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Finite Element Analysis of Natural Vibration in Thin Aluminum Sheet

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ABSTRACT:
Thin aluminum sheet has a lot of applications in automobile industry, aerospace field, shipbuilding and offshore equipment. This thin sheet of aluminum is attractive for its light weight which will safe energy especially in dragging and lifting of airplanes. Natural vibration in such application has a great important and intense, therefore, modal analysis using finite element method is carried out over a thin aluminum sheet of (100 mm ×100 mm× 2 mm). The application of these sheet may have a stress riser. Therefore, the analysis is extended to involve circular holes for or even elliptical ones. The finite element results give a little difference between the natural vibration of un-notch plate and other with circular or elliptical ones, moreover the eigenvalue and mode contours are explained.
Keywords: Aluminum strip, Natural frequency, Angular velocity, Mass system

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I. INTRODUCTION:

The analysis of natural frequencies of structure material has intensive demand in designing and safety requirements in mechanical and aerospace application. Aluminum alloy and its composite material distinguished by relatively high strength to mass ratio. In dynamic analysis, the characteristics like natural frequencies and mode shapes are important to study. The natural frequency of any material should have the material mass and young's modulus or stiffness.

Klimenda and Soukup [1] performed a modal analysis and finite element technique on natural frequency of thin aluminum sheet using Ansys software. Effect of stress riser did not consider.

Ramu and Reddy [2] experimentally and numerically studied the natural frequency of aluminum alloy 6061 on shape of plate. The used plate was square of 300 mm side length and 10 mm thickness. The modal analysis is extracted using Data acquisition system. The experimental results were compared by a finite element result. The simulation results were in good agreement.

prasad et al [3] investigated the free vibration of thin and thick plate of brass, copper, stainless steel and aluminum. They carried out modal analysis using finite element method, then the obtained results were validated using experimental study using hammer with data acquisition device. The finite element model used to give five first modes of natural frequencies. The FEM used linear elastic behaviors of all tested material. The finite element ANSYS software is used in the calculations.

Usoltsev et al. [4] studied the influence of exciting vibration frequency on the crystallization and density of aluminum alloy AK9M2 AK12M2. The results provide data that alloy crystallization time decrease, this was depending on the vibration amplitude. The material density slightly increases with the rise of vibration amplitude.

Rebaïne et al. [5]studied static and dynamic vibration of aluminum and steel used in bus farm in Canada. They preformed two types of analysis; the first method used modal analysis to obtain the natural frequencies without any excitation stress, the explained that as any excitation may cause harmful or even discomfort of the vehicle. The second method used ANSYS finite element workbench to solve static analysis of the fram with external stress distribution and deformation.

Ajay S. Patil [6] investigated the free vibration of isotropic plate at changing end boundary conditions using finite element model. This attempt was new as earlier it was only used static analysis.

Many works [7-21] experimentally and numerically studied the natural vibration of metal structure which have series role on a lot of applications.

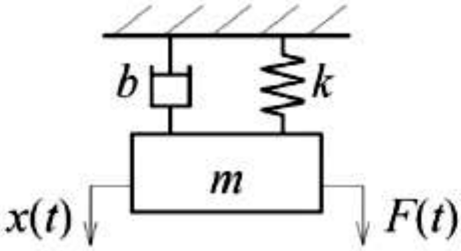
The present study, natural frequency of alumunim thin sheet without and with stress raiser is measured using finite element method. The aluminum plates are un-notch, or having central circular or elliptical hole. The plate is loaded based on cantilever beam modal analysis.

Modal analysis:

Modal analysis for vibrated members helps in determine eigenvalues and shape modes. The mechanical system used in modal system with one degree of freedom is shown in Fig. 1. The equation of motion of such system which characteristic by mass m, stiffness modulus K, damping factor b and applied force F(t).

$$m\ddot{x}(t) + bx(t) + k\dot{x}(t) = F(t) \quad 1$$

where x – displacement [m], $\dot{x}$ – velocity [m/s], $\ddot{x}$ – acceleration [m/s^2], F – applied force [N].



