Research on Characteristics of Cylindrical Fragment Penetrating Steel/Ceramic/Steel Compound Target

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ABSTRACT

Ceramic Composite Armors have fine anti-bullet property. In order to know the anti-bullet property of the steel/ceramic/steel compound target, the residual velocity of the fragment after penetrating the compound target must be known. The steel/ceramic/steel compound target is regarded as a compound plate which is composed of a single steel plate and the ceramic/steel compound plate. Taking the residual velocity of the fragment after penetrating the thin steel plate as the initial velocity of the fragment impacting the ceramic/steel compound target and combining with the Florence’s model, the residual velocity of the fragment after penetrating the steel/ceramic/steel compound target is deduced by the energy method. The process of the cylindrical fragment penetrating the steel/ceramic/steel compound target is simulated by the nonlinear finite element software AUTODYN. The diameter of the fragment is 8mm. Comparing the residual velocity of the theoretical results to the numerical results, the results show that the theoretical results are a good agreement with the numerical results which verifies the accuracy and reliability of the theoretical formula.

KEY WORDS: cylindrical fragment; steel/ceramic/steel compound target; energy method; residual velocity

INTRODUCTION

Ceramic composite armors has a fine anti-bullet property and has been widely used in the military. In recent years, composite armor structures composed of high strength steel and armor ceramic are not only used in tank protection, but also in aviation, aerospace, warship and other protection equipments. The application range of the composite armor structures becomes wider and wider. Zaera and Sanchez (1998) analyzed and calculated the anti-bullet property of the ceramic/aluminum alloy compound target by using Tate and Alekscevskiis’s model. Ben-Dor (Ben-Dor G, Dubinsky A and Elperin T, 2000), Lee(Lee M and Yoo Y H, 2001), Espinosa(Espinosa H D, Brar N S and Yuan G, 2000) and Wang(Wang B and Lu G, 1996 ) carried out optimization design on the thickness ratio of the front plate and rear plate of the ceramic/aluminum alloy by using Florence’s model. Du-Zhonghua, Zhao-Guozhi and Wang-Xiaoming (Du Zhonghua, Zhao Guozhi, Wang Xiaoming, and Shen Peihui, 2002; Du Zhonghua, Zhao Guozhi, Ou Yangchun and Li Wenbin, 2002) studied on the double and three-layer ceramic/metal compound target by simulations and experiments and the results showed that the intermediate sandwich could improve the anti-bullet property of the compound plate. Jing Yuan and Guo Shiju (Jing Yuan, Guo Shiju and Han Jingtao, 2007) established the limit velocity prediction model of the steel/ Al2O3 ceramic/steel compound target through combining the limit velocity equation of the thin plate with the Florence’s model. The results showed that the calculated values of the limit velocity were a good agreement with the experimental values.

In this paper, the steel/ceramic/steel compound target is regarded as a compound plate which is composed of a single steel plate and the ceramic/steel compound. Taking the residual velocity of the fragment after penetrating the thin steel plate as the initial velocity of the fragment impacting the ceramic/steel compound target and combining with the Florence’s model, the residual velocity of the fragment after penetrating the steel/ceramic/steel compound target is deduced by the energy method. The process of the cylindrical fragment penetrating the steel/ceramic/steel compound target is simulated by the nonlinear finite element software AUTODYN. The diameter of the fragment is 8mm. Compared the residual velocity of the theoretical analysis results to the numerical results, the results show that the theoretical results are a good agreement with the numerical results which verifies the accuracy and reliability of the theoretical formula.

THEORETICAL ANALYSIS MODEL

The interaction between the fragment and the target is a complex physical process. As the fragment penetrate the steel/ceramic/steel compound plate, the fragment contact with the steel plate at first. Because of the larger initial velocity of the fragment, the caused contact stress is large too. The contact areas produce high temperature and high pressure, where the mediums of the plate approximately change into fluid and diffuse around which make a hole reaming be formed. As the fragment penetrates further, the sum of the anti-invasion force is larger than the shear plugging strength until the plug is formed completely and goes ahead with the fragment. As the fragment and the plug act on the ceramic together, the radial and circular crack is produced and finally the inverted ceramic cone is formed. Then the fragment, the