ENHANCED FRAGMENTATION MODELING

Peter Rottinger*, Richard Fong, William Ng
U.S. ARMY ARDEC
Picatinny Arsenal, NJ, 07806

ABSTRACT

Enhancing the fragmentation capability of current and future projectiles is critical to meeting the armies Future Combat Systems, FCS, requirements. In order to meet these requirements, enhancements to the fragmentation capabilities of these future weapons is needed. Only through the use of the latest modeling tools can these goals be achieved. The U.S Army Armament Research and Development Center, ARDEC, has continued its efforts to develop its modeling capabilities further to generate these optimized warheads.

1. INTRODUCTION

Over the years ARDEC has continued to develop its modeling capability for generating enhanced fragmentation warheads. This capability has been developed for a wide variety of munition types and sizes. Much of this capability is in the use of finite element and statically based codes. These cover both the predictive capability of the fragmentation phenomena and the on target lethality effects.

2. TECHNICAL APPROACH

The development of a modeling capability requires a multistep process. Firstly, whether you are starting a new design or advancing an existing technology the appropriate modeling tools must be selected. This is usually a choice between using a finite element or statistical code. The next step is to gather test data. Existing test data of the same or similar design should be used to validate the model and calibrate as necessary. If this data is unavailable testing must be completed. Care must be taken ensuring the proper test setup so as to achieve the most useable data to verify the model. From this point the model can then be calibrated. In many cases several iterations of testing and calibration will be necessary to achieve a reliable model.

3. NUMERICAL MODELING

There are several modeling codes that can be used to properly simulate enhanced fragmentation warheads. The selection of the right code will be critical to modeling success. The code selection depends strongly on the fragmentation mechanism. For example, natural fragmentation is predicted best with a statistical code fed with large amounts of test data. For preformed fragmentation a Lagrangian based code, such as Ls-Dyna works well. For fragmentation techniques that generate large localized deformations, an Eulerian based code, such as CTH, will probably work best. Of course these are only guidelines and there is overlap as to which code is best.

No matter which of finite element codes is selected the refinement of the mesh is critical. A mesh that is insufficiently refined can add artificial stresses, resulting in an erroneous fragmentation prediction. It can be useful to run the same model with varying refinement to identify this sensitivity.

4. TESTING FOR MODEL VALIDATION

In order to validate any fragmentation model it is necessary to obtain as much of the following test data as possible:

1. Fragment size including length, width, height, and mass.
2. Fragment distribution including fly-out angles and pattern.
3. Fragment velocities and velocity gradients.
4. Fragment counts.

Depending on the design goal for the warhead, all of this data may not be required. Conducting all of these tests can be costly and in some cases recovering all of the data may require several tests. Existing test data from similar tests should be used when applicable.

To gather the required data, a variety of equipment will be needed. For dimensional analysis and fragment counts a water pit test or Celotex recovery bundles to soft recover the fragments can be used. For recovering the velocity and fragment fly-out data the use of multiple x-rays can achieve reliable results. For recovering the pattern data typically a steel target plate is setup to receive impacts.

5. TEST DATA

To demonstrate the modeling compatibility, select groups of model vs. test comparisons are described. These include a variety of common fragmentation techniques developed over many years. The discussed fragmentation phenomena are natural fragmentation, pre-scoring, preformed fragments and Multiple Explosively Formed Penetrators, MEFP’s.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **DEC 2008**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Enhanced Fragmentation Modeling**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. ARMY ARDEC Picatinny Arsenal, NJ, 07806**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002187. Proceedings of the Army Science Conference (26th) Held in Orlando, Florida on 1-4 December 2008, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**4**	

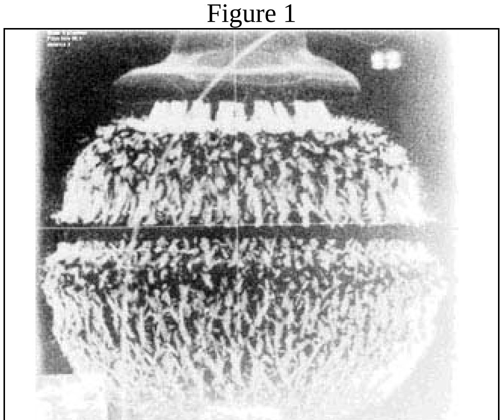
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

5.1 Natural Fragmentation

With natural fragmentation the projectile consists of a solid shell, usually steel, that is allowed to breakup naturally without any enhancements. This results in a large variation in fragment size and distribution with many more large fragments than desired, figure 1. This large variation in fragment size and distribution results in sub-optimal lethality due to either significantly overmatching or under-matching of the desired targets. The typical method of validating the performance of these warheads is to complete a large number of tests and rely mainly on statistical modeling tools.

