COMPUTER MODELLING OF FULL SIZE FRAGMENTING AIMABLE WARHEADS USING AUTODYN-3D

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As trials costs continue to rise it becomes increasingly attractive to design and assess fragmenting warheads using a combined approach of numerical analysis and prototype test firings. This paper describes an integrated methodology where three dimensional Computer Aided Design (CAD) data can be used to create prototype warheads for testing, and as an input to define the warhead geometry in a numerical model. The 3D numerical simulation can produce complete fragment performance data in a format suitable for use in vulnerability modelling tools. The prototype trials can be used to verify the numerical results and confirm the warhead's performance. This integrated approach allows fast and efficient analysis of fragmenting warheads.

INTRODUCTION

Modern requirements for increased warhead lethality with decreased mass, together with their use in complex systems, mean that many systems are now aimable. This may be achieved in an axi-symmetric warhead by means of multiple detonation points offset from the symmetry axis, or the warhead may use a novel geometry. Both of these aiming methods lead to strongly three dimensional geometries that can only be accurately solved using three dimensional analysis tools. For novel warhead geometries, the complex initial fragment distribution and initiation systems often lead to strong interaction between fragments and this interaction can be extremely important in determining the final fragment distribution. For this reason it may not be appropriate to model the fragments in this type of warhead as a single porous layer as has been previously proposed[(1)], and all of the individual fragments must be represented in the numerical model.

CONCEPT DESIGN PROCESS

This paper describes an integrated experimental and numerical analysis approach to assessing fragmenting warhead concept designs. A flow chart describing the stages in this process is shown in Figure 1.

The process starts with the creation of an engineering drawing of the concept warhead. The geometry of the warhead can then be exported for use in the preparation of physical prototypes and numerical models of the warhead.

Prototype Manufacture and Testing

A physical model of the warhead structure is created using the stereolithography rapid prototyping system which was originally demonstrated in 1982[2]. DERA has operated an SLA 500/30H Stereolithography Rapid Prototyping machine since May 1993. Using the 3D CAD model of the geometry a representation of the structures surfaces is created using triangular facets. Based on this data the component is oriented, supports are added, and the component is 'sliced' in the horizontal plane. The 'slice' data is used to control the movement of an ultra-violet laser focused onto the surface of a vat of photocurable resin. After each thin layer of solidified resin has been added, the component is lowered into the resin vat ready for the next layer to be added. The final stages in the process are the removal of the supports, washing of the component, and final curing in an ultra violet oven. This process can be used to produce very complex geometries that would otherwise be very expensive to produce in the limited quantities required for concept trials. An example of a complex component which is easy to produce using this process is shown in Figure 2, which shows three equal length initiation tracks moulded into the outer surface of a research warhead. The final stages of the prototype manufacture process are filling the structure using a castable explosive, and bonding the warhead fragments into position.

Various techniques can then be used to determine warhead performance. Flash x-rays can record snap shots of the fragment positions in a given plane at a pre-set time after warhead initiation, velocity screens can be used to determine fragment velocities at set distances from the warhead, and an arena of straw board packs can be used to determine the fragment distribution and approximate impact velocities at a given distance from the charge. It can, however, be very time consuming to experimentally determine performance data for each of the many hundreds of fragments in a full size warhead.

The results of numerical analyses are most valuable if they closely correlate with experimental firings. The analysis methodology and numerical tools used here were compared with several experimental warheads and gave encouraging results[3]. This comparison showed that 3D numerical tools were necessary to accurately predict the performance of 3D fragmenting warheads. A comparison between a tracing taken from an x-ray of an experimental firing and fragment locations from an equivalent numerical simulation are shown in Figure 4 and Figure 5. Figure 3 shows typical post experiment distorted fragments caused by interaction between the initially cubic fragments. Once confidence has been gained in the accuracy of the analysis methodology, the analyses can be useful in understanding the fundamental mechanisms that lead to a particular warhead characteristic.

3D Numerical Modelling

Recent advances in numerical techniques, and increasingly powerful desktop computers, mean that it is now possible to analyze full size fragmenting warheads containing many hundreds of discrete fragments using a personal computer. All of the analyses reported here used Lagrange grids to represent the charge and the fragments; with each discrete fragment represented in the mesh so that all of the fragments could interact as they would in reality. Relatively simple geometries such as cylindrical or conical charges can be set up using the pre-processor built into AUTODYN[4]. More complex novel warhead geometries can be created using the True*Grid*[5] grid generation package based on CAD design data. Importantly, True*Grid* incorporates powerful geometry manipulation capabilities for easy design modifications or parametric studies. Essential features of the numerical solution within AUTODYN are an efficient and robust contact algorithm which can track the many contacting surfaces between adjacent fragments and between the fragments and the explosive, and an erosion algorithm that allows highly distorted numerical cells to be automatically removed from the explosive or the fragments.

