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The research on penetration of New Annular MEFP

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Abstract: According to the detonation wave collision theory, initiation from two ends of charge, the liner will close to the middle to form high velocity MEFP. The software Autodyn to be used to study the penetration capacity of a single Annular MEFP was studied. With increase of axis curvature radius, the ratio of length of width is decrease, the penetration capacity declined. It is partitioned hole into two parts which is formed gourd-shaped in the typical penetration. For equal liner and unequal liner, although the velocity of unequal liner is higher, the penetration capacity is weaker.

Introduction

With the development of shaped charge, MEFP was studied further by scholars at home and abroad. The control of the size shape and distribution patterns was research by Richard Fong and William Ng[1]. The MEFP warhead structure was proposed by Yin JianPing and Wang ZhiJun, and the detonation wave formation and growth to be carried on the thorough analysis [2].

Detonation wave collide will produce over temperature and overpressure, the collision pressure climbs sharply, and can achieve common CJ detonation 2-3 times. Based on collision theory, a new type of EFP put forward by ZhongHua Du and Gou RuiJun [3-5]. This EFP is based on linear charge structure and beneficial to the detonation wave collision. They studied the detonation wave collision pressure, formation of penetrator and penetration capacity. The detonation wave conflict theory was brought into the annular MEFP, impinging high pressure formation can be multiple high-speed penetration body. Based on the annular MEFP structure, because of the axial radius of curvature it can be form closed and high penetrator. The effect of axial radius of curvature on formation has been researched [6]. So the penetration of the new annular MEFP was studied in this paper.

Establishment of the Simulation Model

The Autodyn software was used to simulate the collision pressure and formation of penetrator. The numerical model is showed as Fig.1. HIGH_EXPLOSIVE and JWL equation were adopted in comp B explosive. The liner material was copper; Shock of EOS and Piecewise JC of Strength were adopted. Ideal gas equation was adopted in air. Euler algorithm was used of all parts. The 2D axis symmetry was adopted. The condition of flow-out was used of air material. The parameters of material(except steel) are to be found in Table 1.The material of target is steel 4340, whose depth is 30mm, and the steel data of target are to be found in Table 2.

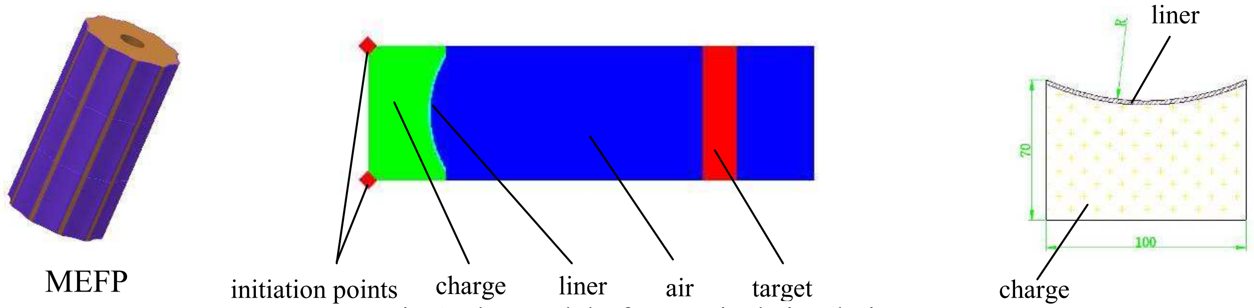


Fig.1 The model of numerical simulation

Table 1 Parameters of material model (expect steel)

Comp B	$\rho(g/cm^3)$	$D(km/s)$	$P_{cj}(GPa)$	$A(GPa)$	$B(GPa)$	R_1	R_2	ω
	1.71	7.98	29.4	524.2	7.68	4.2	1.1	0.34
Copper	$\rho(g/cm^3)$	Gruneisen coefficient	$C_1(cm/\mu s)$	S_1				
	8.93	1.99	0.394	1.489				
Air	$\rho(g/cm^3)$	Gamma	Reference temperature	Specific heat(terg/gk)				
	0.00123	1.40	288.2	7.176e-6				
Steel	$\rho(g/cm^3)$	Bulk						
	7.83							

Table 2 Parameters of Steel model

steel	EOS	Bulk modulus(kPa)					
	Liner	1.59E+08					
	Strength	Shear moudulus(kPa)	Yield stress(kPa)	Harndening constant(kPa)	Hardening Exponent	Strain Rate Constant	Thermal Softening Exponent
	Johnson cook	7.70E+07	7.92E+05	5.10E+05	2.60E-01	1.40E-02	1.03E+00
	Failure	D1	D2	D3	D4	D5	
	Johnson cook	0.05	3.44	-2.12	0.002	0.61	
	Erosion	Geometric Strain					
		1.5					

