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Low-velocity impact response of metal-ceramic functionally graded plates: A novel numerical modelling approach

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Abstract: This study presents a numerical modelling procedure for the low-velocity impact response of metal-ceramic FGM (Functionally Graded Materials) plates. Numerical modelling is performed using the explicit finite element code, LS-DYNA®. The actual mechanical response of the FGM plates is considered to develop a realistic numerical model, and the actual plasticity behaviour of the FGM plates is described using an elastoplastic material model, MAT_PIECEWISE_LINEAR_PLASTICITY. The numerical results are evaluated in terms of contact force and kinetic energy histories of the plates. To represent the accuracy and success of the developed numerical model, it is compared to the low-velocity impact test results and an existing elastoplastic model from the literature that is widely used to describe the elastoplastic behaviour of FGM structures, TTO (Tamura-Tomota-Ozawa) model. It is stated from the results that the present numerical model shows a good agreement with the experimental results, and the TTO model exhibits a stiffer response overestimating the contact force and underestimating the contact duration.

Keywords: functionally graded materials, low-velocity impact, numerical modelling, finite element method

1. Introduction

Functionally graded materials (FGMs) are a special class of composite materials with a continuous material composition change throughout the volume with respect to spatial coordinates that is obtained by a gradual variation of the volume fractions of constituents. FGM structures generally consist of metal and ceramic materials, and the material properties vary through the thickness direction. By combination of metal and ceramic constituents in a single volume and varying their combined properties continuously, they provide additional special features over conventional composite materials such as good thermal resistance and toughness which are very important in extreme loading conditions. FGMs are used in some critical fields such as aerospace, nuclear, automotive, and defence industries where dynamic effects are highly important. Therefore, it is important to determine the dynamic mechanical behaviour of FGMs subjected to impulsive loadings and to develop an accurate numerical model for saving experimental costs and predicting plasticity, damage, and fracture phenomena of FGMs for engineering design. However, numerical modelling of FGMs, especially for nonlinear impact problems, has some difficulties by reason of complexity of their structure.

In the literature, studies on the low-velocity impact response of FGMs are generally performed using only numerical or analytical approaches [1-2]. However, there is a lack of knowledge about combined experimental and numerical investigations on the low-velocity impact behaviour of FGMs. Therefore, a realistic numerical model that considers the actual mechanical response and plasticity of the FGM plates are developed in this study. A comparative evaluation between the present numerical model, experiment, and an existing elastoplastic model, TTO (Tamura-Tomota-Ozawa) model [3] is performed for the low-velocity impact response of the FGM plates. For this purpose, different stress to strain transfer ratios in the TTO model are considered from the literature [4-5]. It is indicated that the present numerical model shows a good agreement and gives more accurate results than the TTO model.

References

[1] APETRE NA, SANKAR BV, AMBUR DR: Low-velocity impact response of sandwich beams with functionally graded core. *International Journal of Solids and Structures* 2006, **43**(9):2479-2496.

[2] MAO YQ, FU YM, CHEN CP, LI YL: Nonlinear dynamic response for functionally graded shallow spherical shell under low velocity impact in thermal environment. *Applied Mathematical Modelling* 2011, **35**(6):2887-2900.

[3] TAMURA I, TOMOTA Y, OZAWA M: Strength and ductility of Fe-Ni-C alloys composed of austenite and martensite with various strength. *Proceedings of the 3rd International Conference on Strength of Metals and Alloys* Cambridge, 1973, pp. 611-615.

[4] GUNES R, AYDIN M, APALAK MK, REDDY JN: Experimental and numerical investigations of low velocity impact on functionally graded circular plates. *Composites Part B: Engineering* 2014, **59**:21-32.

[5] BHATTACHARYYA M, KAPURIA S, KUMAR AN: On the stress to strain transfer ratio and elastic deflection behavior for Al/SiC functionally graded material. *Mechanics of Advanced Materials and Structures* 2007, **14**(4):295-302.