An example 3D warhead geometry, which consists of two truncated conic sections, is shown in Figure 6. The maximum diameter of the charge is 120mm, tapering to a minimum diameter of 90mm with a total length of 150mm. The charge is Composition B with a mass of 2.3kg. The curved surfaces of the charge are covered with 3.5g steel cubes with sides of 7.6mm. Moving away from the mid length of the warhead, the first three rows contain 36 fragments. The complete warhead contains 816 fragments with a total mass of fragments of 2.9kg. The model did not include a case. Two initiation options were considered. In the first the charge was simultaneously initiated at the center of both end faces. This meant that three symmetry planes could be used to reduce the size of the numerical model to 1/8 of the complete geometry, and the model took approximately 24 hours to run on a 300MHz Pentium II PC. The second case used three initiation points on a vertical line down the surface of the charge. Points were placed at both ends and at the mid length of the charge. This model used two symmetry planes so that 1/4 of the geometry was included in the model, and took approximately 48 hours to run on a 300MHz Pentium II PC.

The geometry of the warhead, and the location of the ignition points, mean that the majority of the fragments converge towards the mid plane of the system for both initiation systems. They then interact, and some fragments undergo significant distortion before travelling in a radial direction in a plane normal to the warhead's axis. A plot of fragment trajectory angle from the warhead mid-plane for the end initiation case is shown in Figure 7, with negative angles showing that the fragment is moving towards this plane. At this time the fragments closest to the mid-plane have started to interact. Figure 8 shows absolute fragment velocity at 100μs for the end initiation case. The two rings of fragments closest to the mid-plane have been compressed by their neighbours and ejected with a significantly enhanced velocity of about 2200m/s. The velocity of the remainder of the fragments drops from 2000 to 1100m/s with increasing distance from the warhead's mid-plane. Absolute velocities for the second initiation case are shown in Figure 9. The change in initiation pattern changes the fragment behaviour at the mid length of the warhead compared with the end initiation case, and gives a peak velocity in the fragment columns opposite the initiation points of about 2200m/s dropping to about 1900m/s adjacent to the initiation points.

After completion of the analyses, fragment position and velocity data can be produced in any desired format. For example, a tabular data file suitable for direct input to vulnerability codes, which contains the coordinates of the centre of each fragment and the fragment velocity components.

CONCLUSIONS

This paper has described an integrated testing and numerical analysis system for the assessment of fragmenting warhead concept designs.

This integrated approach can lead to significant programme time and cost savings by efficient creation of prototypes and a reduction in the number of trials due to the increased reliability of numerical predictions.

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(4) Century Dynamics, "AUTODYN Version 3.0 Documentation", 1997
(5) XYZ Scientific Application Inc, "True*Grid* User's Manual", 1997

