

# The research about the effect of initiation point to the forming of cutting MEFP and the penetration characteristics

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**Abstract.** In order to study the effect of the initiation point position to the molding of cutting MEFP, divergence angle and 45 steel penetration, we used LS-DYNA dynamic finite element program, and adopted the fluid solid coupling method, then we made numerical simulation about the process of the formation of cutting MEFP and penetration plate, and the simulation results fit with the tests results. The research indicates that the head velocity of the formation of MEFP in bottom initiation increased by 27% than in top initiation, tail speed increased by 14%, divergence angle reduced by 39%, and penetration aperture reduced by 12%. The 25 sub-EFP formed by the warhead are possessed with certain quality and direction, and can penetrate 45 steel target of 9mm in 8m distance.

## 1 Introduction

Multi shaped charge warhead is allocating several shaped charge structures on cylindrical charge surface, after the explosion it forms jet or projectile flying around. Multi shaped charge warhead forming explosive is referred to as MEFP warhead. MEFP is mainly divided into combined, integrated and cutting. Cutting warhead is adding a metal cutting net in front of the single shaped charge, putting the formed EFP into MEFP. Cutting warhead can achieve conversion among a single EFP、JPC and cutting MEFP [1-3].

Guo Meifang [4] preliminarily analyzed the effect of material and structure of liner, the type of explosive and loaded constitution to multimode warhead performance, explaining the importance of multimode warhead technology. Li Weibing [5] analyzed the initiation of the main charge central point and the detonation wave propagation about the apex initiation of liner, achieving the conversion between the rod type EFP and EFP. Zhang Yangyi [6] analyzed a loaded constitution ,ten shape cutting mesh, which is appropriately installed in front of a liner .It indicated that the loaded constitution can penetrate 6mm thick 45# steel at 48m, and can be used to combat helicopters 、light armor and so on. These studies focused on the effect of numerical simulation analysis of figure ten mesh cutting MEFP and the position of the initiation point of EFP to the mode conversion of EFP, but didn't study the effect of the position of the initiation point to the formation of mesh cutting MEFP.

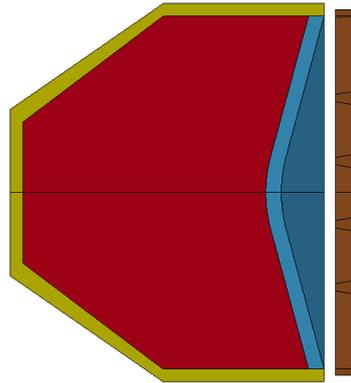
In this paper, we make numerical simulation about appropriately installing a cutting mesh warhead structure in front of the liner, and analyze the effect of the axial distance between the initiation point and the top of the liner to the forming of MEFP, then achieve a projectile serves multiple purposes. It has certain reference value for further study of the multi-mode warhead.



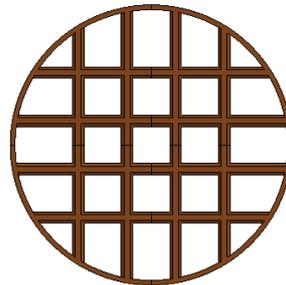
## 2 Calculation model and the selection of parameter

### 2.1 The structure of warhead

The designed structure of mesh cutting MEFP warhead is shown in Figure 1, which is comprised of liner, explosives, shell and mesh. The bore of the warhead power charge is 140mm, the height is 112mm. The liner is arc cone, whose angle is  $150^\circ$ , curvature radius R is 56mm and wall thickness is 5.88mm. There is a hole, which is 7.2, at the top of the liner. Mesh structure is shown in Figure 2, the rack section is ladder-shaped, the upper width is 3mm, the width is 6mm, the distance between the two meshes is 22mm. The material of the warhead shell is 45 steel, and the wall thickness is 4mm.



