Bulgarian Chemical Communications, Volume 49, Number 1, (pp. 210 – 216) 2017

Study on the influence of different clearance on the crack of PBX explosive

G. Zhenzhi[1,2*], H. Bin[1], G. Zhengming[1], N. Libo[1], C. Lujie[1]

[1]Xi'an High Tech Research Institute
[2]NO.96401 Force

Received March 24, 2016; Revised November 22, 2016

Explosives are widely used in military affairs. Aiming at the characteristics of the explosive component, the paper analyzes the stress intensity factor of the surface crack of the spherical shell and ellipsoidal shell made of explosive material. The results show that the stress intensity factor of the inner surface of the component is larger than that of the outer surface and the stress intensity factor of the surface crack of the explosive component with a cushion layer is larger than that without a cushion. These conclusions provide theoretical guidance for the actual assembly of the nuclear components.

Keywords*:* PBX Explosive, Crack, Stress Intensity Factor, J-Integral, Clearance Contact.

INTRODUCTION

The JOB-9003 plastic bonded explosive (PBX) is a kind of polymer binder as a continuous phase, an explosive mixed with high-energy particles and two-phase composite materials. It has good detonation and safety characteristics together with excellent mechanical properties. It plays an important role in the development of national defense and modern weapons. The explosive component is composed of a main explosive and a binder.

The main ingredient is Cyclotetramethylene tetranitramine also called octogen (HMX), this is a powerful and relatively insensitive nitroamine high explosive. It is a white crystal and the chemical formula is C4H8N8O8. Its chemical structure is shown in Fig.1

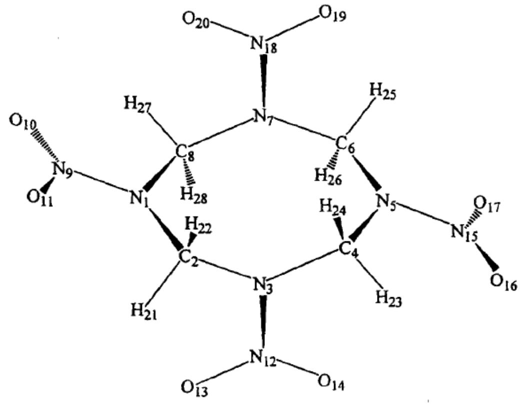


Fig.1. Schematic diagram of the atomic number and optimized geometry of HMX.

The binder is used to ensure the explosives have plastic properties, appropriate sensitivity and should possess a strong adhesive force, good plasticity and coating performance, while kept at a low glass transition temperature, have good physical and chemical properties and a lower cost. At present, the majority of explosive materials use a polymer binder and its molecular structure is shown in Fig.2.

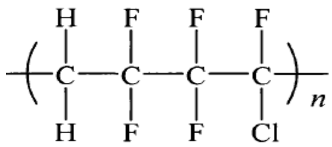


Fig. 2. Molecular structure of the binder

There are many factors affecting the surface cracking of the ellipsoidal explosive. In the process of being formed, processed and used, the explosive parts may be damaged or even generate cracks due to the effect of temperature and mechanical stress, which will cause great loss and influence the original performance. In the long-term the storage of the explosive parts, the bonding surface of the base and the binder is likely to crack under the action of a compressive force or tensile force, as shown in Fig.3 and Fig.4.

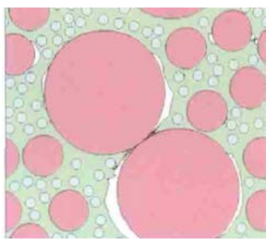


Fig. 3. Cracks under the action of a compressive force.

* To whom all correspondence should be sent:
E-mail: happywells@163.com; 542900823@qq.com

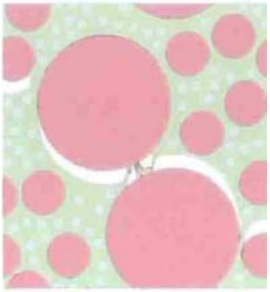


Fig. 4. Cracks under the action of a tensile force.