Penetration of axis curvature radius at 300 burst height

Penetration on Axis curvature radius of 100mm-400mm of equivalent liner is studied. The shapes of penetrators of axis curvature radius of 100mm-400mm are showed as Fig.2 and the velocity is showed as Table.3. As increase of axis curvature radius, the ratio of length of width is decrease, and velocity change is the same. When the axis curvature radius is at 100mm and 150mm, the penetrator may be the middle between EFP and shaped charge jet, approximation for rod jet whose velocity is higher. After 200mm, the penetrator can be thought of EFP.

The target shape after penetration shows the penetrators' capacity, showed as Fig.3, and the depth of penetration was showed in Table.4. Although the body at 100mm has a higher penetration velocity, but it did not form complete EFP, which is poor molding, large tail and small head. Also it is dispersible easily. So the depth of penetration is only 13mm at 100mm of radius. The best penetration capacity is showed at 150mm radius obviously, and the target of 30mm is penetrated. The shape of hole is thought of two aspects, and it is about being separated from the middle of hole. In the initial stage the head of body impact the target, then the target is penetrated to form hole. Because of the shape of larger tail and smaller head, the tail of body begins to flow to form two sides. So the energy of tail expands the remaining half of the hole to form gourd-shaped.

With decrease of the velocity and ratio of length and width of penetrator, the penetration capacity declined. The shape of hole at 200mm and 250mm is uniform, because of smaller ratio of head and tail of body. It is the same as the ordinary EFP. The shape of hole at 300mm-400mm is like the lower half of the hole at 150mm. The head of penetrator is smaller, so the effect of head capacity is very weak, and their penetrations mainly rely on the tail of body.

However, this new EFP has the greater characters than the same scale ordinary EFP, mainly in high velocity. And its capacity of penetration is also better than ordinary EFP.

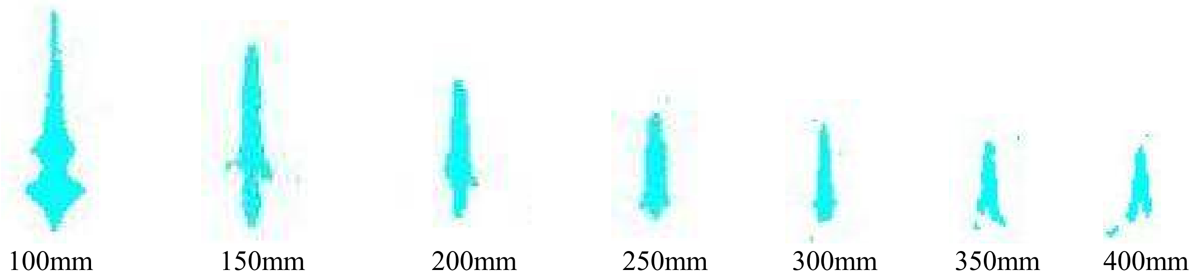


Fig.2. The formation with different axis curvature radius

Table.3 The velocity of different axis curvature radius

axis curvature radius（mm）	100	150	200	250	300	350	400
velocity（m/s）	4524	3451	3321	3296	3285	3257	3246