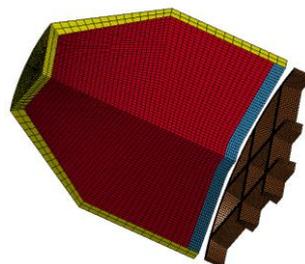
**Figure 1.** The structure of Cutting MEFP warhead



**Figure 2.** The mesh structure of cutting MEFP warhead

### 2.2 The finite element model

The ANSYS/LS-DYNA program is used to establish the finite element of explosives, air, shaped charge calculation model. We use HYPERMESH finite element software to establish the shell and grid finite element computing model, then put the two results into LS-PREPOST to location and assemble. Considering the structure is symmetrical, we just establish a quarter of the model structure. Applying the symmetry constraint in the plane of symmetry of the model that is, constraining the translational and rotational freedom degrees on the plane of symmetry. We use a single automatic contact between the shell and the grid. The finite element model is shown in Figure 3.



**Figure3.** The finite element model

The reason why use ALE algorithm to calculate is that the calculation involves large mesh deformation and material flow. Explosives, liner and the air adopt multi-material flow Euler algorithm, then explosives, liner, the air, shell and the grid use fluid solid coupling algorithm. For the multi-material ALE, in addition to shaped charge, it also need to build a air grid which is enough to cover the entire projectile range, and apply the non-reflect boundary conditions at the boundary of the model, in order to avoid reflecting street at the boundary of the model.

In the calculation model, the main charge use 8701 explosive, whose density is 1.695 g/cm<sup>3</sup>, detonation velocity is 8425m/s, stable detonation pressure is 29.6 GPa. The selection of the material is MAT\_HIGH\_EXPLOSIVE\_BURN high explosive material model and JWL state equation. The material of the liner is military copper, whose density is 8.9 g/cm<sup>3</sup>, material velocity is 3490 m/s, and the model of the material is MAT\_JOHNSON\_COOK, then under high strain rate material, using the EOS\_GRUNEISEN state equation to simulate liner. The material of the shell is 45 steel, its material model is MAT\_JOHNSON\_COOK, and using EOS\_GRUNEISEN to describe the state equation. The material of the cutting reseau is tungsten alloy, the selection of the material is MAT\_JOHNSON\_COOK model and GRUNEISEN state equation. The fluid model of the air material is MAT\_NULL, its state equation is liner polynomial, which is described by EOS\_LINER\_POLY\_NOMIAL. The material parameters, material models and equation of state of the numerical simulation are shown in table 1. The way of the initiation is single point initiation.

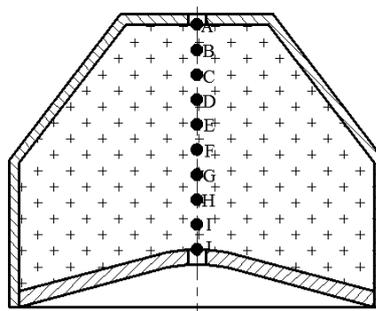
**Table 1.** Material parameters.

| Name           | Material  | Density (kg/m <sup>3</sup> ) | Material Model      |
|----------------|-----------|------------------------------|---------------------|
| Liner          | Copper    | 8960                         | JOHNSON_COOK        |
| Explosive      | 8701      | 1713                         | HIGH_EXPLOSIVE_BURN |
| Shell          | Steel 45# | 7830                         | JOHNSON_COOK        |
| Cutting reseau | Tungsten  | 17600                        | JOHNSON_COOK        |
| AIR            | Air       | 1.205                        | NULL                |

### 3 The influence of the position of the initiation on mesh cutting EFP

#### 3.1 The structure and scheme of cutting MEFP

The structure of the shaped charge is cylindrical charge shown in Figure 1. The way of the initiation is the center point initiation, by setting the initiation point of A,B,C,D,E,F,G,H,I,J to study the effects of the initiation position on sub-EFP forming. The distance of initiation of each scheme is 10.58mm. Initiation point settings are shown in Figure 4.