Properly modeling the breakup of this type of warhead prior to testing is difficult and less accurate with the use of finite element codes. The fragmentation that is predicted in these codes is highly dependent on the refinement of the Eulerian or Lagrangian mesh.

Figure 1

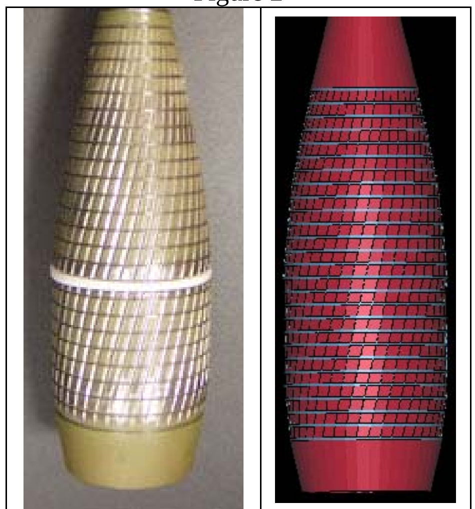


Natural fragmentation of 60mm mortar

5.2 Pre-scoring

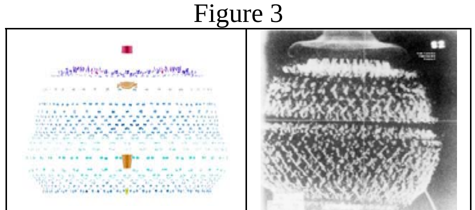
A good example of the pre-scoring technique can be seen in a modified 60mm mortar. The mortar was scored with a pattern to generate 0.5 gram fragments on average. By scoring the mortar it introduced stress risers giving the warhead a preferred location to fracture. A scoring depth of 30% of the shell thickness was selected with a 60 degree chisel cut type. This configuration was selected based on past experience and reports. Two codes were used to model these designs. Ls-Dyna was used to show the expansion of the fragmentation pattern assuming breakup would occur. This was used to predict the on target pattern and velocity gradient. The model was meshed so that the contours of the geometries would align to the mesh, see figure 2. This way the scored areas could be dropped at the same time as the explosive and the fragments would be free to expand. To predict whether the fragments would breakup along the scoring lines the item was also run in CTH as well. Figure 3 shows the predicted fragmentation breakup side by side with an X-ray from the test. You can make out the cross hatched fragmentation pattern from the X-ray. In the x-ray you will also notice a distortion in the fragmentation pattern. This is due to the feature for the obturating ring. A target plate was also setup at a 5 foot standoff to capture the fragmentation pattern, see figure 4. Looking closely at the target plate it is also possible to make out the pattern.

Figure 2



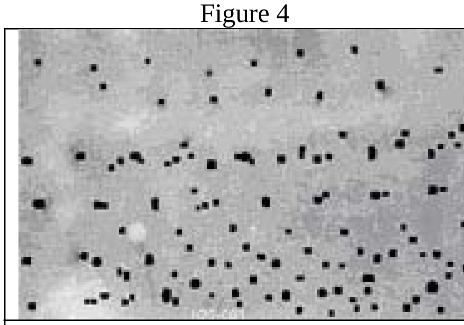
Hardware | Simulation

Figure 3



Simulation | X-ray

Figure 4



Target Plate

For a 155mm program, tests were setup to gain a better understanding of the scoring depth needed to cause full breakup of a shell. These tests were then used to calibrate the CTH simulation. A series of five tests were prepared. The series consisted of steel shells which were cut circumferentially with slots. Each of the five shells were cut at different depths ranging from 15% - 75% of the shell thickness. With the circumferential slots, the fragmentation showed continual improvement as the slot depth got deeper. The Figure 5 shows the modeling compared to an x-ray from the test. A reasonable match can be seen. Figure 6 shows recovered fragments from these tests. You can clearly see the fragments from the lower depth cuts resulted in larger fragments since the cut depth was not deep enough.