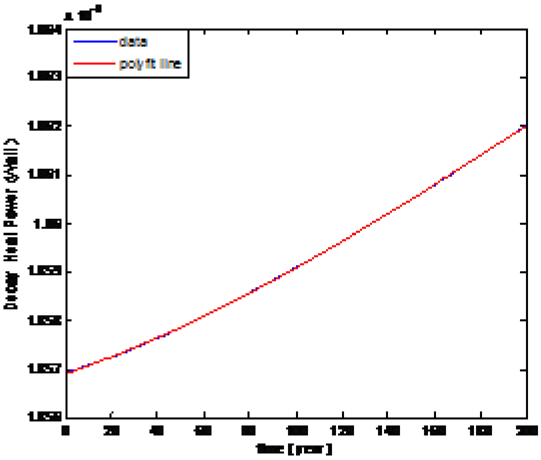


Fig. 5. WgPUecay heat power

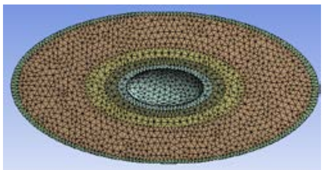
The stress conditions of the explosive parts in the structure of the assembly and the simulation analysis of the nuclear material and the structure of heat, the heat power is shown in Fig. 5. From the figure, we know that in 200 years time, the decay power of plutonium have reached a peak of 2.6887W/Kg.。The more the heat released from plutonium, the greater the thermal stress produced by the structure. The heat power produced in this paper is based on the calculation of the peak power of plutonium. According to the storage environment of the parts, the temperature of the component in a ventilated environment is 22~25˚C and the convection coefficient of air is 3.8 * 10-6W/m^2.

ANALYSIS MODEL AND VERIFICATION CALCULATION

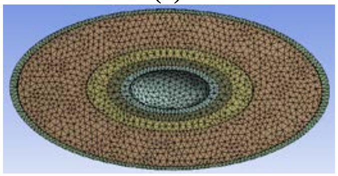
Analysis model

The crack surface at the top of the crack surface on the outer surface of the explosive component is parallel to the crack surface of the top surface of the outer surface of the short diameter parallel explosive component.

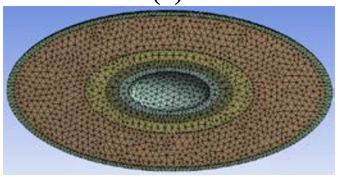
It can be seen from the figure that FEM analysis value and theoretical value is relatively close. The results show that the FEM simulation has a very good effect.



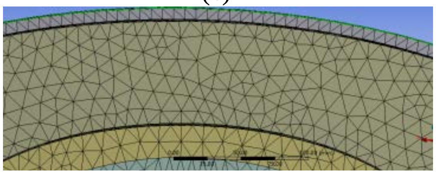
(a)



(b)



(c)



(d)

Fig. 6. Several contact modes on the ellipsoid: (a) Surface contact without clearance; (b) Surface contact with long axis clearance; (c) Surface contact with short axis clearance; (d) Enlarged view with short axis clearance.

Finite element analysis and theoretical calculation analysis

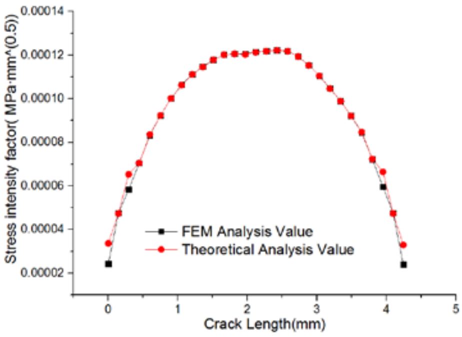


Fig. 7. Crack surface parallel to the short diameter.

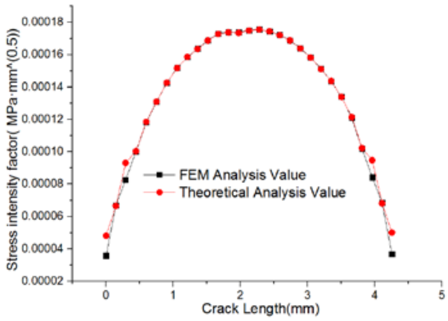


Fig. 8. Crack surface parallel to the long diameter.

