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Void Generation Between Shell and Charge of Warhead under the Projection Load

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ABSTRACT

In the process of projecting, the coupled property of warhead shell and charge is an important issue of the launching safety study. To maintain charge in close contact with the shell is one of the requirements for quality. For solid-liquid mixed charge , its tensile strength is very small, the dynamic response characteristic between warhead shell and charge make it possible to form instantaneous void between the shell and charge. his paper studies the impact of factors of instantaneous void and its development law by numerical simulation. This work lays foundation for warhead charge quality control and projection safety.

Keywords: Projection load, charge, warhead, safety, explosive

1. INTRODUCTION

Hot-spot formation is regarded as the principal phenomenon by which energetic materials start to react, deflagrate, and in some cases, detonate. The principal mechanisms by which these localised regions of high-temperature have been identified and widely studied[1-4]. Hot spots are critical for the initiation of explosives because reaction rates are very much temperature sensitive[5].

Since the physical and mechanical properties of solid-liquid mixed charge and shell material of the warhead are different, the dynamic response characteristics of charge and shell are different under the projection load. This leads to generate instantaneous void between the shell and the charge. The authors[6] first proposed the concept of instantaneous void. The close process of instantaneous void may be the process of hot-spot growth. The characteristic of an instantaneous void has to do with the physical properties of charge and shell and also the projection load. Since the instantaneousness of projection process and the covering up of charge placed within the shell, it is difficult to observe the coupled process of charge and shell through experiment under the projection load. Due to the projection load, material constitutive relationship and geometry shape of warhead shell and charge are nonlinear, it is impossible to analyse the instantaneous void issue. Therefore numerical computation is the only possible method to study the instantaneous void of shell and charge in the process of projection at present.

2. COMPUTATION MODELS AND PARAMETERS

The instantaneous coupled characteristic of a warhead shell and its charge under the projection load is presented. In this work, DYNA (explosion dynamic finite element program) is used to simulate the instantaneous void between the shell, and the charge of a warhead under the projection load. Figure 1 shows the projection load taken in this study. The relationship between the warhead and the gun tube is shown in Figure 2 .

The warhead charge material is assumed to be elastic-plastic. The dynamic plastic model is used.

For the charge mixture,

Density ρ = 1.47 g/cm^3,

Elastic modulus E =0.0474 GPa,

Poisson's ratio μ = 0.3,

Shear modulus G = 0.016 GPa, and

Yield strength σ = 7.7 MPa .

The shell material for projectile is 45 *Cr* steel , assumed to be elastic-plastic. The dynamic plastic model is used.

For the shell material, density ρ = 7.81 g/cm^3,

Elastic modulus E = 230 GPa,

Poisson's ratio μ = 0.3,

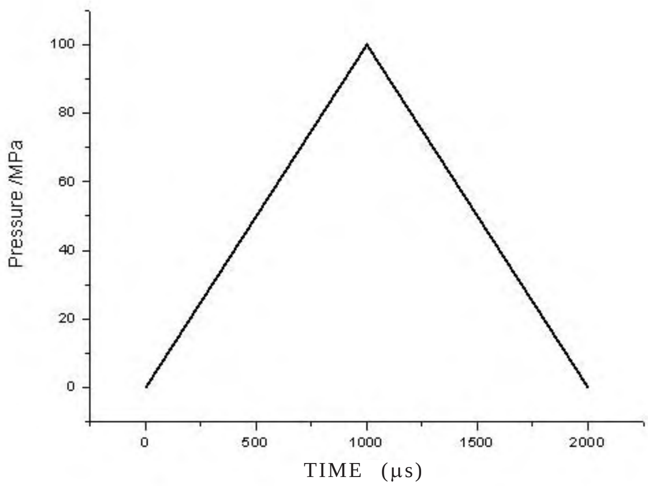

Figure 1. Projection load.

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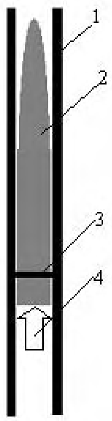

Figure 2. Warhead and gun tube, 1–gun tube, 2–warhead, 3–bearing band, 4–projection load.

Shear modulus G = 82 GPa,

Yield limit σ = 920 MPa .

The gun tube is defined using a rigid body model.

The bearing band material is H96 brass, assumed to be elastic-plastic. A dynamic plastic model is used.

