Flutter Reliability Analysis of Laminated Composite Plates

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Abstract

Composite materials are widely used in modern aerospace flight vehicles, especially because of their high specific strength and lightweight than other materials. Since the study of reliability and uncertainty of composite material design variables in aeroelasticity has received less attention, in the present work the reliability of the laminated composite plate due to uncertainty in variables including elastic model, Poisson coefficient, density, thickness, and length is examined. The composite laminated plate is symmetric with different boundary conditions subjected to supersonic airflow. The classical plate theory and the first-order piston theory are utilized to derive the equation of motion. The differential quadrature method has been used to discretize and analyze the aeroelastic equations. The governing equations after discretization are solved by calculating and analyzing eigenvalues and the occurrence of the flutter phenomenon for the laminated composite plate is obtained. To examine the reliability, the distribution of random variables as a normal distribution has been used. Finally, the Monte Carlo simulation method was used for five different boundary conditions to obtain the reliability of the plate flat threshold. According to the presented results, the reliability value of the composite plate flutter threshold for the full hinge boundary condition (SSSS) will be higher than other boundary conditions and the all-bound boundary condition (CCCC) will be lower than other boundary conditions Also, according to the studies on the condition of the fiber angle of the composite plate, it can be concluded that increasing the angle of the fiber of the composite plate increases the reliability of the occurrence of the filter threshold.

KEYWORDS
Laminated composite plates, Reliability, Flutter, Monte-Carlo simulation, Differential Quadrature Method

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1- Introduction

The interaction of aerodynamics, elasticity, and inertia causes aeroelasticity problems in aerospace structures. The phenomenon of flutter is a kind of dynamic instability in which the elasticity of the structure plays a very important role. This phenomenon usually has the most important effect on the design of the structure of flying objects. In the classic type of flutter, as usual, and not always, two degrees of freedom of the body are coupled with each other and cause instability [1]. In this article, the reliability of the laminated composite plate due to uncertainty in variables including elastic model, Poisson coefficient, density, thickness, and length is examined.

2- Equation of Motion

Fig. 1 shows the configuration of a laminated composite plate. To simulate the behavior of the plate, the classical plate theory is used. The linear displacements field of any generic point at position (x, y, z) and at time t on the plate are indicated by (u, v, w) and represented by Ref [2].

$$\begin{aligned} u(x,y,z,t) &= u_0(x,y,t) - z\frac{\partial w_0(x,y,t)}{\partial x} \\ v(x,y,z,t) &= v_0(x,y,t) - z\frac{\partial w_0(x,y,t)}{\partial y} \\ w(x,y,z,t) &= w_0(x,y,t) \end{aligned} \tag{1}$$

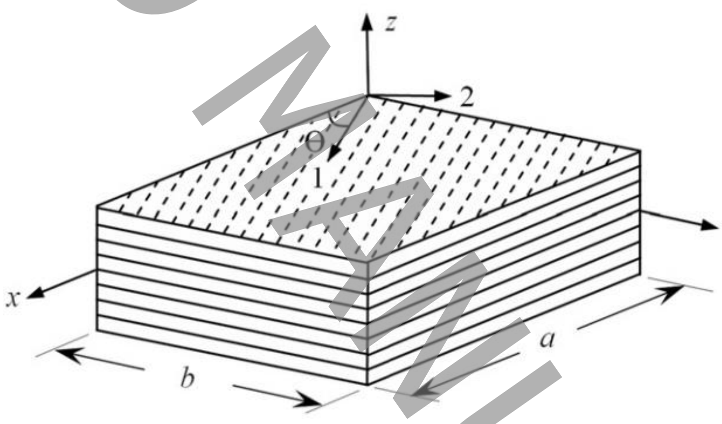

Fig. 1 Coordinate systems of fiber-reinforced materials

In the present study, the linear piston theory is utilized as follows,

$$\Delta p = \frac{2q_\infty}{U_\infty\sqrt{M^2-1}}\left(U_\infty\frac{\partial w}{\partial x} + \frac{M^2-2}{M^2-1}\frac{\partial w}{\partial t}\right) \tag{2}$$

According to Hamilton’s principle, the governing equations of motion are obtained.