CRACK ANALYSIS

Analysis of the inner surface of a crack

The inner surface of the spherical explosive without clearance

It can be seen from the figure that there is a big difference of the crack intensity factor between the spherical parts with a cushion and the spherical parts without a cushion layer. The stress intensity factor of the top of the inner surface of the explosive component with the cushion is close to zero and the value of the stress intensity factor is positive. It shows that the crack is open and the stress intensity factor at the inner surface is less than zero, which shows that the crack is closed. From the section stress contour of the explosive component, we can see that the top of the inner surface of the explosive component without a cushion layer is as high as 171.76MPa and the top of the inner surface with a cushion layer is 144.97MPa. The stress of the surface cushion should be much higher than that without a cushion. The cushion plays a certain role in relieving the stress of the crack of the explosive components.

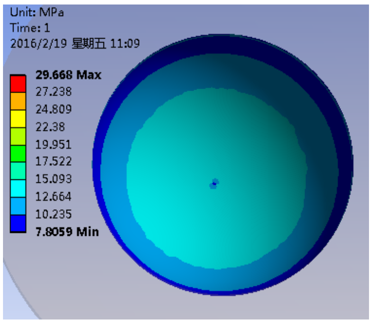


Fig. 11. Contact pressure on the inner surface of the sphere.

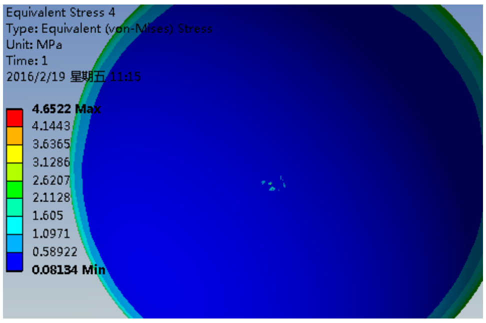


Fig.12. Equivalent stress of the inner surface crack of the spherical component

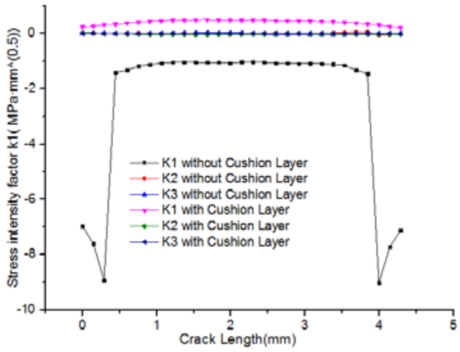


Fig. 9. Stress intensity factors.

Crack surface parallels short diameter

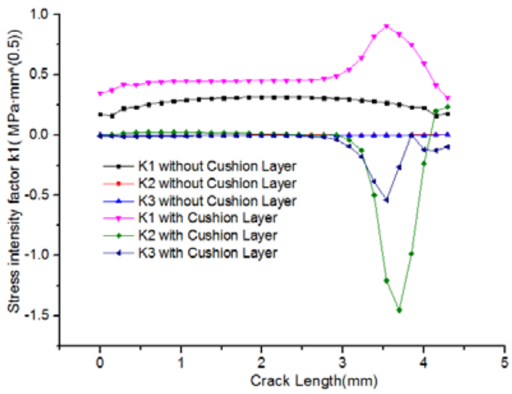


Fig. 13. Stress intensity factor.