For the bearing band material,

Density ρ = 8.86 g/cm^3,

Elastic modulus E =117 GPa,

Poisson's ratio μ = 0.345,

Shear modulus G = 41 GPa,

Yield limit σ = 390 MPa .

The dynamic analytical software was used in the numerical simulation in this study. The momentum equation is given as

$$\sigma_{ij,j} + \rho f_i = \rho \ddot{x}_i \quad (1)$$

where $\sigma_{ij,j}$ is Cauchy stress; f_i is unit mass volume force; $\ddot{x}_i$ is acceleration.

Conversation equation of mass is given as

$$\rho = J\rho_0 \quad (2)$$

where ρ is density; ρ_0 is initial density; $J = \left|\partial x_i / \partial X_j\right|$; x_i is space coordinate, and X_j is matter coordinate; $\partial x_i / \partial X_j$ is strain grad.

Energy equation is given as

$$\dot{E} = VS_{ij}\dot{\varepsilon}_{ij} - (p+q)\dot{V} \quad (3)$$

Where V is volume; $\dot{\varepsilon}_{ij}$ is strain rate tensor; q is artificial viscidity; δ_{ij} is Kronecher's symbol.

Deviatoric stress

$$S_{ij} = \sigma_{ij} + (p+q)\delta_{ij} \quad (4)$$

where δ_{ij} is Kronecher's symbol. Hydrodynamic pressure is

$$p = -\frac{1}{3}\sigma_{kk} - q \quad (5)$$

3. COMPUTATION RESULTS AND ANALYSIS

To compare the instantaneous coupled characteristic of the charge and the shell under the projection load, some places on the interface between the shell and charge were selected to observe the instantaneous void. The distances from the places to the bottom of the projectile body were 0.349 m, 0.339 m, and 0.330 m, respectively. The horizontal (vertical direction with the launch) particle velocity and instantaneous displacement of the shell and charge on the test points were calculated.

To study the affect of bearing band (the coupled degree of projectile body and gun tube) on the instantaneous void of the shell and the charge in the projection process, computation conditions were varied by taking the projectile body with bearing band and without bearing band. To ensure computation accuracy, the sizes of mesh elements near the interface of charge and shell were taken as 0.19 mm.

3.1 Instantaneous Void for Projectile Body with Bearing Band

If a projectile body has a bearing band, the state between the projectile body and gun tube is not coupled in the projection process. In this case, the horizontal velocities were obtained and displacements of three different places, *a*, *b* and *c* (as shown in Fig. 3) through calculations.

From Fig. 4, one can see that the maximum difference in horizontal vibration velocity of change and shell is about 0.3 m/s in this condition. Instantaneous void size can be calculated by the following formula:

$$\delta = \int_0^t (v_s - v_c)dt \quad (6)$$

Where δ is the size of instantaneous void, t is the operate time of instantaneous pore, v_s is the horizontal

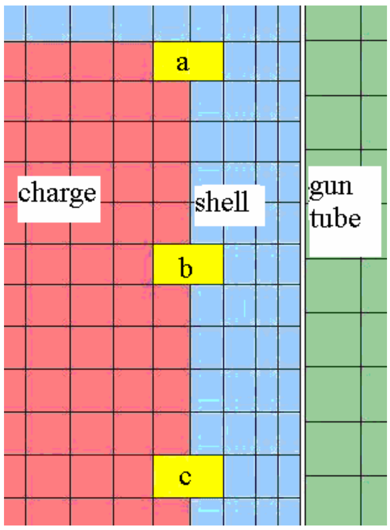

Figure 3. The mesh local magnification of gun tube, shell, charge and the places observed on the interface between the shell and the charge.The distance from projectile body bottom to place *a* is 349 mm , that to *b* is 339 mm and to *c* is 300 mm.

