1 [kPa] | 1.2130E+007 | 1.430E+007 |
| Parameter A2 [kPa] | 1.7980E+007 | 1.860E+007 |
| Parameter A3 [kPa] | 0.0000 | 0.0000 |
| Gruneisen coefficient [none] | 1.50E-001 | 3.0E-001 |
| Expansion Coeff. [none] | 2.50E-001 | 2.50E-001 |
| Sublimation energy [J/Kg] | 2.0930E+006 | 8.00E+005 |
| **Strength** | Von Mises | - |
| Shear Modulus [kPa] | 4.6750E+006 | - |
| Yield Stress [kPa] | 1.431E+005 | - |
| **Failure** | Hydro (Pmim) | Hydro (Pmim) |
| Hydro Tensile Limit [kPa] | -1.59E+005 | -1.50E+005 |

**Table 3 :** Material modeling for high explosive Materials

| **Explosives** | **Comp-B** | **Comp-A3** |
|---|---|---|
| **Equation of State** | JWL | JWL |
| Reference density [g/cm3] | 1.67 | 1.70 |
| Parameter A [kPa] | 5.2423E+008 | 6.1130E+008 |
| Parameter B [kPa] | 7.6780E+006 | 1.065E+007 |
| Parameter R1 [none] | 4.20 | 4.40 |
| Parameter R2 [none] | 1.10 | 1.20 |
| Parameter W [none] | 3.4E-1 | 3.20E-1 |
| C-J Detonation velocity [m/s] | 7.98E+003 | 8.30E+003 |
| C-J Energy / unit volume [kJ/m$^3$] | 8.50E+006 | 8.90E+006 |
| C-J Pressure [kPa] | 2.95E+7 | 3.00E+007 |

## 3. RESULTS AND DISCUSSIONS

The expansion process in different times for the two composite models is shown in **Figure 2**. The two models has the same expansion behavior up 20 µs, as the detonation wave reached the composite part.

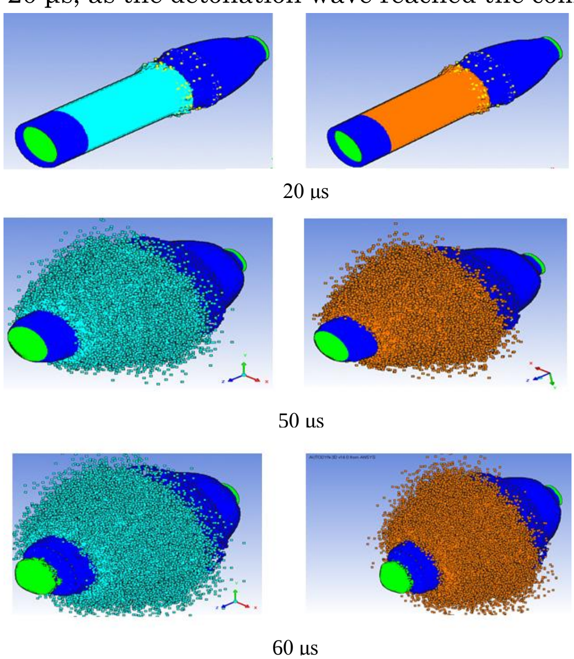


**Figure 2 Fragmentation Process in Autodyne SPH solver in Different time. Left Figures for fiberglass epoxy, and Right Figures for carbon fiber epoxy**

As the time increases, the differences between the two models become clear as shown in figure 3 to figure 8 which represent the fragment balls for each model, this is due to the carbon fiber high strength over fiberglass. The simulation results show similar expansion behavior up to 50 µs for the two models, and then, the first model shows the effect of explosive energy to the glass fiber expansion process, figure 2. Figures 3 and 4 represent the velocity versus time at the four gauges along the length of warhead. From these figures we can see velocity increases with time as the detonation velocity propagate through the explosive charge, this velocity gives the steel balls their kinetic energy to accelerate and fly to the target.

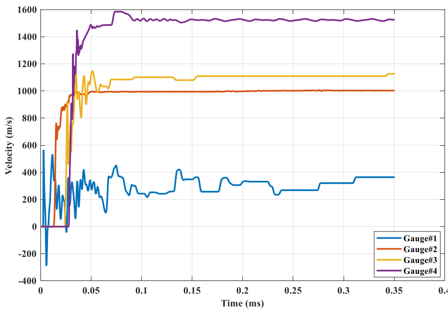


**Fig. 3 Velocity vs. Time of Fiberglass Case**

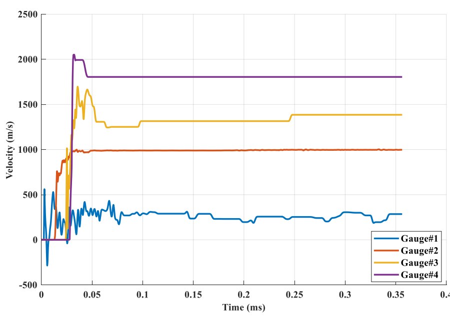


**Fig. 4 Velocity vs. Time of Carbon Fiber Case**

Figure 5 to figure 8 show the comparison between the velocity of fiber glass model and carbon fiber model at different gauges in which carbon fiber case give velocity greater than fiber glass case.