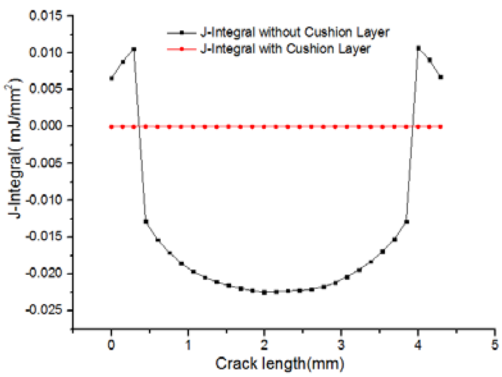


Fig.10. J-integral

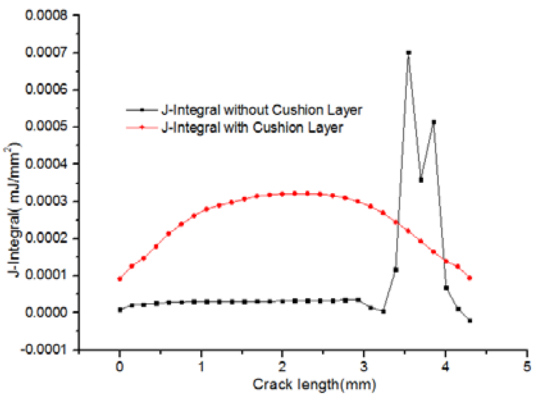


Fig.14. J-integral contrast.

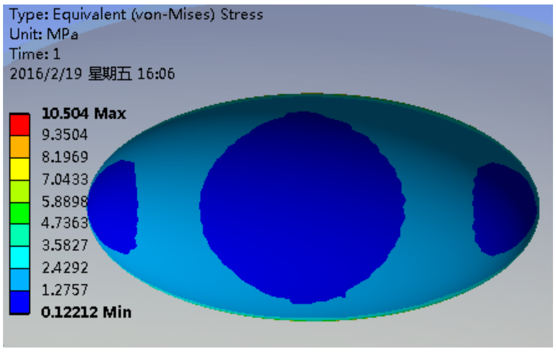


Fig. 15. Inner surface stress without a cushion.

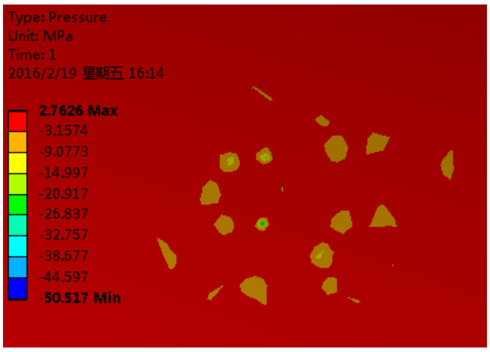


Fig.16. Inner surface contact pressure with a cushion.

The crack is located on the inner surface of the ellipsoidal explosive without clearance. It can be seen from Fig.15 and Fig.16 that the contact pressure without a cushion of inner surface in general is more than that with a cushion, but in some areas of the crack with a cushion contact the pressure reached -50MPa. From Fig.13 and Fig.14, the stress intensity factor K1 with a cushion is more than that without a cushion. The stress intensity factor with a cushion occurs with mutations at 3.8mm, we can see that the partial stress of the cracks change the surface with a cushion.

Crack surface paralleled to a long diameter

The crack is located on the inner surface of the ellipsoidal explosive without clearance. From Fig.17 it can be seen that the stress intensity factor of the explosives components with a cushion is similar to that without a cushion and the stress intensity factor K1 is more than that without a cushion. As seen from Fig. 20, the maximum stress of the crack reaches 30.157MPa, which is much larger than that without a cushion.

Analysis of the outer surface of the crack

The outer surface of the spherical explosive without clearance

The crack is located on the outer surface of the spherical explosive without clearance. It can be seen from Fig.21 that the stress intensity factor K1 without the cushion is less than zero. According to the definition of K1, the crack is in the closed state. The stress intensity factor K1 is greater than zero with a cushion and the equivalent stress of the crack is shown in Fig.24. It can be seen from Fig.23 and Fig.24 that the equivalent stresses of the outer surface of the PBX component with a cushion and without a cushion arevery different.