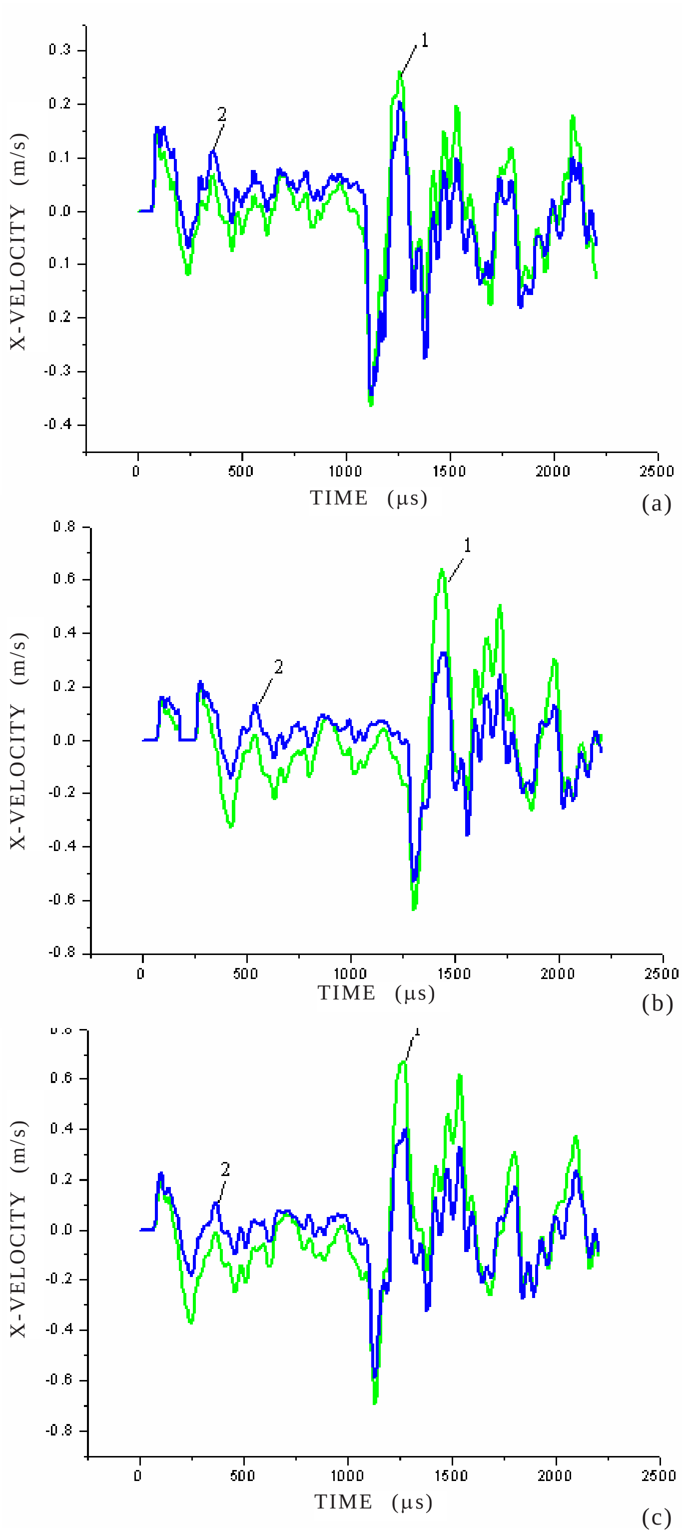

Figure 4. The horizontal vibration velocity of charge and shell when projectile body and gun tube is not coupled. 1– the horizontal vibration velocity in charge medium and 2- that in shell: (a) the horizontal vibration velocity of place *a*, 349 mm to projectile body bottom, (b) the horizontal vibration velocity of place *b*, 339 mm to projectile body bottom, and (c) the horizontal vibration velocity of place *c*, 300 mm to projectile body bottom (as shown in Fig.3).

