Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 197 (2017) 233 – 243

Procedia Engineering

www.elsevier.com/locate/procedia

DYMAT 23rd Technical Meeting

Dynamic Fracture of Ductile Materials

Interaction of structural elements of space vehicles with high-velocity projectiles

Alexander V. Gerasimov[a,*], Sergey V. Pashkov[a], Yury F. Khristenko[a], Roman O.Cherepanov[a]

[a]*Research Institute of Applied Mathematics and Mechanics, National Research Tomsk State University, 36, Lenin av., Tomsk, 634050,Russia.*

Abstract

The paper represents the study concerning the high-velocity interaction of textolite and glass with aluminum and steel particles which simulate technogenic space debris, as well as with ice and granite particles which simulate natural materials of natural space bodies.

Peer-review under responsibility of the scientific committee of the International Conference on Dynamic Fracture of Ductile Materials

Keywords: High-velocity impact; fracture; fragmentation; space debris; space vehicles;

1. Introduction

Providing the strength of textolite and glass elements for space vehicles is an important practical problem. Textolite (fabric-phenolic resin laminate) is a structural material, a laminate based on a fabric of fibers and a polymeric binder (for example, bakelite, polyester resin, epoxy resin). These materials are used as structural elements of space vehicles: windows, glass in optical instruments, heat shields, etc.

There is a need to investigate the interaction of glass and textolite with the flows of technogenic and natural space debris to maintain the integrity of space vehicles exposed to the impact by large fragments and to reduce the erosion of structural elements exposed to the flow of ultrafine particles.

* Corresponding author. Tel.: +7-913-805-0074; fax: +7-382 -252-9547.
E-mail address: ger@niipmm.tsu.ru

Peer-review under responsibility of the scientific committee of the International Conference on Dynamic Fracture of Ductile Materials
doi:10.1016/j.proeng.2017.08.100

Therefore, the theoretical and experimental determination of maximum strength for the structural elements of space vehicles exposed to high-velocity particles is an urgent problem from a practical point of view. This work represents the theoretical and experimental study concerning the interaction of high-velocity compact projectiles with the glass and textolite targets of finite thickness. The paper considers the impact with aluminum and steel

particles which simulate space debris, as well as with ice and granite particles which simulate natural particles of space bodies.

To study the high-velocity interaction processes, an experimental stand was developed, manufactured and installed. This stand includes a universal base frame that can be used for fixing of any available accelerators at SRI AMM (T-29, 23/8 PPH, 34/8 PPH, 34/23/8 PPH, 50/23 GDI), as well as a new three-stage light-gas installation (RF patent, No. 2490580) and an evacuated chamber. The stand is equipped with units for the measurement of dynamic pressure in barrels, as well as with the sensors of the muzzle and trajectory velocity of models and projectiles, including original sensors (RF patent, No. 2193207).

The stand allows the various studies of high-velocity impact to be conducted at velocities up to 8 km/s and higher. The uniqueness of the stand is that the base frame for the fixing of the accelerator and the evacuated chamber are mounted on a single platform suspended. This eliminates the negative influence of shot on the foundation of the building. To calculate elastoplastic flows used technique implemented on tetrahedral cells and based on the combined use of the Wilkins method [1] for calculation of internal body points and Johnson method [2] for calculating contact interactions. The most common way to protect objects is to use materials with high physical and mechanical properties, such as ceramics and composites based on it. Layered barrier enable prevent damage and destruction of protected structures or stretching of the pressure pulse in the layered system due to multiple reflection of waves from layers with different acoustic impedances, or pressure pulse energy dissipation during plastic deformation of highly porous layers or fragmentation of ceramic materials.

The second possible way to counter high-velocity projectiles is to throw groups of spaced plates and rods from conventional and composite materials towards projectiles. As a result of the dynamic interaction and intense deformation occurs the partial destruction of the projectiles or the deviation projectiles from the line of collision. Consequently, the projectiles can rebound from the surface barrier, or deviate from the object to be protected and do not interact with the barrier. All these factors reduce the penetration of projectiles into the protected object. In this work numerical simulation of the interaction of high - velocity projectiles with groups of spaced rods and plates is carried out.

2. Equations describing the motion of a compressible elastoplastic body with an allowance for probabilistic fracture

The equations describing spatial adiabatic motion of a solid compressible medium are differential consequences of the fundamental laws of conservation mass, pulse and energy. In general they have the forms [1-5].

To equations we must add the equations taking into account relevant thermodynamic effects associated with adiabatic compression and strength of the medium. In general case, under the influence of the forces on the solid-deformable body, both volume (density) and the shape of the body are changed by different dependencies. Therefore, stress tensor is the sum of spherical tensor and the stress tensor deviator. The equation of a solid state was chosen in the form of Mie –Grüneisen.

In addition, the two fracture mechanisms can be implemented during the high-velocity interaction, namely the shear and spall mechanisms. The criterion of critical equivalent plastic strain [6] was used as a criterion for the shear fracture.

For the computation of the plastic material fracture (aluminum, steel), the Johnson - Cook relation was also used [7]. For the computation of the brittle material fracture (glass, ice, granite), the Johnson - Holmquist relation was used (JH2) [8].

Three-dimensional simulation for the interaction of targets with high-velocity projectiles is based on the equations which describe the spatial adiabatic motion of a solid compressible medium and are the differential consequences of the fundamental laws, such as the conservation of mass, momentum and energy. To compute elastoplastic flows, the tetrahedral cells are used to apply a technique that is based on combined using the Wilkins