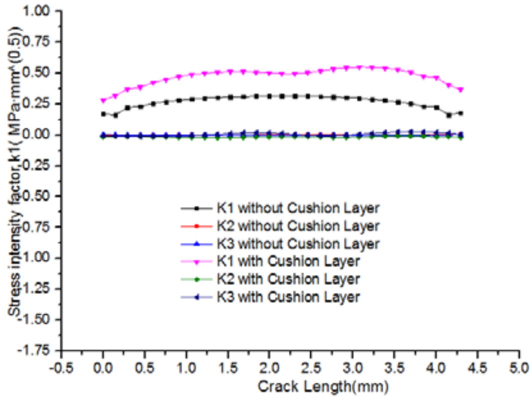


Fig.17. Stress intensity factor

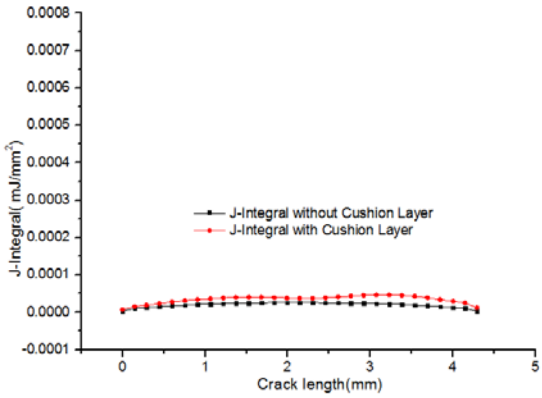


Fig. 18.J-integral.

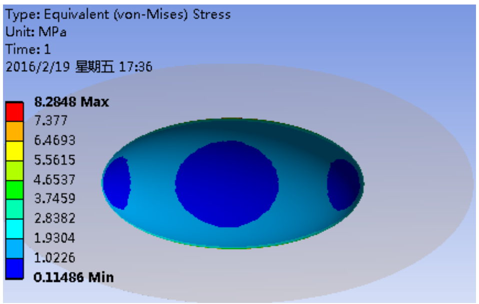


Fig.19. Equivalent stress without a cushion

Fig. 20. J-integral with a cushion

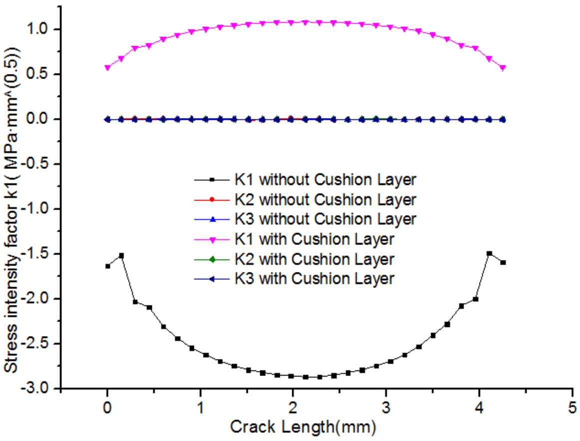


Fig. 21. Stress intensity factor.

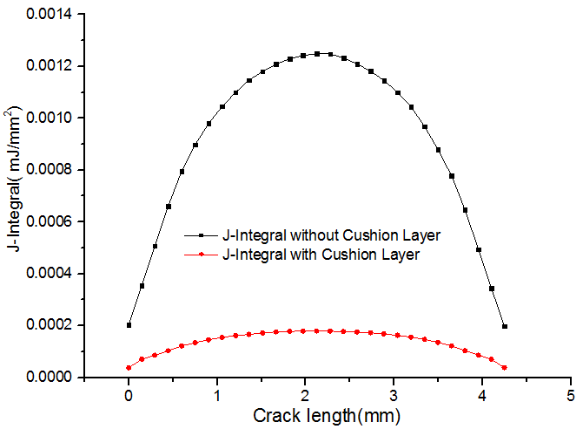


Fig. 22.J-integral.

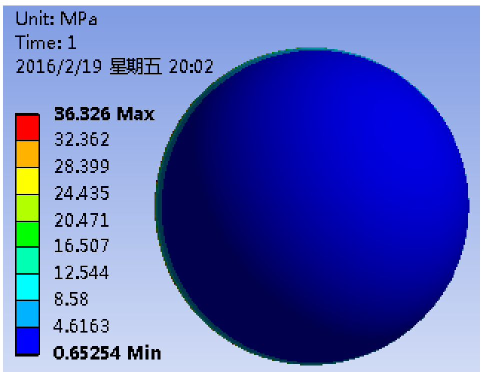


Fig. 23. Contact pressure without a cushion.