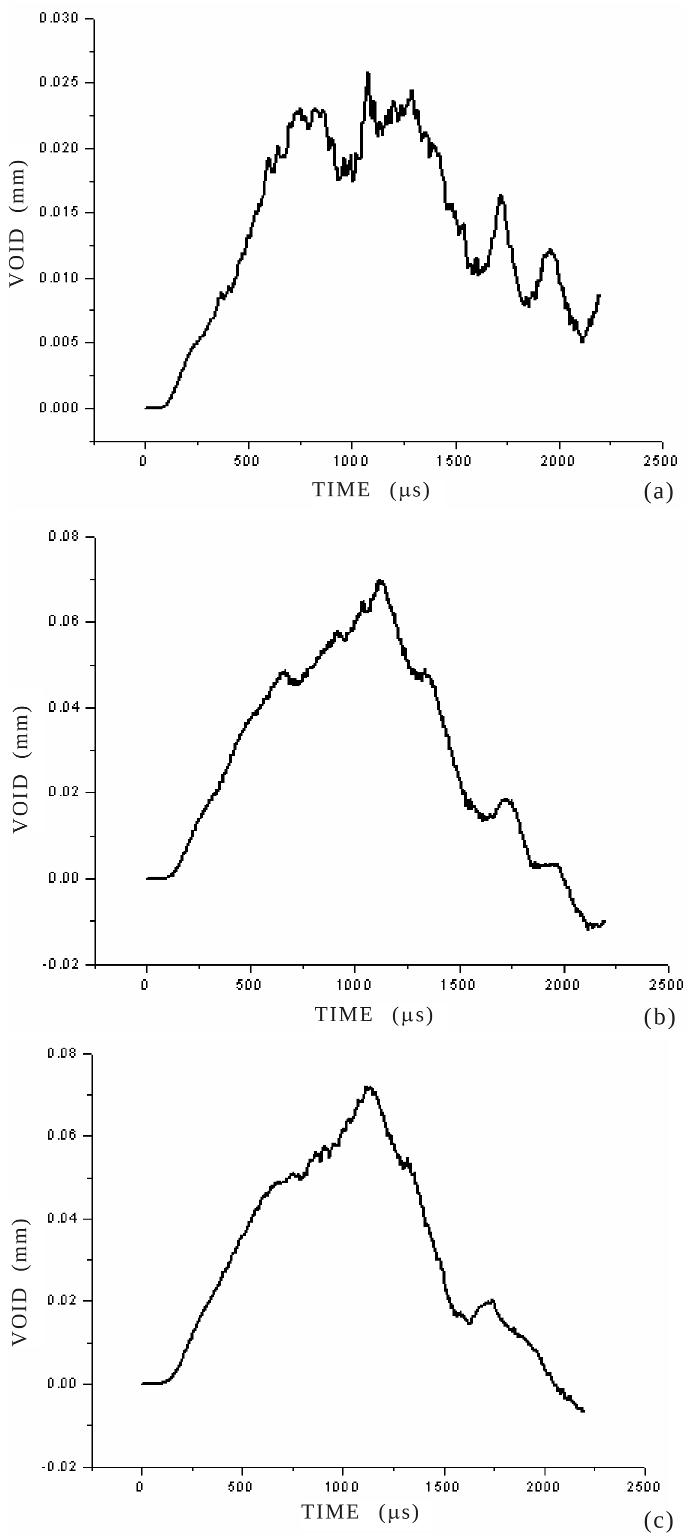

Figure 5. The instantaneous void *vs* time at the places *a*, *b*, *c* (Fig.3) when projectile body and gun tube is not coupled: (a) instantaneous void of place *a*, 349 mm to projectile body bottom, (b) instantaneous void of place *b*, 339 mm to projectile body bottom, and (c) instantaneous void of place *c*, 300 mm to projectile body bottom.

velocity of shell on the interface, v_c is the horizontal velocity of charge on the interface. From Fig. 4 and Eqn.(6) , one Fig. 5 was obtained. From Fig.5, one can see that in this condition , there is a instantaneous void between the shell and the charge . In the given projection conditions, the instantaneous void size has to do with the location closely. The largest size of instantaneous void is 0.072 mm in this case.

3.2 Instantaneous Void for Projectile Body without Bearing Band

If warhead shell and gun tube contacts closely (coupled state) in the process of projection, through calculation, one can get the velocity and displacement of warhead shell and charge on the interface in the process of projection. The velocity and displacement are perpendicular to the projection direction. One can study the change process of instantaneous void as the time.

The results show that the couple state of the projectile body and gun tube have impact on the instantaneous void.

3.3 Effect of Mechanical Property of Charge on the Instantaneous Void

To compare the effect of the physical and mechanical properties of charge on the instantaneous void, the same projection load and the same warhead size were used to calculate. In this computation case, the warhead was charged with solid explosive TNT. The instantaneous velocity and instantaneous displacement were obtained on the interface of the charge and the shell. From further analysis on computation results, one can get the instantaneous void. Shell and charge are used as non-coupled state.

Solid explosives TNT material is assumed to be elastic-plastic and plastic dynamic model was used. The parameters contain: density ρ = 1.616g/cm^3 , elastic modulus E = 3.3 GPa, Poisson's ratio μ=0.4, shear modulus G = 1.18GPa , and yield limit strength σ = 40 MPa .