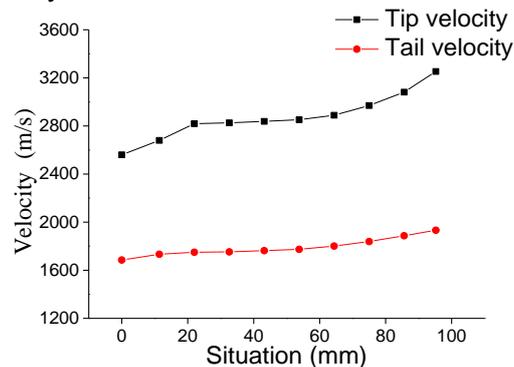


**Figure 4.** Shaped loaded constitution structure and the position of the initiation point

#### 3.2 The influence of the position of initiation point on the speed of the cutting MEFP

Table 4 shows the simulation results of the cutting MEFP warhead, and Figure 5 is a relation curve which shows the relationship between the cutting MEFP and the position of the initiation point. According to the Table 4, with the continuous increase in the position of the initiation point, the speed of

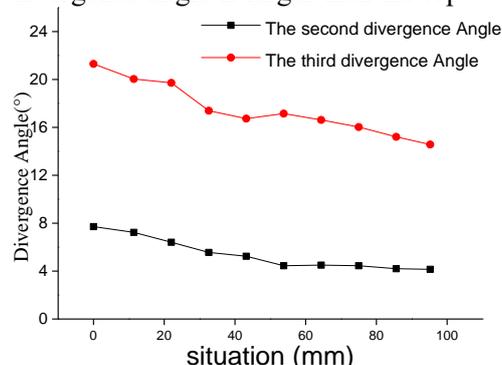
the head and the tail of the cutting MEFP is increasing. When the position of the initiation point is lower than 64mm, the speed of the head increases relatively. When the position of the initiation point is higher than 64mm, the rate of the head increases rapidly, and the rate of the tail increases along with the position of the initiation point, the speed of the tail increases more slowly. When the position of the initiation point increases from 0mm to 95.21mm, the velocity of the head increases from 2560m/s to 3253m/s, the speed is increased by 27.1%, and the velocity of the tail increases from 1685m/s to 1933m/s, the speed is increased by 14%.



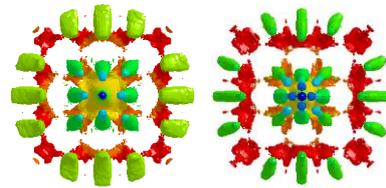
**Figure 5** The velocity of the head and tail varies with the position of the initiation point

### 3.3 The influence of the position of the initiation point on the divergence angle of the cutting MEFP

Figure 6 are the results of numerical simulation which shows the influence of the changes of the initiation point position on the divergence angle of MEFP. According to the Figure 6, with the distance between the initiation point and the top of the liner, the divergence angle of the sub-EFP decreases. Simulations show that the distance influences the velocity and spread area of the MEFP bullet, and it is one of the factors that influent EFP molding. With the increase of the distance, the average radial velocity of the sub-EFP decreases, which leads to the flight divergence angle of the sub-EFP decreases. The reason for this trend is that with the increase of the distance, the peak of the detonation pressure suffered by liner increases, causing the velocity difference after the flip increases, the speed of the formed cutting sub-EFP still exists velocity gradient, so it continue to generate axial tensile, and bullet pill covers axis of the closure to generate the radial compression. So, the liner produce divergence angle under the action of axial tension and radial compression. It is visible that the reduction of the distance is good for increase the divergence angle of the EFP. When the distance is very small, although the formed divergence angle of the sub-EFP is very large, the speed is low, the ability to damage the target is weak. Although the larger distance leads to the speed of the sub-EFP increased, and the ability to penetrate target is enhanced, it causes the divergence angle of MEFP bullet pill decreased and spread area reduced. Figure 7 shows the formed MEFP of different initiation point. According to Figure 7, the bottom initiation of the MEFP divergence angle is larger than the top.