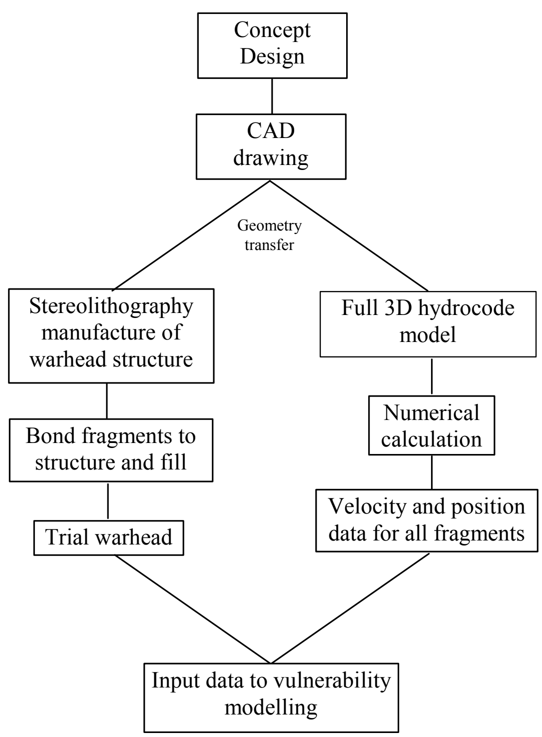

Figure 1 Integrated Concept Design Process

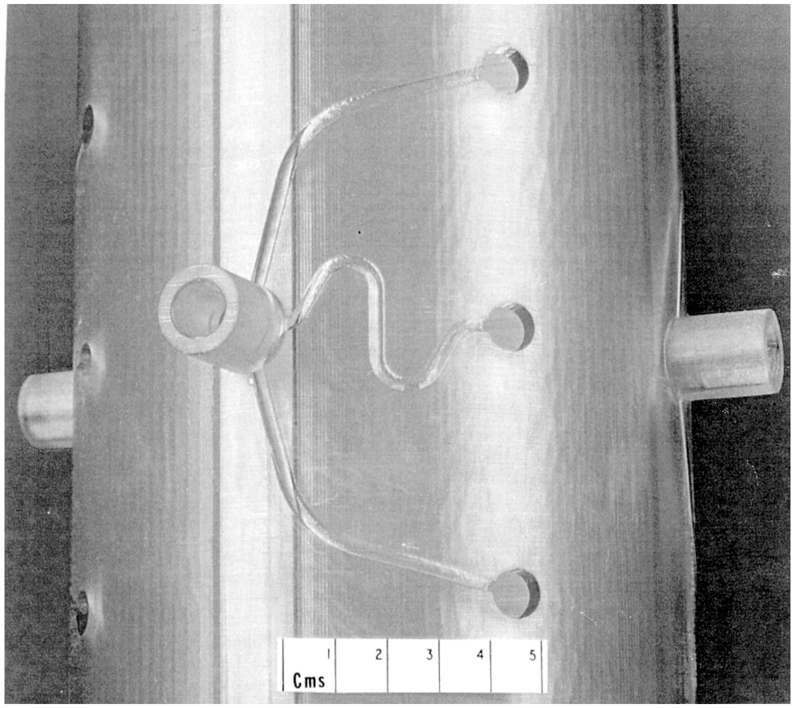

Figure 2 Rapid prototype component showing initiation tracks

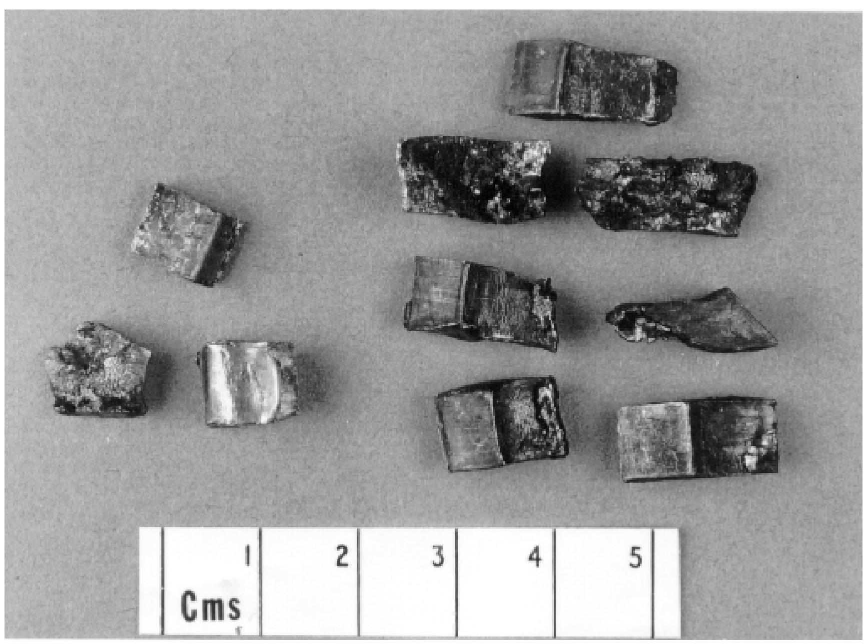