The results show that when the charge is TNT, instantaneous void decreases significantly (about smaller two orders of magnitude than solid-liquid mixed charge , it is about micron magnitude under this calculation condition). The instantaneous void such as this small can be ignored for the projection safety.*

4. POSSIBILITY OF INSTANTANEOUS VOID BECOMING HOT SPOT

The danger of instantaneous void in the process of projection comes from two aspects, the first is high temperature generated by the process of compression of pore internal medium. The prerequisite of this case is that the pore is non-vacuum; The second is impact action between the shell and its charge in the process of compressing. The impact action mainly depends on the relative velocity of shell and charge. By calculating, it was known that the

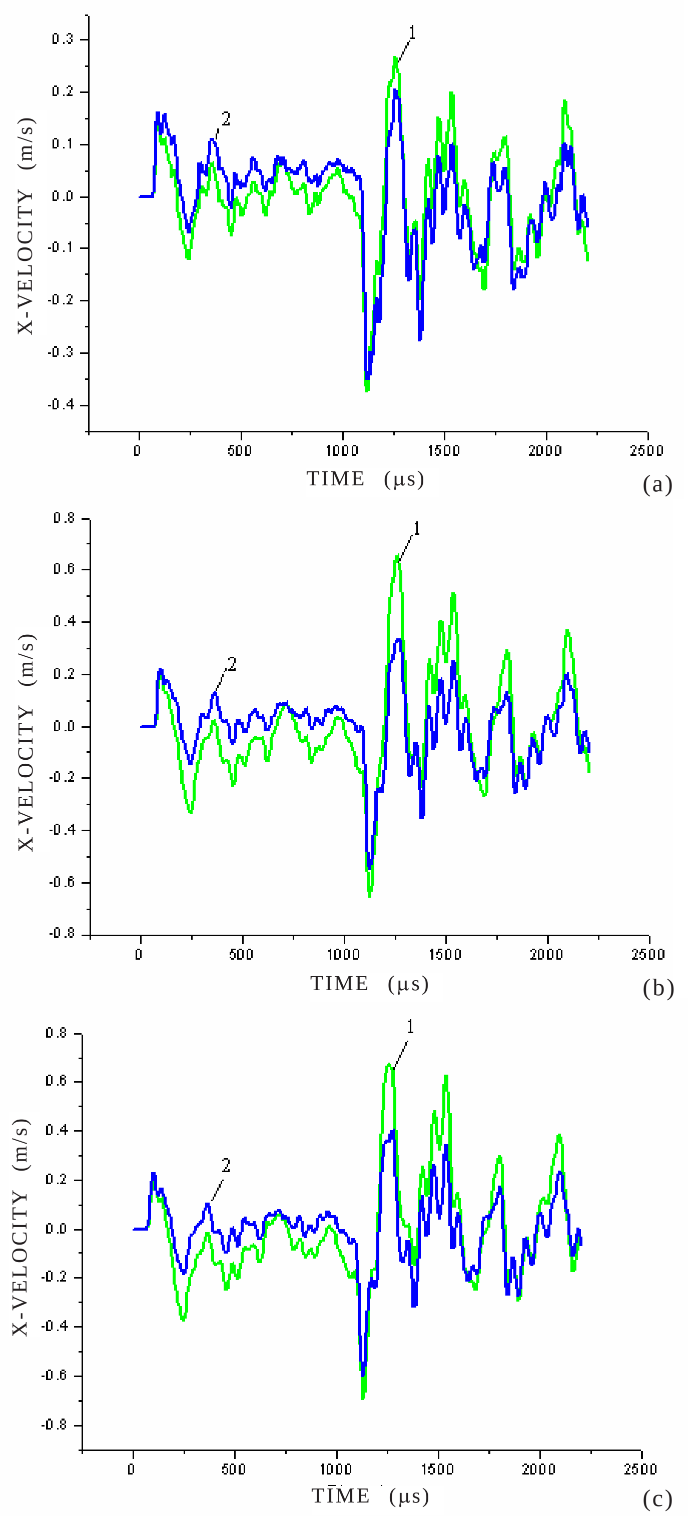

Figure 6. The horizontal vibration velocity of charge and shell when projectile body and gun tube is coupled: 1–the horizontal vibration velocity in charge medium and 2–that in shell: (a) horizontal vibration velocity of place *a*, 349 mm to projectile body bottom, (b) horizontal vibration velocity of place *b*, 339 mm to projectile body bottom, and (c) horizontal vibration velocity of place *c*, 300 mm to projectile body bottom (as shown in Fig.3).