**Figure 6** The divergence angle of the second and the third layer EFP vary with the position of the initiation point

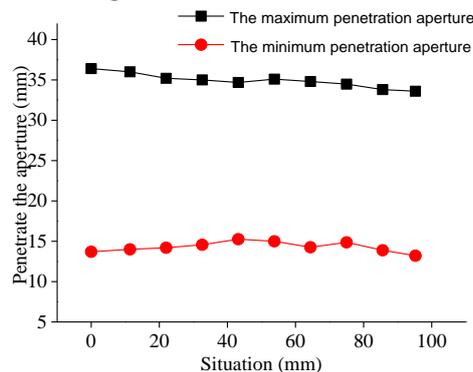


Bottom initiation      Top initiation

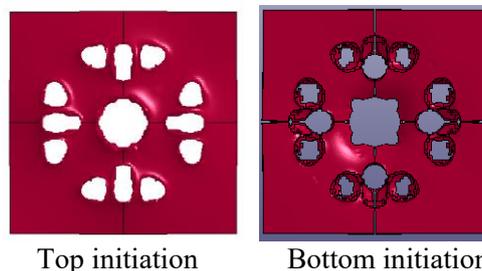
**Figure 7** MEFP formed in different position of the initiation point

#### 4 Analysis of the penetration characteristics of mesh cutting MEFP

Under a long distance conditions, as a result of the formed MEFP which is mesh cutting possesses radial velocity, a EFP in the middle would be fused with the adjacent 6 EFP to form a large EFP, and form a large penetration aperture on the target board. The other sub-EFPs penetrate the target to form independent holes. Figure 8 shows the penetration aperture differs with the initiation position. According to the Figure 8, the maximum penetration diameter increases with the initiation position gradually become smaller, and the minimum penetration diameter changes little vary with the position of the initiation point. This is because with the increase of the position of the initiation point which is formed by the intermediate EFP, the radial and axial velocity is larger, the head diameter is smaller. In the simulation plan, we can only see 21 holes, but can not see the 4 drum kits. This because the MEFP velocity which is formed in the mesh triangular region is very small, it is just 1000m/s, while using the LS-DYNA to calculate, calculation time is only 200us. Therefore, there is MEFP which is formed by the triangle region does not affect the targets.



**Figure 8** MEFP penetration aperture differs with the position of the initiation point



Top initiation

Bottom initiation

**Figure 9** The results of MEFP penetrating target in different position of initiation point

#### 5 Test verification

Setting the 45 steel plates, the thickness is 9mm, in the distance of 7.5m from the warhead, and the warhead and the center of the power target are located at the same level, test arrangement is shown in Figure 10. Through the net target perforation experiments, the mesh cut the liner into 21 EFP fragments, 1 piece is in the middle, the remaining's are distributed around, and the shape of the intermediate projectile is regular. The Figure 11 shows the MEFP effectively through 7.5m steel target. There is

a need to explain, because the results is the MEFP penetrate 5 times fried high target, the MEFP distribution range is smaller than the experiment. Both trajectory observation network target and penetration results show that the simulation results agrees well with the actual. The reason for the difference is that there are various external accidental factors, such as wind resistance, in addition to the difference of the numerical simulation and the distance of the experiment target.



**Figure10** The test arrangement of cutting MEFP



**Figure 11** The contrast between the simulation and test penetration

**Table2.** The comparison between the simulation and the results of the penetration test

|            | The maximum aperture(mm) | The minimum aperture(mm) | The maximum divergence angle(°) |
|------------|--------------------------|--------------------------|---------------------------------|
| Simulation | 36                       | 13.7                     | 21.3                            |
| Test       | 33                       | 11.9                     | 18.6                            |

## 6 Conclusion

1) In the numerical simulation of mesh cutting MEFP forming, the fluid solid coupling algorithm can effectively overcome mesh distortion which is produced by Lagrange algorithm simulation of detonation process, and improve the accuracy of the numerical simulation results. The circular cutting grid can produce 21 sub-EFPs which process certain power and direction in the basis of originally single EFP charge structure, and the sub-EFPs can be used to attack light armor.

2) Through the numerical simulation, we research the effect of single point initiation position to the EFP forming. When the axial distance between the initiation and the liner increases from 0 mm to 95.21 mm, the axial mean speed of the sub-EFP increased by 27.1%.

3) Through analyzing the influence of the position of the initiation point to the EFP divergence angle, we can properly reduce the distance of the initiation point to increase the spread area of the sub-EFP, in order to improve the hit probability of MEFP. 4)Cutting MEFP warhead can penetrate the 45 steel plates, the thickness is 9mm, in the distance of 8m, with the ability of attacking light armor.

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