Figure 3 Post Firing Fragment Deformation

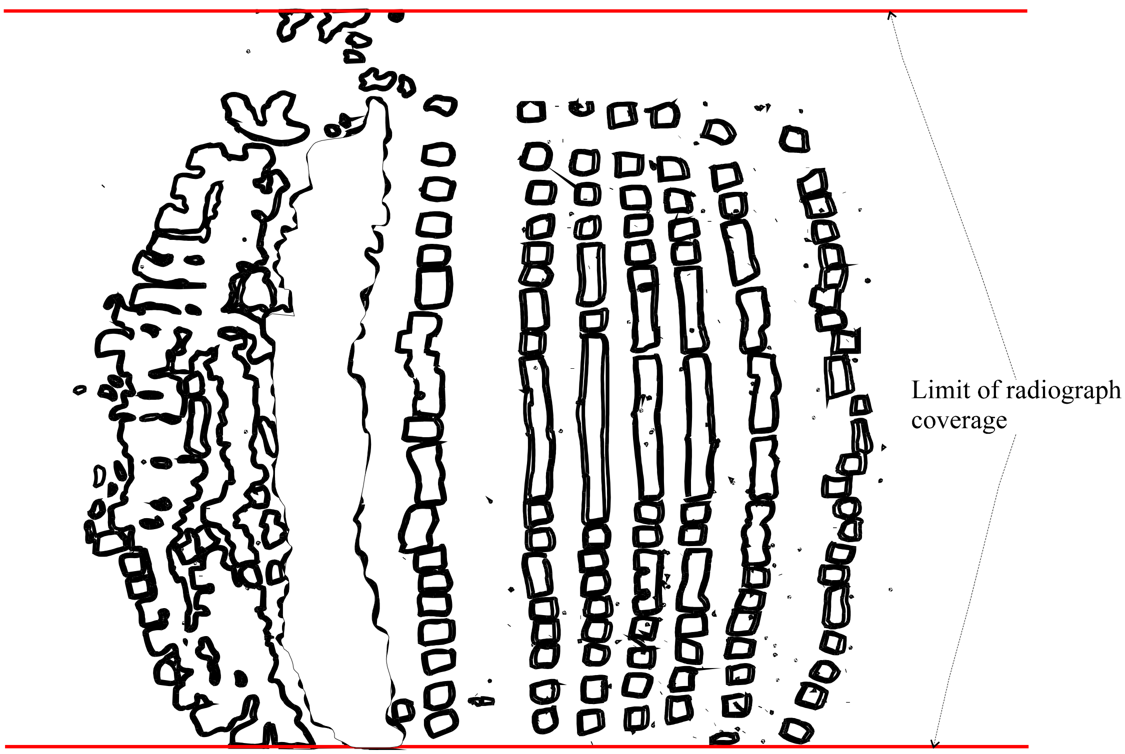

Figure 4 Experimental Fragment Locations

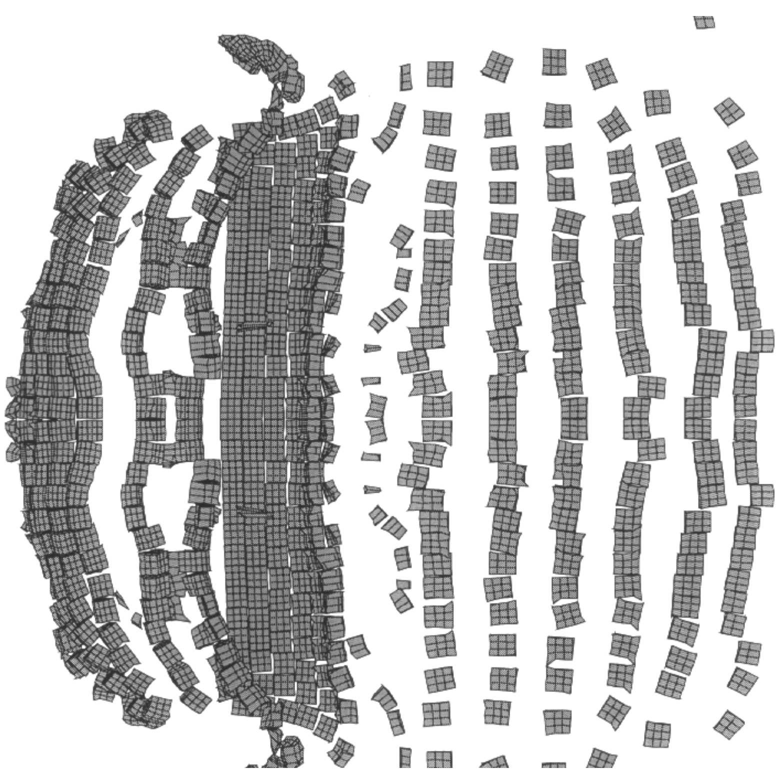

Figure 5 Calculated Fragment Locations