If it neglects the damping the equation (1) derived asm

$$m\ddot{x}(t) + kx(t) = F(t) \quad 2$$

a boundary conditions $x(0) = x_0, \dot{x}(0) = \dot{x}_0$, $F(t) = 0$ The equation (2) will give the following:

$$\ddot{x}(t) + \Omega_0^2 x(t) = 0 \quad 3$$

Where $\Omega_0^2 = \frac{K}{m}$

Solution of eqn. (3)

$$x(t) = C\ \sin(\Omega_0\, t + \phi) \quad 4$$

where Ω –angular frequency [rad/s], C – amplitude [m], φ – phase angle [rad].

Finite element domain

The finite element model is used linear behavior of aluminum with young's modulus 71 GPa and passion ratio of 0.34, while density is considered 2700 kg/m^3, the plate is of dimension (100 mm ×100mm ×2 mm) the plate is fixed in one end to let it like cantilever supported beam. Three types of plates domain are implemented in the model; un-notch plate with number of mesh element 2500 (Fig. 2-a), a plate with central elliptical hole of 3032 mesh element (Fig.2-b) and finally a plate with circular holes of 2899 element (Fig. 2-c). The element type of C3D8R: An 8-node linear brick, reduced integration and hourglass control are used, this give swelling and help to well convergence. Fig. 3 illustrate finite element domain with boundary condition

Fig. 2 Mesh domain a) un-notch, b) elliptical hole, c) circular hole

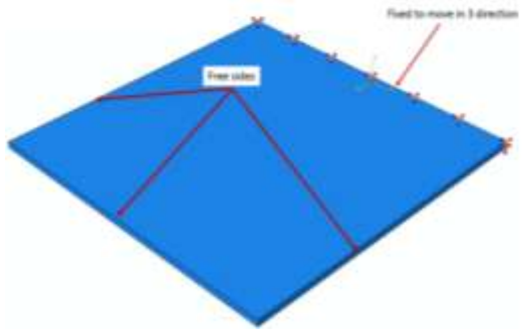


Fig. 3 Domain with B.C

II. RESULT AND DISCUSSION

Fig. 4 shows relation between shape modes and eigenvalues of three-square plate samples, un-notch, a plate with circular open hole and a plate with elliptical open holes. These holes consider a stress raiser at which stress concentration or stress intensity increase around it. But in natural vibration application, the stress raiser has a little effect for shape modes or even frequencies see (Fig. 5). The contour for the five first modes is illustrated in Fig. 6. The deference in the contour in the first two modes might be identical for all specimens, while the 3 next contour the deference is a little increase. This due to that the stress raiser make dissipation for the frequency waves through it. The difference is very little, because there are not an exciting force. It is clearly observed that the red color which means large elastic deformation is near the side far away the supporting sides. This result is due to large bending due to hammer action. It is also observed that the elastic displacement distributed uniformly with to longitudinal band (blue color), while the focus blue color pale.

