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Buckling Analysis of Designed Fiber Metal Laminate Circular Cylindrical Shell Based on Maximum Tension Fracture Criterion

A. Nazari , K. Malekzade Fard

Department of Aerospace Engineering, Aerospace Research Institute, Tehran, Iran

ABSTRACT: In the fiber metal laminated shell with determination the proper fiber angle orientation is achieved the arrangement with maximum performance. For this purpose in this study the fiber angle orientation of composite layers of the fiber metal laminate circular cylindrical shells are changed frequently and each cases being subjected to lateral load and the tension of all composite layers are calculated for all cases. Then the fiber angle orientation that cause to maximum stiffness based on maximum tension fracture criterion is selected. For this purpose an analytical program linked to the numerical program is used and calculated result. The buckling analysis is applied to determine the performance of design process. The results of buckling analyses show that determination of the optimum fiber angle orientation causes to improvement of the fiber metal laminated shell stability. Comparing the effect of variation of the fiber angle orientation, variation of the metal layer properties and variation of the thickness shell on the buckling load is the another innovation of this study and it is determined that for various amount of metal volume fraction with change in which item the maximum stability is achived.in order to improve the result accuracy high order shear deformation theory is utilized for buckling analysis.

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1- Introduction

Using Fiber Metal Laminated (FML) shell in aerospace, civil and other engineering fields with weight sensitive applications has been increased due to their high strength to weight ratios. in recent decades, many investigations have performed on the buckling analysis of the composite shells but few literatures are available about the FML shells. Some of the notable study on the optimum design and buckling analysis of the laminated structure are discussed in [1, 2, 3]. There are also some good reviews on buckling of composite shells in the following lines. An excellent review of researches in this area was collected by Civalek [4] that presented a study based on Donnell's shell theory and first shear deformation shell theory on the static buckling problem of circular cylindrical panels, conical panels and circular shells under axial load. Arbelo et al. [5] investigated presented an experimental and numerical validation of a novel approach, using the vibration correlation technique for the prediction of realistic buckling loads on unstiffened cylindrical shells loaded in compression.

In this paper, buckling of FML circular cylindrical shell that designed based on maximum tension fracture criterion are analyzed using standard Galerkin procedure. For this purpose through a MATLAB program linked to the finite element software of ABAQUS, different shells with various fiber orientation are created and studied from optimization aspect. However this comprehensive program is able to analysis the FML shells with various fiber angle orientation, various metal layer properties and various thickness.

Corresponding author, E-mail: nazariali23@yahoo.com

2- Methodology

In this paper the fiber orientation of the FML cylindrical shells is optimized to achieve the best fiber angle of the FML cylindrical shells that cause to maximum stiffness based on maximum tension failure criterion. In the design procedure failure criteria is defined as:

$$\begin{aligned} &\frac{X_c}{\cos^2\theta} \prec \sigma_x \prec \frac{X_t}{\cos^2\theta} \\ &\frac{Y_c}{\sin^2\theta} \prec \sigma_x \prec \frac{Y_t}{\sin^2\theta} \\ &|\sigma_x| \prec \left|\frac{S}{\sin\theta\cos\theta}\right| \end{aligned} \tag{1}$$

In the Eq. (1), Y_C is bearing strength along vertical line of fiber, Y_T is tensile strength along vertical line of fiber, X_C is bearing strength along of fiber and X_T is tensile strength along of fiber.

Buckling of FML circular cylindrical shell based on three-dimensional higher order theory is analyzed. The formulation was based on an enhanced higher order theory that the vertical displacement components were assumed as quadratic one while a cubic pattern was used for the in-plane displacement components. In this formulation, the transverse normal stress was considered and the twelve variable displacement field, which can demonstrate kinematics better, compared to the First order Shear Deformation Theory (FSDT) and Classical Laminate Plate Theory (CLPT), no shear correction factors are needed. It also represents more accurate interlaminar stress distribution. The equations of motion and boundary conditions were derived via the Hamilton principle.

Hamilton's principal is used to define the equations of motion the analytical form is stated as follows:

$$\int_0^t \delta L dt \equiv \int_0^t \left[\delta K - \delta U + \delta w\right] dt = 0 \tag{2}$$

Where δk denotes the virtual kinetic energy, δU the virtual strain energy and δV the virtual potential energy due to the applied loads. In order to solve the equations of motion, these equations should be transformed in to the displacement coefficients. Galerkin method and the double Fourier series is utilized to solve the governing equations

3- Results and Discussion

The FML shell considered in this study consist of five aluminum and four glass epoxy layers. Each composite layer organized from four singular layer. Reinforce fiber in each singular layer could lie in 0, 30, 60 and 90 directions. If reinforce fiber of each composite layer lies in 0/60/60/0 directions achieves the maximum stiffness and lies reinforce fiber in 90/90/90/90 directions causes to minimum stiffness for FML shell.