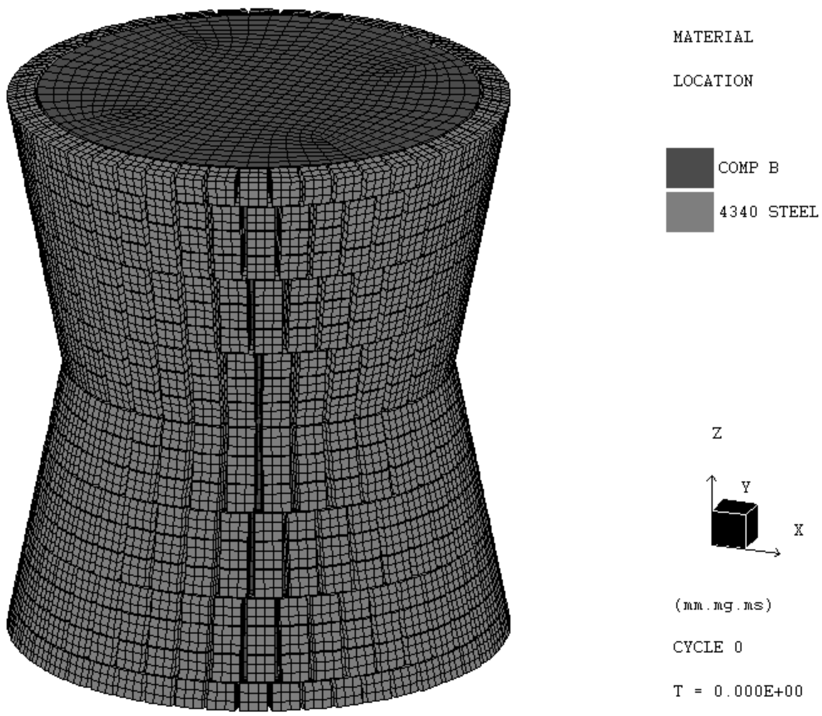

Figure 6 Example Warhead Geometry

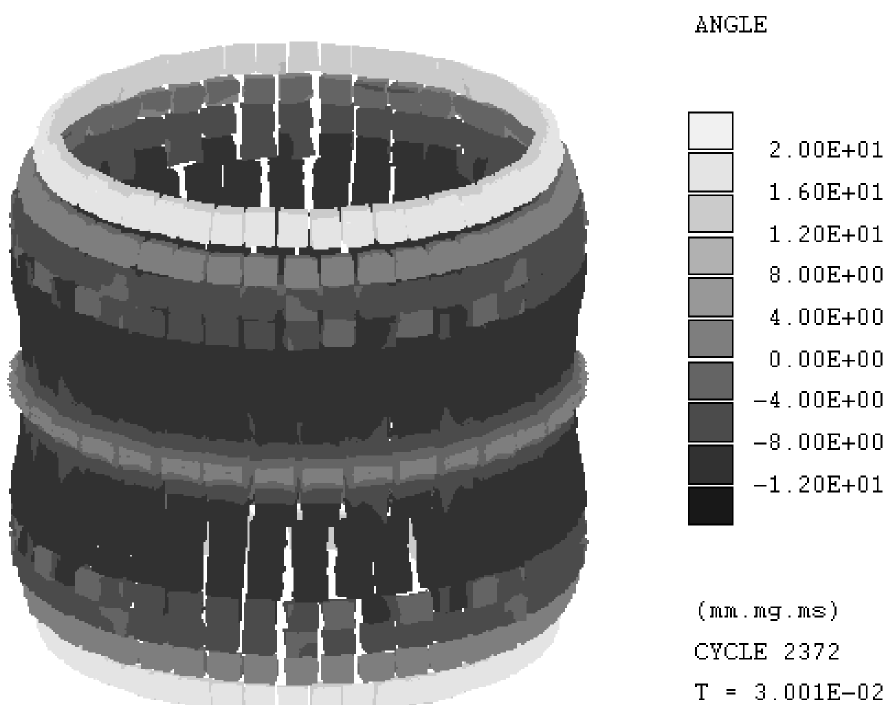

Figure 7 Fragment Ejection Angles for End Initiation Case at 30μs