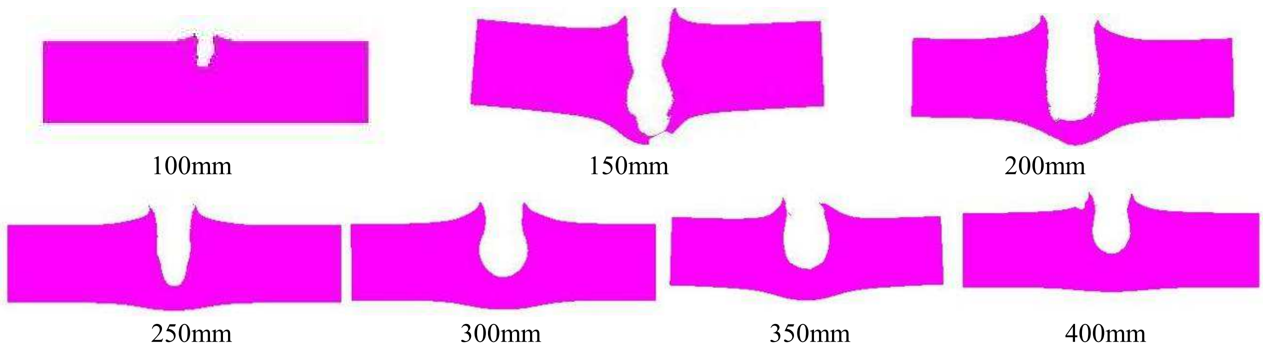


Fig.3. The target shape after penetration

Table.4 The depth of penetration

axis curvature radius(mm)	100	150	200	250	300	350	400
depth of penetration(mm)	13	penetrated	28	25	19	17	15

Penetration of two liner shapes

The new annual MEFP is based on the collision of detonation waves at initiation of two points synchronously. The key is the high pressure with collision and close with two ends of liner. So the two kinds of liner were studied. The structures of equal and unequal liner are showed as Fig.4, it keeps the thickness with the peak of the liner as 2mm, one is equal liner, and the other is unequal liner. Also, it keeps the inner radius as 100mm, and the outside radius is changed.

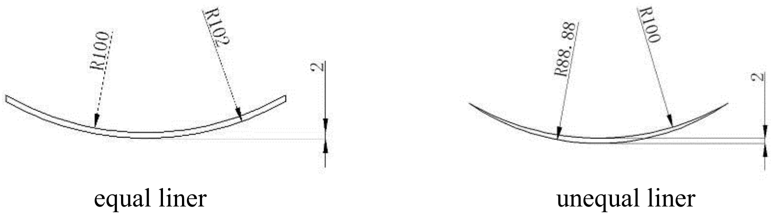


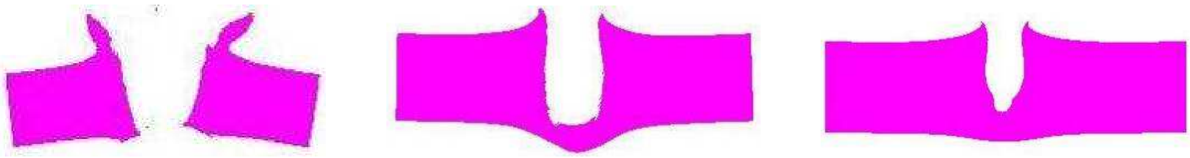
Fig.4. The equal and unequal liner

The difference between both liners is the formation that the two ends of liners close to middle line. Because of larger mass of ends of liner, in the process of close, it is a small amount of mass loss of ends of liner that the detonation waves is not enough energy to let ends of liner to be collapsed. However, the ends of unequal liner are smaller, so it easily to close to middle line of liner, but almost no mass loss. The velocity of both liners is showed as Table.5. Obviously, the velocity of unequal liner is higher than the other one. When the penetrators are steady that their velocity is almost no change, the velocity of unequal liner is more about 130m/s than equal liner. For high EFP, it is considerable of the velocity gain.

But the penetration capacity depends not only on the high velocity, but also the section quality. Because of the unequal thickness of liner, the mass of unequal liner is less than other one. So the section quality of formed penetrator of unequal is less. The shape of target after penetration is showed as Fig.5, and the depth is showed as Table.6. Obviously, the penetration capacity of equal liner is stronger than other one. The target is penetrated at 200 burst height, and the target is cut into two parts. But the depth of penetration of unequal liner is only 24mm. For theses liners, the key of penetration capacity difference is the larger mass difference. So although the velocity of unequal liner is higher, the penetration capacity is weaker.

Table.5 The velocity of two liners

time（μm）	40	50	60	70	80	90	100
velocity of equal liner（m/s）	3546	3492	3443	3289	3288	3285	3281
velocity of unequal liner（m/s）	3869	3552	3479	3423	3420	3416	3412



200mm burst height 300mm burst height 400mm burst height

equal liner

200mm burst height 300mm burst height 400mm burst height

unequal liner

Fig.5. The target shape after penetration with two liner

Table.6 The penetration depth of two liners

burst height(mm)	200	300	300
depth of penetration of equal liners(mm)	penetrated	28	24
depth of penetration of unequal liners(mm)	24	15	13

Conclusion

1. With increase of axis curvature radius, the ratio of length of width is decrease, the penetration capacity declined. It is partitioned hole into two parts which is formed gourd-shaped in the typical penetration.
2. For equal liner and unequal liner, although the velocity of unequal liner is higher, the penetration capacity is weaker.

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