After analysis of The simulation results and figures 9 to 12 and the comparisons of results **for arena** test of 80 mm warhead, it found that the lethal range are 24m and 25 m of fiberglass and carbon fiber model respectively. The lethal range of the two models in experimental arena test was 19, and 25 meter respectively. The experimental and simulation results were analyzed by MATLAB math work. Figures below show the same behavior of the results. The variation on results, between experimental arena test, and Autodyne SPH 3D simulation can be explained by the difference in shell body materials used in simulation and experimental work those are not identical.

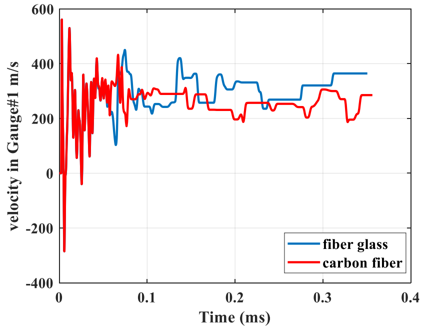


**Fig. 5 Fiberglass and Carbon Fiber velocities in Gauge#1**

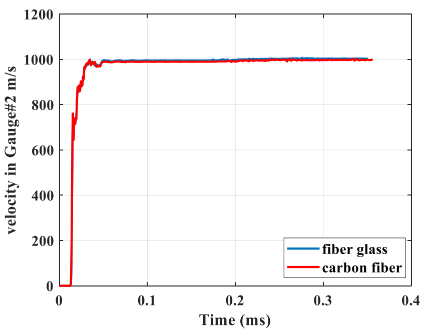


**Fig. 6 Fiberglass and Carbon Fiber velocities in Gauge#2**

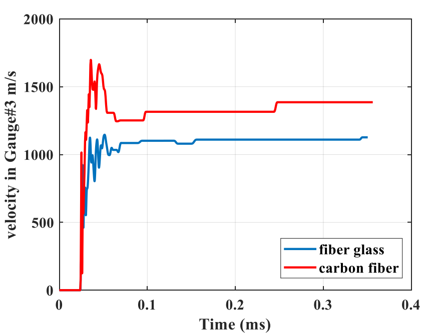


**Fig. 7 Velocity Comparing of Fiberglass and Carbon Fiber in Gauge#3**

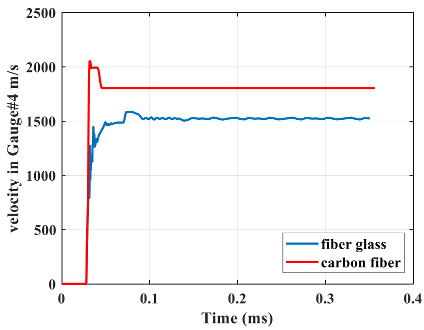


**Fig. 8 Velocity Comparing of Fiberglass and Carbon Fiber in Gauge#4**

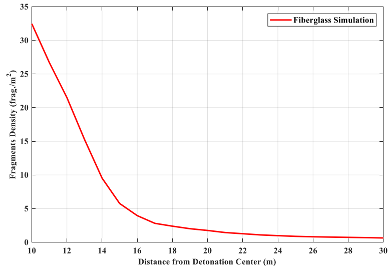


**Fig. 9 Fiberglass model simulation result**

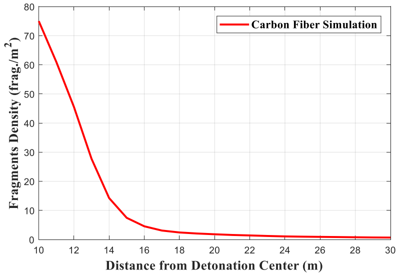


**Fig. 10 Carbon fiber model simulation result**

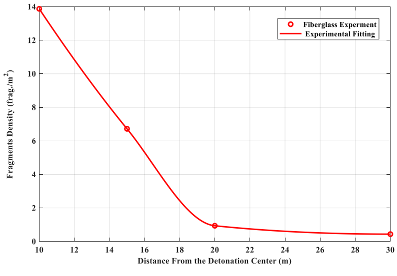


**Figure 11: Fiberglass case arena test result**

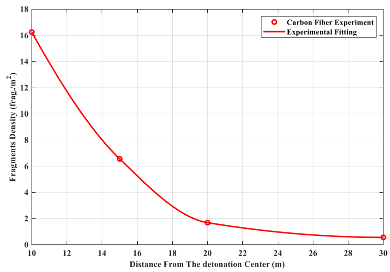


**Figure 12: carbonfiber case arena test result**

## 4. CONCLUSION:

Simulation results by Ansys Autodyne SPH 3D give good agreement to experimental results. Carbon fiber case gives high lethal range than fiberglass case in both simulation and experimental situations. The lethal range of fiberglass case and carbon fiber case are 24, 25 meter in simulation, and 19, 25 meter in experimental respectively. The results of carbon fiber case are closely same in simulation and experimental. Lastly it be concluded that Autodyne SPH 3D is a good method to predict efficiency of warhead instead of high expensive experimental tests.

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