Figure 5

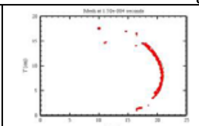
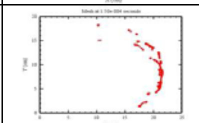
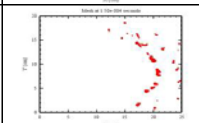
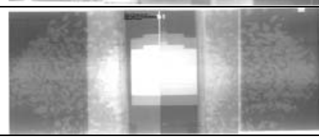
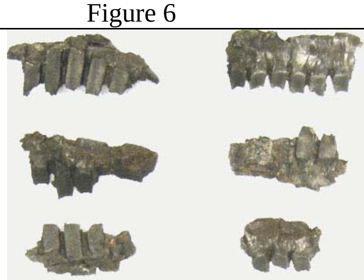
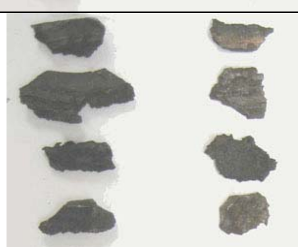
15%		
45%		
75%		
Cut Depth	2D Simulation	X-ray

Figure 6

15%	
45%	
75%	
Cut Depth	Recovered Fragments

5.3 Pre-formed fragmentation

Testing was completed for a variety of warhead programs that incorporated a pre-formed fragmentation warhead. For one program a 3 sided warhead was desired that could fill a tight area with a large amount of fragments. The selected warhead consisted of a liner containing 25 fragments high x 11 fragments wide, see figure 7. The liner was curved inward to focus the fragmentation to the desired width. The fragments were bonded to a thin aluminum plate, which acted as a pusher plate, preventing explosive from venting through the fragments too early.

Figure 7

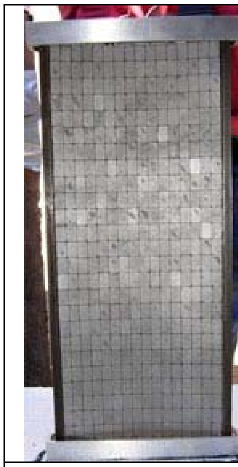
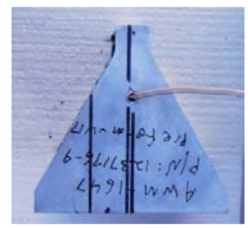
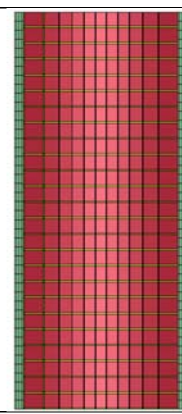
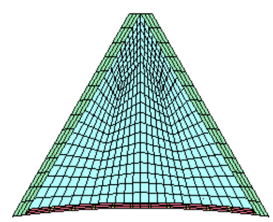
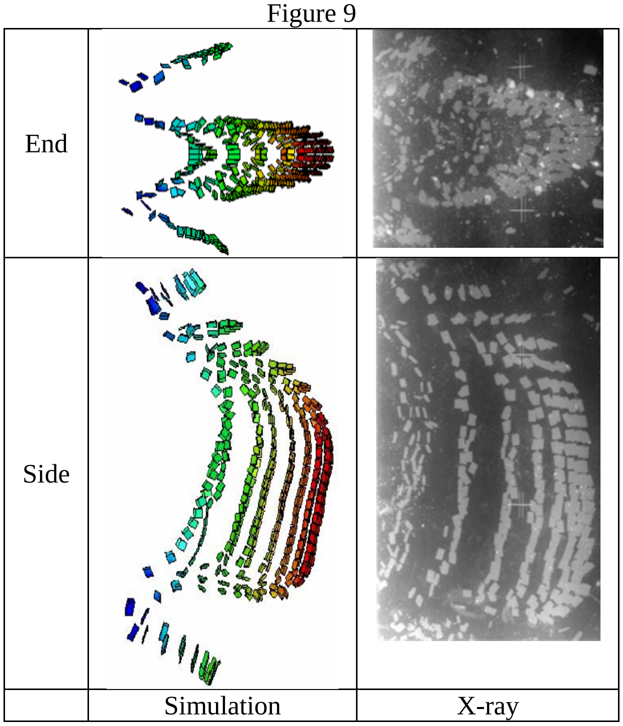
	
