



Effects of Position and Shape of Cutout on the Axial Buckling Load of Composite Cylindrical Panel

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ABSTRACT: In this paper, the effects of position and shape of cutout on the buckling load of composite cylindrical panel under compressive load are investigated. The laminated cylindrical panel with an arbitrary cutout shape is simulated by the spline finite strip method. The first-order shear deformation theory is considered in this study. Using a linear buckling analysis, an eigenvalue problem is solved to obtain the buckling load of the panel under the compressive axial load. A comparison between the results obtained from the finite strip, finite element, and analytical methods was made to show the validity of the results obtained in this study. Several case studies are presented to investigate the effects of some parameters such as shape and position of cutout, central angle of panel, ply sequence of the composite layers, and boundary condition of the panel on its buckling load. The results show that the position and shape of cutout have considerable effects on the buckling load of the panel. The buckling load of the panel reaches its minimum when the cutout center has eccentricity from the loading direction. The results also show that the buckling load with quasi-isotropic configuration is greater than those of cross-ply and angle-ply.

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1- Introduction

Cylindrical shells/panels are widely used in the civil and mechanical engineering industries. Consequently, the buckling load of the shells/panels is investigated by several researchers. For instance, Shariati and Sedighi [1] evaluated the buckling load of the steel cylindrical panel using numerical and experimental approaches. Several studies have been conducted to investigate the effect of circular and rectangular cutouts on the buckling load of cylindrical shells [2]. According to previous studies, cutout shape and its position have a considerable effect on the buckling load of the composite cylindrical shell [3]. The cylindrical panel is a truncated cylindrical shell. Several investigations have been performed to evaluate the buckling load of these panels. For instance, Moradi and Khajehdezfuly [4] investigated the post-buckling behavior of composite cylindrical panels using spline finite strip method. Allahbakhsh and Dadrasi [5] evaluated the effects of area and shape of the cutout on the buckling load of square composite cylindrical panel using finite element method. In their studies the cutout was placed on the center of the panel and the buckling load was calculated using eigenvalue analysis.

A survey of the literature shows that the position of cutout has a considerable effect on the buckling load of the cylindrical shell and has gained much attention in the literature. However, the influence of cutout position on the composite cylindrical panel is not investigated in the literature. Moreover, the effects of different cutout shapes such as circular, elliptical, square and diamond on the panel buckling load have not been compared

with each other in the previous studies. Therefore, this study is performed to eliminate the above-addressed limitations. To this end, a composite cylindrical panel with arbitrarily shaped cutout placed in the desired position is simulated using the spline finite strip method. The buckling load of the panel is calculated based on the eigenvalue analysis. The validity of the results obtained from the current study is checked using comparison made with those obtained by the finite element and analytical approaches. Through a parametric study, the effects of shape and position of cutout on the buckling load of the composite cylindrical panel are investigated.

2- Methodology

A cylindrical panel with an elliptical cutout under the compressive load is shown in Fig. 1. As shown in this figure, l , b , R and ϕ are the panel length, width, radius and central angle of the panel. As illustrated in Fig. 1, Compressive load with magnitude of P_0 is applied to the curved edges of the panel. In this study, the cylindrical panel is modeled using the spline finite strip element.

The panel is divided into several strip elements. Four nodal lines are considered in each strip element and m knots are considered on each nodal line. B3 spline and Lagrangian shape functions are considered in longitudinal and transverse directions of the strip element to estimate each node displacement in the strip element. First-order shear deformation theory is used in this study and according to the normal-tangential local coordinate system, five degrees of freedom are considered in each node. u , v , w , ψ_x and ψ_y are membrane displacement in longitudinal direction of panel, membrane displacement in tangential direction, radial displacement, rotation about the tangential direction and rotation

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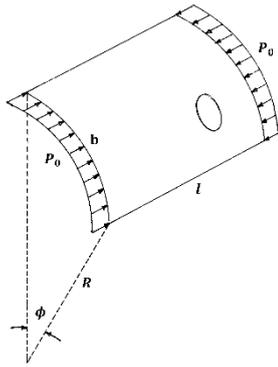