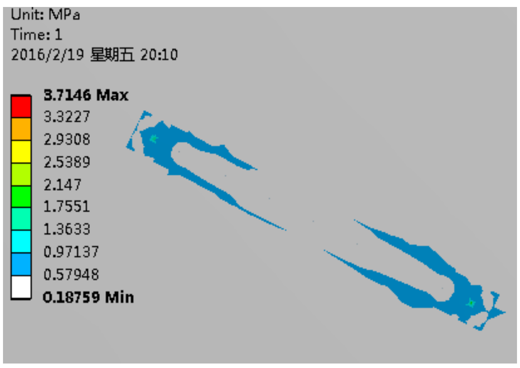


Fig. 24. Equivalent stress with a cushion.

Crack surface parallels a short diameter

The crack is located on the outer surface of the ellipsoidal explosive without clearance. The maximum elastic stress of the ellipsoid without a cushion is 6.3165MPa and at the top of the outer surface of the explosive it was the lowest.

From the stress intensity factor of the crack it can be seen, that the stress intensity factor with a cushion is more than that without a cushion and the J-integral with a cushion is more than that without a cushion, because the J-integral and stress intensity factor K1 are related. As observed in Fig. 27 the maximum equivalent stress of the outer surface is 4.5459MPa and the shape of the elastic stress is the same as the crack shape. The stress intensity factor of the crack is shown in Fig. 25 and the maximum value of the stress intensity factor K1 is concentrated in the middle part of the crack.

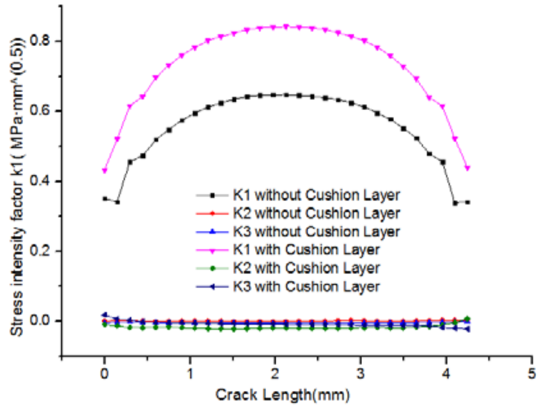


Fig. 25. Stress intensity factor K1.

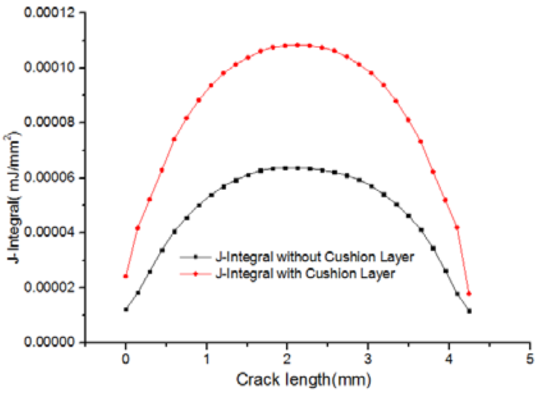


Fig. 26. J-integral.

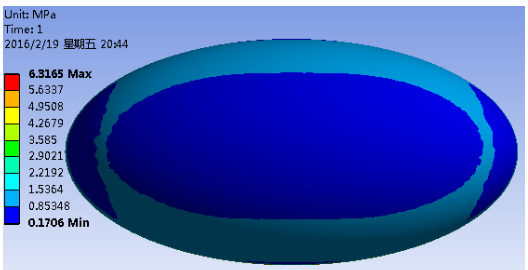


Fig. 27. Elastic stress without a cushion.

Fig. 28. Elastic stress with a cushion.