Hardware Front	Hardware Top

Figure 8

	
Front View	Top View

The figure 8 shows a Lagrangian mesh from Ls-Dyna3D of this warhead. The mesh was zoned up to align with each fragment and an artificial drop zone was added between each fragment. The drop region is necessary to prevent the explosive in the simulation from venting through the liner. Since the drop zone is artificial, it was kept as small as possible to minimize influencing the results. The mesh was kept as square as possible in the locations close to the liner to improve results. The explosive and housing material were deleted from the simulation once the explosive energy had dropped off and is no longer accelerating the fragments further. The use of M&S enabled the designer to predict the fragmentation and uniformity of the pattern, see figure 8.

Figure 9



5.4 MEFP's

Another form of controlled fragmentation is through the use of Multiple Explosively Formed Penetrators, MEFPs. MEFP liners consist of a dimpled surface whose geometry is defined typically with intersecting spheres. By controlling these intersections the MEFP is capable of generating very controlled on target patterns. Through the use of modeling and simulation the shape, velocity and pattern of the fragments can be predicted. In most instances a 3D Lagrangian model can be setup that yields reasonable results in the shortest time. As in previous models the mesh is again contoured to follow the curvature of each individual MEFP as close as possible, see figure 10. In some cases the addition of an artificial drop zone is used to reduce run time and generate a cleaner model. When generating more complex fragmentation patterns where the MEFPs break apart at different times the use of a failure strain to breakup the fragments or the use of an Eulerian code results in better predictions. Ls-Dyna3D has been shown to be extremely useful in predicting the trajectories of each fragment. Figure 11 shows this control and predictive capability of the code.

Figure 10

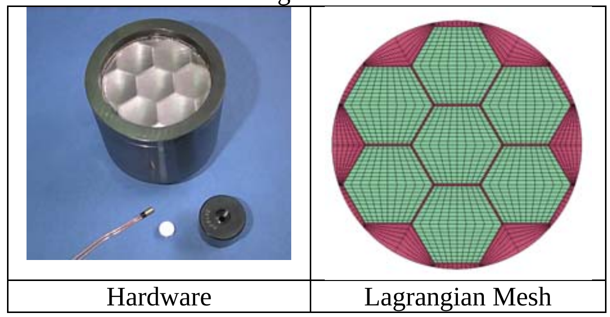
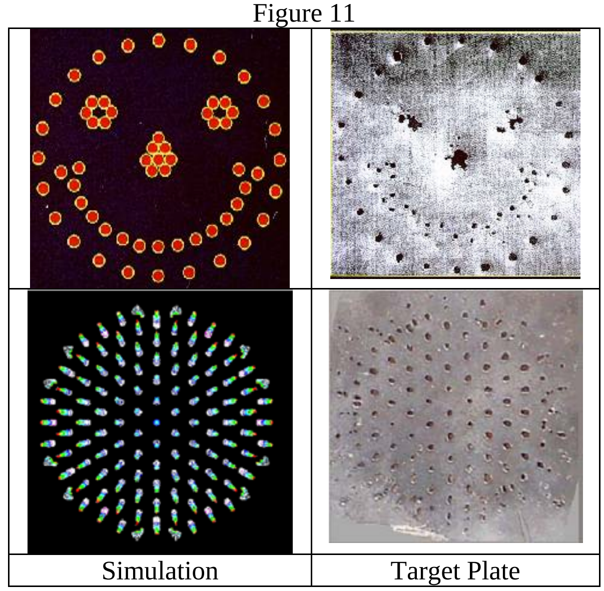


Figure 11



CONCLUSIONS

A modeling capability exists for a variety of enhanced fragmentation techniques. These models have been shown to be valid and reliable through extensive testing. As new modeling tools become available they will be evaluated to provide further enhancement of the current capabilities. Enhancing our modeling capability to provide the soldier with the best munitions will continue to be a major focus at ARDEC.

REFERENCES

Held, Manfred. "Fragmentation Warheads." Tactical Missile Warheads. Ed. Joseph Carleone. **Progress in Astronautics and Aeronautics**/A. Richard Seebass, editor in chief, Washington D.C.: American Institute of Aeronautics and Astronautics, Inc., 1993. 155 vol. 387-464.