Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 173 (2017) 264 – 270

Procedia Engineering

www.elsevier.com/locate/procedia

11th International Symposium on Plasticity and Impact Mechanics, Implast 2016

Low velocity impact responses of functionally graded plates

Hariveer Singh[a], Bulon Ch. Hazarika[b], Sudip Dey[c,*]

[a,b,c]*Mechanical Engineering Department, National Institute of Technology Silchar, Assam, India*
**Corresponding author's e-mail: infosudip@gmail.com*

Abstract

The present study is dealt with the effect of low velocity impact responses of a functionally graded plates. The modified Hertzian contact law is employed in order to account for permanent indentation. The Power law is utilized for the graded characterization of functional material properties. The time dependent constitutive equations are solved by Newmark's time integration scheme. The results are obtained by using code which is validated. The transient low velocity impact response parameters such as contact force, plate displacement, impactor displacement and velocity of impactor are obtained to portray the effects of oblique impact angle and twist angle for aluminum-zirconia functionally graded plates.

Peer-review under responsibility of the organizing committee of Implast 2016

Keywords: Low velocity impact; functionally graded materials; finite element; modified Hertzian contact law; Newmark's time integration scheme

1. Introduction

Functionally graded materials (FGM) are applicable as advanced engineering materials due to its high corrosion and heat resistance properties along with high strength and stiffness. These inhomogeneous materials consist of the mixture of isotropic materials in which the material properties are graded but continuous particularly along a given direction to improve the quality of performance. In general, such materials are made from a mixture of ceramic and metal to gain the advantage of the combined desirable properties such as heat and corrosion resistance of ceramics as well as high toughness, tensile strength and bonding capability of metals.

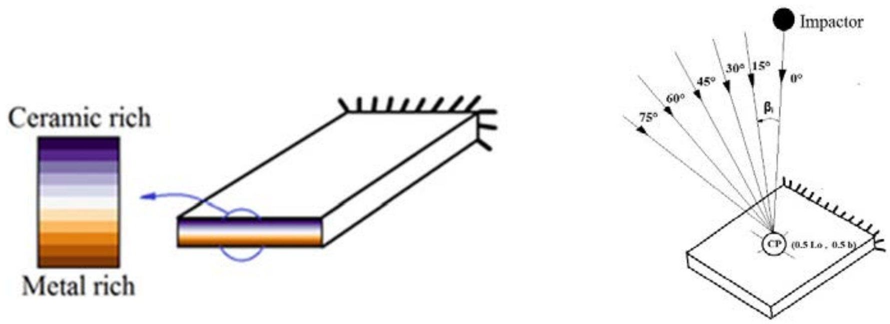
* Corresponding author. Tel.: +91 7086880231
*E-mail address:*infosudip@gmail.com

Peer-review under responsibility of the organizing committee of Implast 2016
doi:10.1016/j.proeng.2016.12.010

Nomenclature

P_i	Material property
V_f	Volume fraction
E, G, υ	Young's modulus, Shear modulus and Poisson's ratio
p	Power law exponent
h	Thickness
r_1, r_2	Radius of curvatures ($r_1 > r_2$)
L, b	Length, Width
$[M]$	Global mass matrix
[K]	Global stiffness matrix
$\{F\}$	Global vector of externally applied load
$\{\delta\}$	Global displacement vector
k_{mod}	modified contact stiffness
Δt	Time step
α	Indentation
F_c	Contact force
Ψ, β	Twist angle and oblique impact angle
w_p	Plate displacement
w_i	Impactor's displacement
V_i	Initial velocity of impactor

Functionally graded plates have potential applicability in aerospace, nuclear and mechanical industries. It has increasing demand for impact resistant structures as well as in design of advanced thermal barrier coatings. A plate with a functionally graded layer from ceramic to metal through its thickness combines the superior features of ceramic and metal. In other words, the ceramic-rich side provides good protection against projectiles while the metal rich side offers toughness and strength to maintain the integrity of the structure as long as possible. Hence, for the purpose of design and manufacturing, the accurate evaluation of their low velocity impact response characteristics of such FGM plate is important for the designers to ensure the reliability and operational safety. The pioneering investigations on FGMs for the low velocity impact analysis were carried out by Goldsmith [1] and Abrate [2]. Several studies on low velocity impact were carried out in past two decades but mostly on composite structures. Shariyat and Farzan Nasab [3] studied the low-velocity impact analysis of the hierarchical viscoelastic FGM plates using an explicit shear-bending decomposition theory and the new differential quadrature method, while previously Yalamanchili and Sankar [4] investigated on indentation of functionally graded beams and its application to low-velocity impact response. Many researchers studied on low velocity impact response [5-10] analysis in past.



(a) (b)

Fig. 1 (a) Cantilever functionally graded plate (b) Impact (normal and oblique) on FGM plate by a spherical mass at centre