Fig. 1. Hybrid turbine model

Table 1. Turbine characteristics

Location	x_c	y_c
1	90	90
2	126	90
3	54	126
4	90	126

about the longitudinal direction, respectively. The displacement of each node is calculated using Eq. (1). In Eq. (1), ϕ_i is spline function of i^{th} knot, L_j is Lagrangian function of j^{th} nodal line [4, 6].

$$\{\Delta\} = \sum_{i=1}^{m+1} \sum_{j=1}^4 \Delta_{ij} \phi_i L_j \quad (1)$$

An isoparametric strip element is used to simulate an arbitrarily shaped cutout. In this regard, mapping functions are used to map the local element into the parent element [7]. Internal and external virtual works are written to derive tangential stiffness matrix and external force vector, respectively [6]. Based on the results obtained from a linear pre-buckling analysis and written internal virtual work, the geometrical stiffness matrix is derived [6]. Finally, the eigenvalue problem is solved to calculate the buckling load of the panel.

3- Results Validation

A comparison has been made between the results of the finite strip, finite element, and analytical approaches to investigate the validity of the results obtained from the proposed method. To this end, a square simple panel with elliptical cutout is simulated using the finite element and finite strip methods and the buckling load of the panel is calculated. The relative error between the buckling loads is limited to 2 percent. This shows that the strip element method is capable of calculating the buckling load of the panel with an arbitrarily shaped cutout. Another comparison between result of the analytical approach available in the literature and that of the finite strip shows the difference magnitude of 1.8 percent which is acceptable.

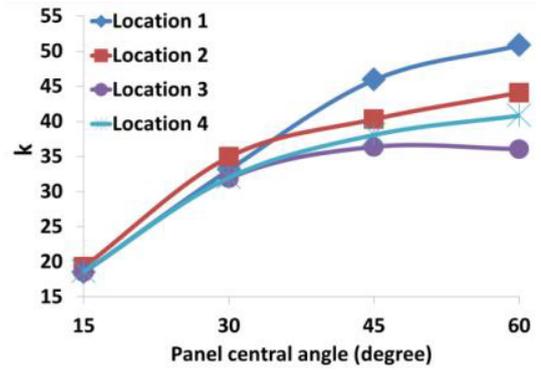


Fig. 2. The flow field and boundary conditions

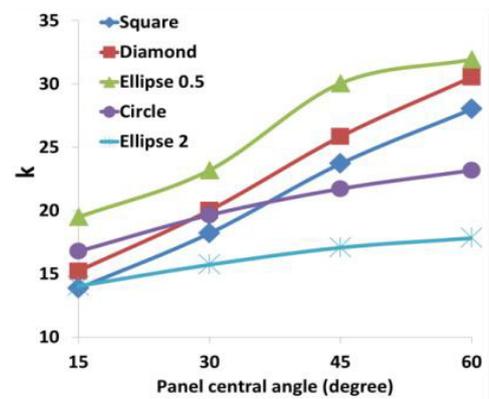


Fig. 3. Verification of straight-bladed turbine total moment coefficient

4- Results and Discussion

Through a parametric study, the effects of cutout shape and position on the buckling load of the panel are investigated. The cutout was placed in four locations (Table 1).

Fig. 2 shows that the central angle of the panel has a significant effect on the influence of the cutout position on the buckling load. When the central angle is greater than 30 degrees, the panel with central cutout has the most buckling load. The results presented in Fig. 3 indicate that the cutout with elliptical shape has lower and greater effects on the buckling load compared to other shapes and its effect depends on the direction of bigger chord of ellipse to the loading direction.

5- Conclusions

In this paper, the effect of cutout position and shape on the buckling load of composite cylindrical panels was investigated. The panel was simulated using the spline finite strip method. The results of current study were compared with those of the finite element method and analytical approach to prove their validity. The results obtained from this study show that when the bigger chord of the elliptical cutout is parallel with loading direction, the panel has the minimum buckling load. The cutout eccentricity has a significant effect on the buckling load. As the eccentricity is increased, the buckling

load is decreased, and when the central angle of the panel increases, the buckling load of the panel increases.

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