* The research results about effect of void size on the projection safety will be published by the authors in other papers.

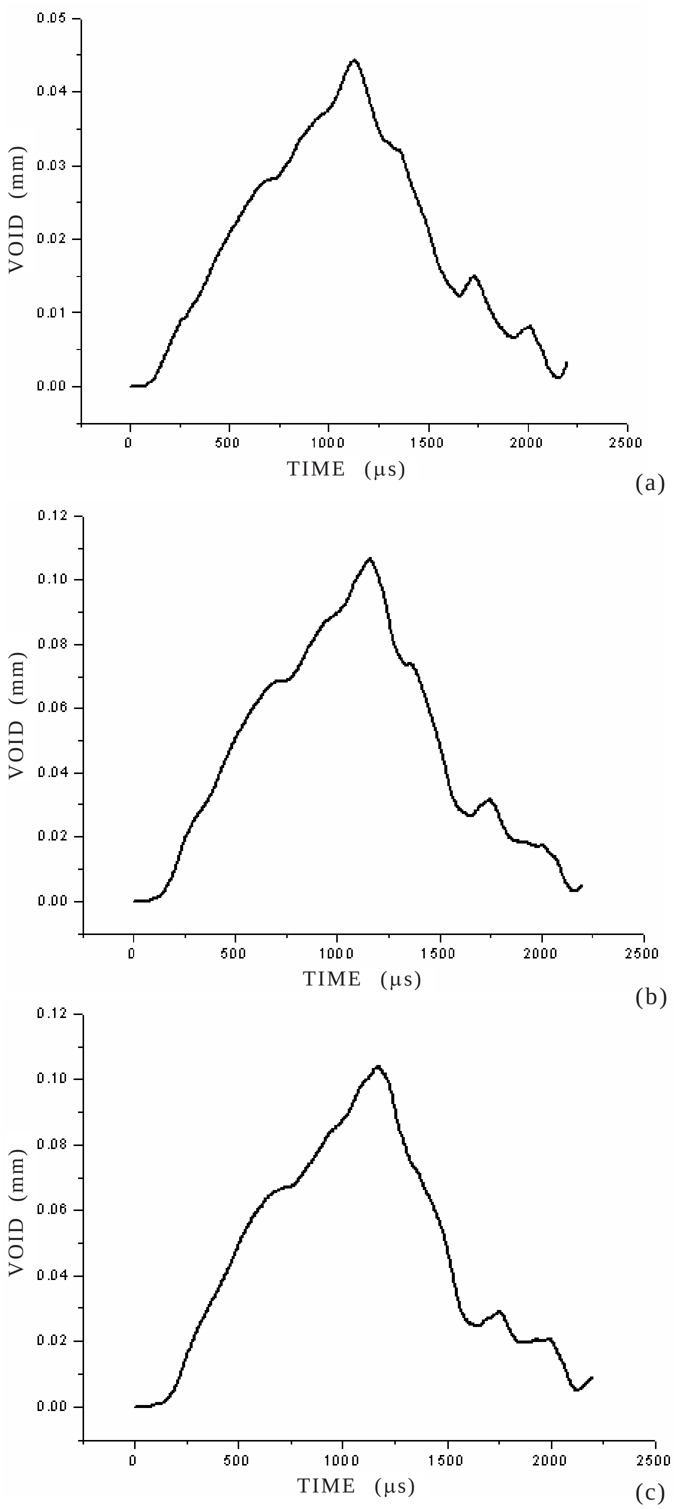

Figure 7. The instantaneous void *vs* time at the places *a*, *b*, *c* when projectile body and gun tube is coupled. (a) instantaneous void of place *a*, 349 mm to projectile body bottom, (b) instantaneous void of place *b*, 339 mm to projectile body bottom (c) instantaneous void of place *c*, 300 mm to projectile body bottom (as shown in Fig.3).