The Fig.1 indicates the variation of buckling load vs. Metal Volume Fraction (MVF) for AL/GE-5-4-[0/60/60/0] and AL/GE-5-4-[90/90/90/90]. Buckling load of AL/GE-5-4-[0/60/60/0] construction vs. MVF is more than AL/GE-5-4-[90/90/90/90] construction. This fact shows the accuracy of design process because based on design process lies reinforce fiber in [0/60/60/0] and [90/90/90/90] directions cause to maximum and minimum stiffness respectively.

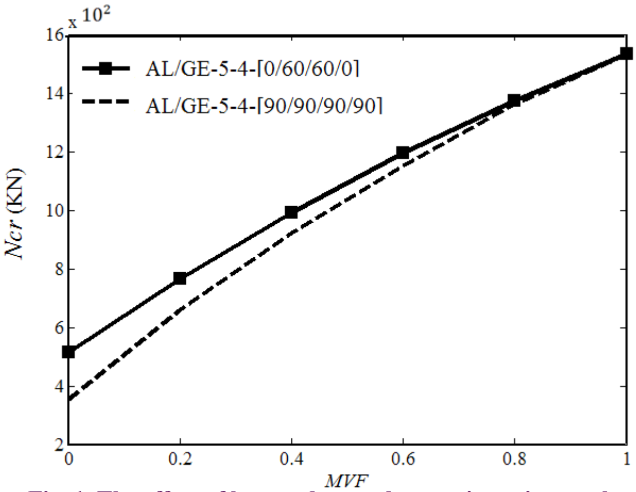

Fig. 1. The effect of best and worst layer orientation on the buckling load vs. MVF for AL/GE-5-4 FML shell

Comparison the efficiency of variation of the layer angle orientation with variation of the metal layer properties on the buckling load of AL/GE-5-4 FML shell is shown in Fig .2

As depicted in Fig.2, the stability of the FML shells depends on the metal layer properties and fiber angle orientation of composite layer. This figure shows that for which range of MVF the change of fiber orientation causes to the maximum stability and for which range of MVF the variation of metal properties have more efficiency on the shell stability in compared with fiber angle orientation.

The elastic module of the AL2024 is more than AL7475 but for MVF less than 0.7 the stability of AL7475/GE-5-4-[0/60/60/0] is more than AL2024/GE-5-4-[90/90/90/90] because for this range of MVF the influence of optimum

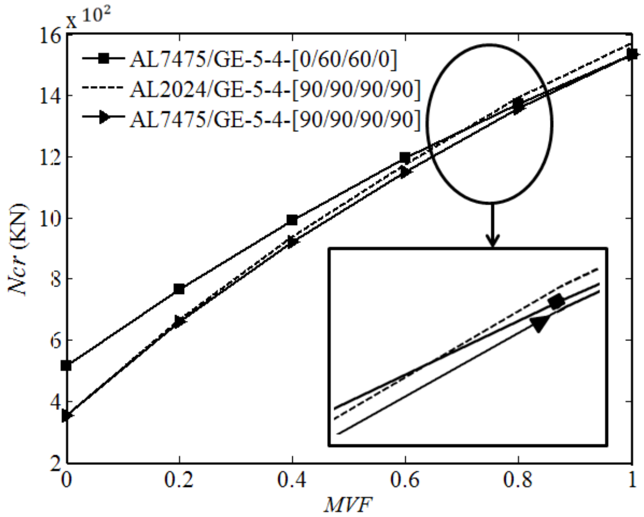

Fig. 2. Comparison the efficiency of the layer orientation variation with change of metal layer material on the buckling load of AL/GE-5-4 FML shell

layer orientation on the shell stability are more than type of metal layer material and for MVF more than 0.7 The stability of AL2024/GE-5-4-[90/90/90/90] is more than AL7475/GE-5-4-[0/60/60/0] because for this range of MVF the influence of type of metal layer material on the shell stability are more than optimum layer orientation

4- Conclusions

One of the most important innovations of this article is determination the best fiber angle orientation of composite layer of FML shells with goal of achieve the maximum stiffness based on maximum tension criterion. For this purpose a MATLAB program linked to the finite element software of ABAQUS is applied. Buckling of FML circular cylindrical shell based on three-dimensional higher order theory with 12 independent variables is analyzed. The characteristic eigenvalue governing equation is obtained based on Hamilton's principle using the Galerkin method. Comparing the effect of variation of the fiber angle orientation, variation of the metal layer properties and variation of the thickness shell on the buckling load is the another innovation of this study and it is determined that for various amount of MVF with change in which theme the maximum stability is achieved. The results of buckling analysis are validated by some common literatures. The results of buckling analyses show that determination of the optimum fiber angle orientation cause to improvement of the FML shell stability.

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