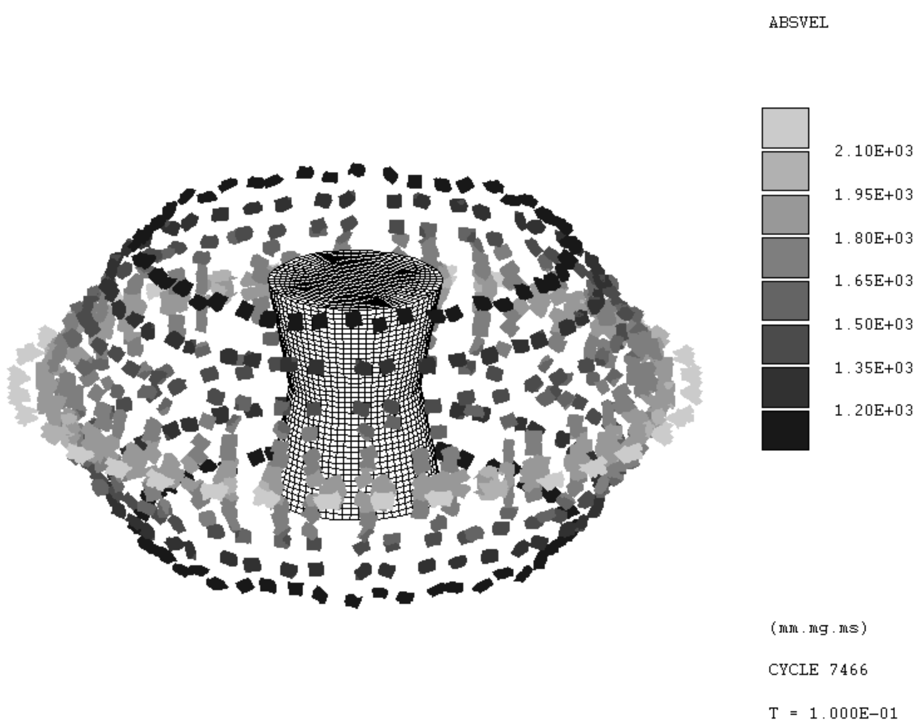

Figure 8 Absolute Fragment Velocity for End Initiation Case at 100μs

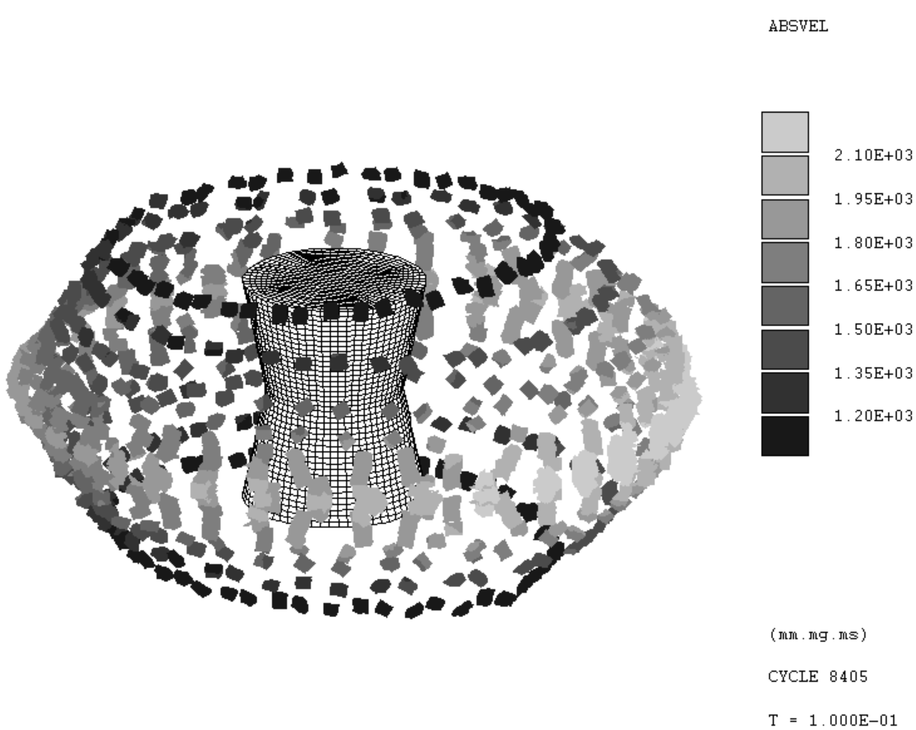

Figure 9 Absolute Fragment Velocity for Side Initiation Case at 100μs