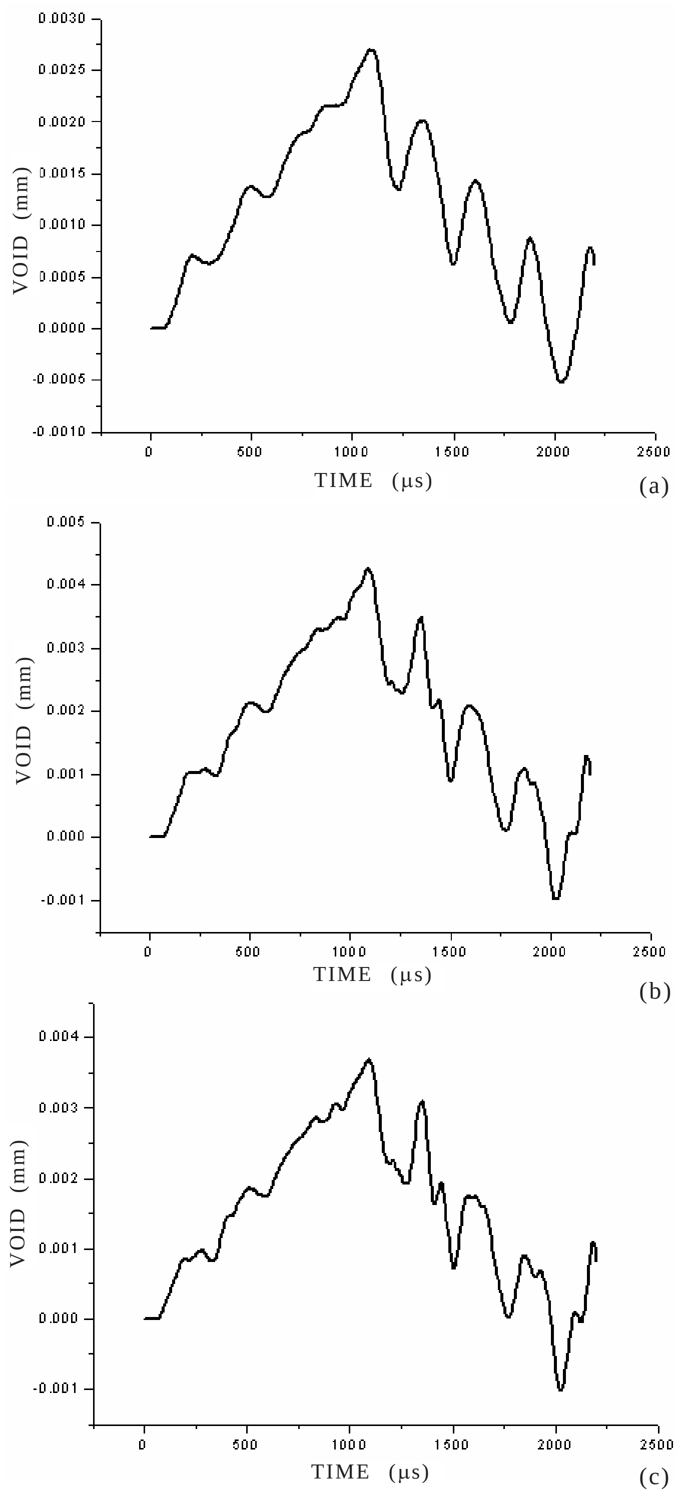

Figure 8. The instantaneous void *vs* time at the places *a*, *b*, *c* in the case of TNT charge. (a) instantaneous void of place *a*, 349 mm to projectile body bottom, (b) instantaneous void of place *b*, 339 mm to projectile body bottom, and (c) instantaneous void of place *c*, 300 mm to projectile body bottom (as shown in Fig.3).

relative velocity of shell and charge is very small. The possibility of explosion caused by impact action doesn't exist for the explosive charged in the warhead shell. Therefore, the main hazard of instantaneous void is the rising of temperature by the process of the pore internal medium compression. The solid-liquid mixed charge components mostly are highly volatile. The liquid components gasify rapidly when these encounter air. For liquid-solid mixed charge, the state of instantaneous void is non-vacuum. The gas compression in void generates high temperature. It is possible for generation of the hot spot in the warhead charged with the liquid-solid mixture.

5. CONCLUSION

In the condition of computation in this paper, the generation of instantaneous void of the warhead charged with solid-liquid mixture in the process of projection is studied. The instantaneous void has to do with the location on the interface of the shell and the charge. The property of charge has significant effect on the instantaneous void. The instantaneous void of shell and solid charge is two- orders smaller than that of solid-liquid mixed charge. For the projection safety, the instantaneous void can be ignored for the warhead charged with solid explosives. The instantaneous void may become hot spot and result in early explosion in the gun tube, for the warheads charged with solid-liquid mixture having the volatile liquid components.

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