3- Results and Discussion

The governing equations after discretization are solved by calculating and analyzing eigenvalues and the occurrence of the flutter phenomenon for the laminated composite plate is obtained. To examine the reliability, the distribution of random variables as a normal distribution has been used. Finally, the Monte Carlo simulation method was used for five different boundary conditions to obtain the reliability of the plate flat threshold. As shown in Fig. 2, for N= 10000, the reliability of the flutter threshold has converged to 89.7627. Therefore, in this paper, the number of Monte Carlo simulation cycles is considered to be N = 10000. To examine the reliability of the occurrence flutter of the composite plate with different boundary conditions and $[-\theta/+\theta/-\theta]_S$, N = 10000 is considered. In Table 1, the reliability of the occurrence flutter of the composite plate with different boundary conditions and different fiber angles is obtained.

4- Conclusion

According to the presented results, as the boundary conditions of the plate move towards the clamped boundary conditions, the reliability value o of the c composite laminated plate decreases, and with increasing the angle of the composite plate fibers, the reliability of the threshold occurrence threshold increases. Also, increasing the number of layers in the composite plate reduces the reliability of the flutter instability. For the symmetrical composite plate with a fiber angle of 30 degrees and the SSSS boundary conditions for the number of layers 2, 4, 6, 8, and 10, it was found that increasing the number of layers in the composite plate causes a decrease of 8 percentage of reliability will be the threshold for the occurrence of flutter. According to the presented results, the reliability value of the composite plate flutter threshold for the full hinge boundary condition (SSSS) will be higher than other boundary conditions and the all-bound boundary condition (CCCC) will be lower than other boundary conditions Also, according to the studies on the condition of the fiber angle of the composite plate, it can be concluded that increasing the angle of the fiber of the composite plate increases the reliability of the occurrence of the filter threshold.

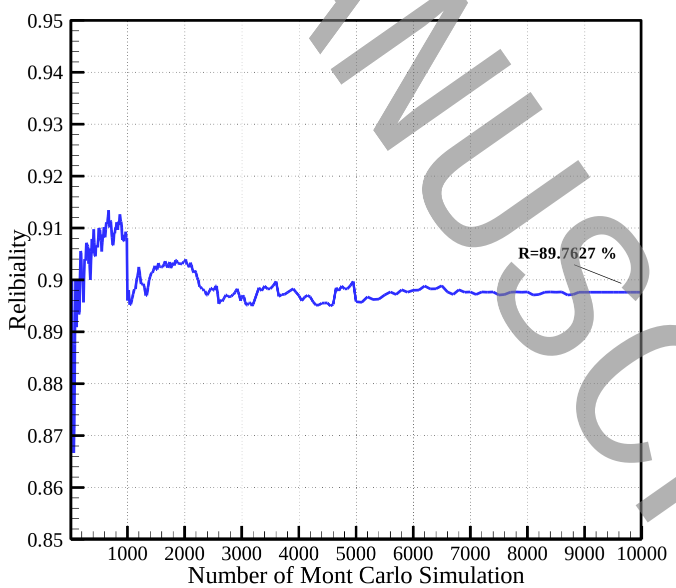

Fig. 2 Convergence study for number of Mont Carlo Simulation

Table. 1 Reliability value of the composite plate flutter threshold for the full hinge boundary

Boundary Conditions	Ө			
	15	30	45	60
SSSS	80.98	90.87	92.23	96.32
SSSC	79.92	90.03	84.18	95.78
SCSC	79.63	89.76	86.23	93.12
SSCC	76.42	85.31	82.79	91.24
CCCC	73.39	78.42	80.18	87.63

5-References

[1] R.L. Bisplinghoff, H. Ashley, Principles of aeroelasticity, Courier Corporation, 2013.
[2] W. Soedel, M.S. Qatu, Vibrations of shells and plates, in, Acoustical Society of America, 2005.