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ScienceDirect

Procedia Engineering 204 (2017) 83–91

Procedia Engineering

www.elsevier.com/locate/procedia

14th Hypervelocity Impact Symposium 2017, HVIS2017, 24-28 April 2017, Canterbury, Kent, UK

Effect of honeycomb core under hypervelocity impact: numerical simulation and engineering model

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Abstract

Honeycomb sandwich panels (HC/SP) are the most common used structures for space vehicle. Under the threat of meteoroid and space debris, the distribution of the fragments produced in a hypervelocity impact event on HC/SP is critical to the vulnerability assessment of space vehicle. CISAS developed an engineering model to describe fragments clouds propagating inside spacecraft in consequence of space debris impact on HC/SP. In this model, the effect of the honeycomb core was modeled by an empirical corrective factor, which was not related to the physical of the impact. To improve this model, a new model to describe the effect of the honeycomb core was developed. In the new model, the honeycomb core was equaled to multi-parallel thin plates, which can represent the discontinuity of honeycomb core without complex boundary. Based on the knowledge of hypervelocity impact on a simple thin plate and approximation supported by numerical simulation results, the model was deduced. The coefficient of the model was fitted by the numerical simulation results.

Keywords: Honeycomb core; Hypervelocity impact; Numerical simulation; Engineering model;

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1. Introduction

As the population of orbital debris grows, the risk of space vehicle being hit by orbital debris becomes higher, which makes vulnerability assessment one of the most important steps in space vehicle design. Honeycomb

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10.1016/j.proeng.2017.09.759

sandwich panel (HC/SP) is a common structural component in space vehicle, and its debris cloud under hypervelocity impact is critical to the vulnerability assessment of space vehicle. There are three ways to obtain the characteristics of debris cloud, which are test [1-4], numerical simulation [5, 6] and using engineering model [7]. In early design stage of space vehicle, since detailed numerical simulation and test are too much expensive, using engineering model becomes the best choice. As a discontinuous structure, the properties of debris cloud of HC/SP are affected by the impact point, the orientation of honeycomb cell, the cell size, the height of honeycomb, the impact angle, and so on. All these factors make it too complicated to model the debris cloud of HC/SP. Existing vulnerability assessment tools usually treat HC/SP as a plate or a triple wall system [8] with additional adjustable parameters, which only predict the ballistic limit, without any information of the largest fragment.

To describe the characteristics of the debris cloud of HC/SP under hypervelocity impact, Alessandro and his team developed an engineering model [7] by using method of equal effect. In this model, the impact process was divided down into three steps: a first impact on the front face, which produces a debris cloud; an interaction with the honeycomb core, which filters out the dust jet and makes the largest fragment smaller and slower; a second impact on the rear face, which takes the output of previous step as input. The honeycomb core is treated as a “filter”, the effect of which is expressed by a corrective factor for both the mass loss and velocity loss after impact with honeycomb. The ballistic limit of HC/SP was obtained based on this engineering model, and the result agrees well with test data. However, the model has defects in two ways. First, the corrective factor for the mass loss and velocity loss could be different. Second, the corrective factor was obtained by reverse fitting the SRL ballistic limit equation, in which the honeycomb core was treated as plate.

To improve the honeycomb model, numerical simulation of projectile hypervelocity impact honeycomb core was carried out, and the mass loss and velocity loss of the projectile were studied. According to the discontinuous impact process of honeycomb core, a model for the honeycomb effect was developed by applying a simplified equivalence of honeycomb core. Based on the knowledge of hypervelocity impact on a simple thin plate and approximation supported by numerical simulation results, the model was deduced. The coefficient of the model was fitted by the numerical simulation results.

Nomenclature

h	Height of honeycomb core, height of thin plates
q	Equivalent diameter of honeycomb cell
t	Thickness of the honeycomb core foil, thickness of the thin plate
θ	Impact angle
d	Projectile diameter
ρ_{hc}	Density of honeycomb core material
ρ_p	Density of projectile material
m_p	Mass of projectile
v_i	Impact velocity
m_i	Mass of the projectile
v_{LF}	Velocity of the largest fragment
d_{LF}	Diameter of the largest fragment
m_{LF}	Mass of the largest fragment
m_t	Silhouette mass of the thin plate.
m_t*	The effective mass of silhouette mass of the thin plate
s	Space between two neighbour parallel thin plates
a, b, $k1$, $k2$	Correction coefficient of the engineering model