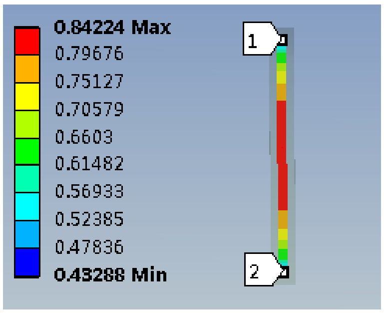


Fig. 29. Stress intensity factor without a cushion.

Crack surface parallels long diameter

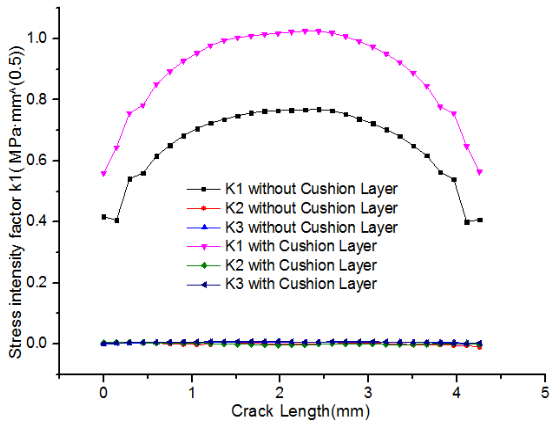


Fig.30. Stress intensity factor.

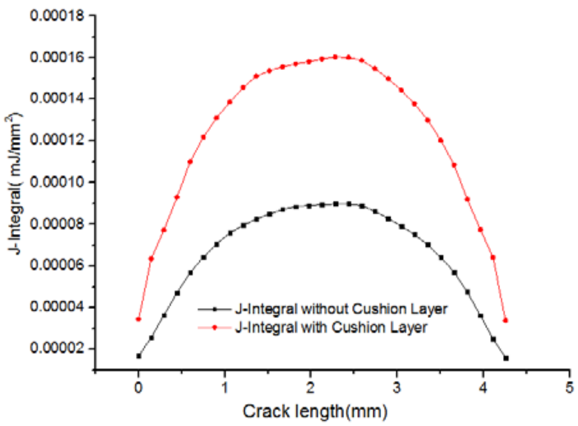


Fig. 31. J-integral contrast.

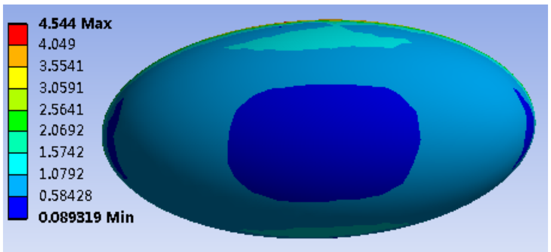


Fig. 27. Elastic stress without a cushion.

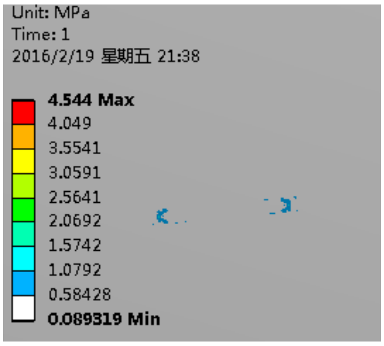


Fig.28. Elastic stress with a cushion.

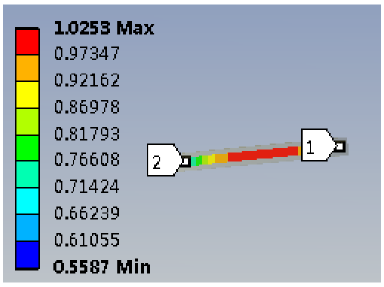


Fig. 29. Stress intensity factor without a cushion.

The crack is located on the outer surface of the ellipsoidal explosive without clearance. The stress value of the crack in the direction of the long diameter is smaller than that of the short diameter. At the same time the stress intensity factors between the crack direction in parallel with the long diameter direction and the short diameter direction are generally the same.

CONCLUSION

1. Under the same condition, the stress intensity factor of the crack in the inner and outer surface is not the same, the stress intensity factor of the inner surface is larger than that of the outer surface, in the middle of the crack, stress intensity factor appears a “broken” phenomenon and the crack in the inner surface occurs as a"break" phenomenon in the 3/4 position of the crack.

2. The stress intensity factor K1 of the crack in the perpendicular direction at the top of the inner surface of the explosive is different and the crack perpendicular to the radial stress intensity factor is greater than the crack parallel to the radial direction.

The two stress intensity factors in the clearance of the explosives components are more obvious.

3. In the proper position of a crack, the stress intensity factor of a crack parallel to a short diameter of the outer surface with a cushion occurs with mutations and the mutations may be caused by the strong strain effect.

4. Without a cushion and sphere the conformal contact and the stress intensity factor is negative, indicating that the crack is in a strong closed state. During the actual engineering, the surface and surface contact state is an ideal state and it will not exist in real life. The crack will not yield a closed state and yet the close state is an ideal result.

5. The stress intensity factor of the inner surface with a cushion is significantly higher than that without a cushion, also the stress intensity factor of the outer surface with a cushion is larger than that without a cushion, but the attenuation stress intensity factor of the inner surface of the explosive is more than that of the outer surface.

6. Under the same conditions, the stress intensity factor of the crack intensity factor of the sphere is larger than that of the ellipsoid.

REFERENCES

1. M.I. Muskhelishvili, Some Basic Problems of the Mathematical Theory of Elasticity [M], Groniagen: Moordhoff, 1953, p. 14,376, 486.
2. A.T. Shitaerman, Contact Problems of the Theory of Elasticity, Gostakhisdat, Leningred, Moscow, Russia, 1949, p. 140, 252.
3. X. Fang, C. Zhang, X. Chen, Y. Wang, Y. Tan, *ActaMech, ActaMech,* **226**, 1657 (2015).
4. J. Jamari, D.J. Schipper, *Tribology Letters*, **21**, 262 (2006).
5. A. Persson, On the stress distribution of cylindrical elastic bodies in contact[D]. Chalmers, Tekniska, Goteborg, Sweden, 1964.
6. M.Ciavarella, P. Decuzzi,*International Journal of Solids and Structures*, 4507 (2001).
7. M.Ciavarella, P. Decuzzi, *International Journal of Solids and Structures*, 4525 (2001).
8. N. Hussain, *International Journal of Engineering Science*, 1149 (1969).
9. H.Nagatanı, A.Imou, *Journal of Advanced Mechanical Design, Systems, and Manufacturing*, **6**, 1055 (2008).
10. C.-S. Liu, K. Zhang, L. Yang, *Journal of Computational and Nonlinear Dynamics*, **4**, 106 (2006).
11. A.A. Griffith, *Phil.Trans.Roy.Soc.London[J]*, **A221**, 163 (1921).
12. E. Orowan, *Welding Journal*, **34**, 1575 (1955).
13. G.R. Irwin, *JAM*, **57**, 361 (1957).
14. P. Paris,F. Erdogan, *Laws.J.Basic Eng.*, **85**, 528 (1963).
15. J.R. Rice, *J.Appl.Mech*., **35**, 379 (1968).

ИЗСЛЕДВАНЕ НА ВЛИЯНИЕТО НА ОТСТРАНЯВАНЕТО НА ПУКНАТИНИ ПРИ PBX-ЕКСПЛОЗИВИ

Г. Женжи[1,2]; Х. Бин[1]; Г. Женгминг[1]; Н. Либо[1]; К. Лужие[1]

[1,] Ксиан Хай-Тек изследователски институт
[2]NO.96401 Force

Постъпила на 24 март, 2016 г.; коригирана на 22 ноември, 2016 г.

(Резюме)

Експлозивите се използват широко във военното инженерство. В тази работа е разгледано влиянието на интензивността на напреженията при сферична и елипсовидна форма на обвивката на експлозива. Резултатите показват, че напреженията са по-големи от вътрешната страна на обвивката и че напрежението е по-голямо при наличие на амортисьор.Тези резултати позволяват съставянето на теоретично ръководство за реално конструиране на ядрените компоненти.