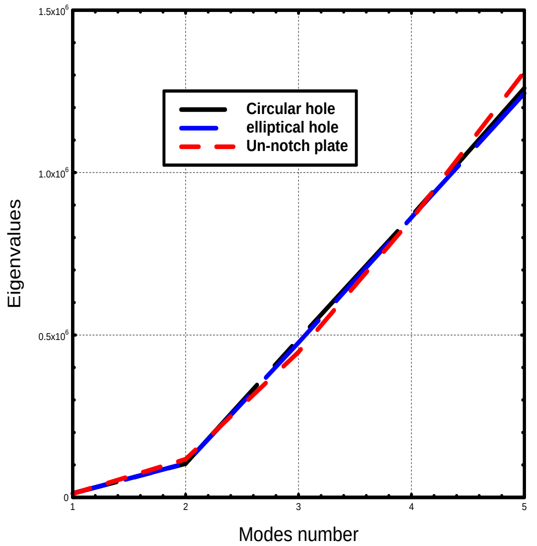


Fig. 4 variation eigenvalues with number of shape modes

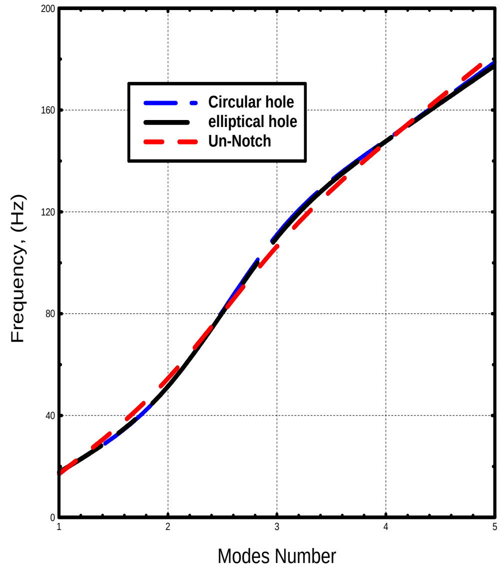


Fig. 5 variation of frequency with number of shape modes

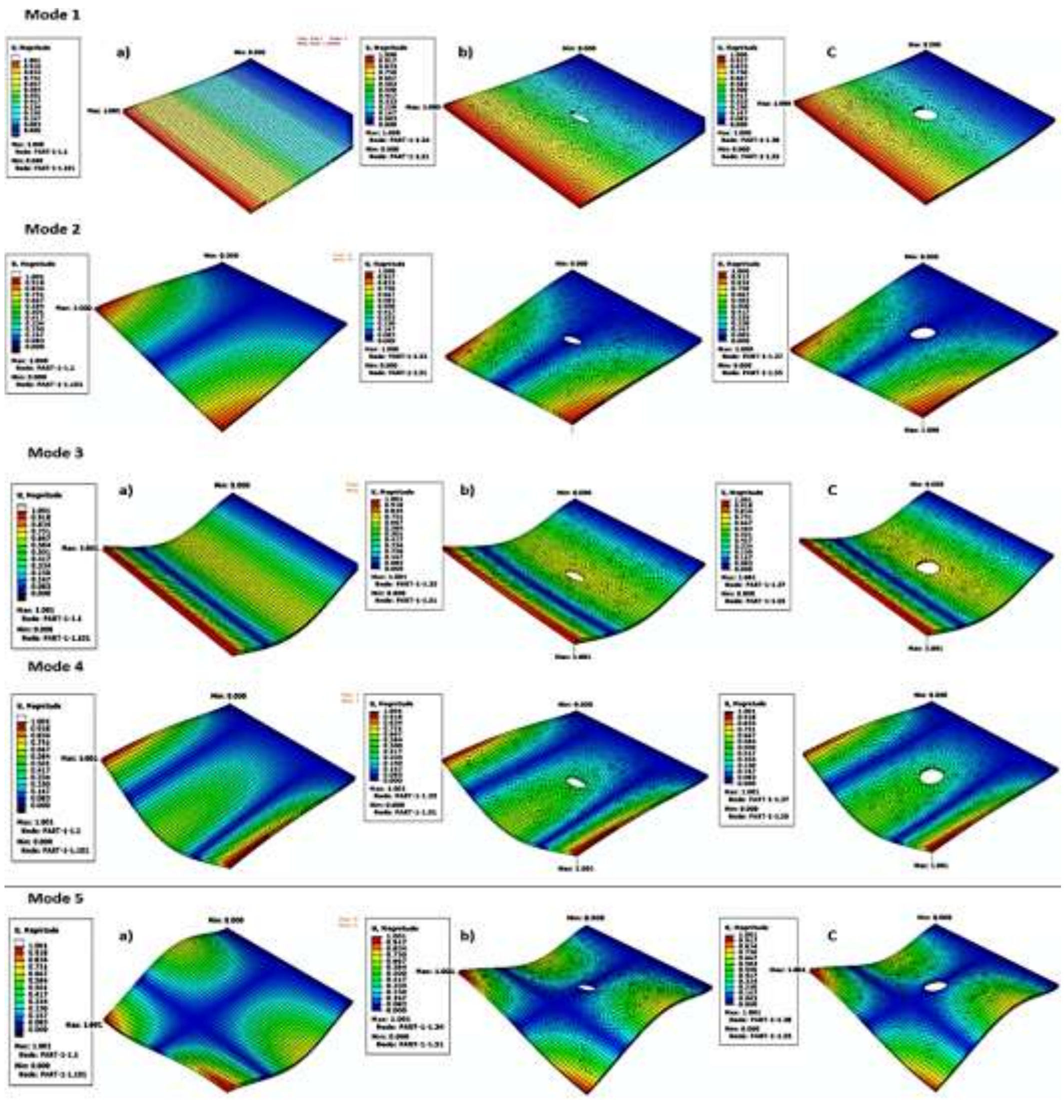


Fig. 6 Shape modes as FEM prediction

III. CONCLUSION

Finite element model is established and well built. The model gives that stress raiser shape in aluminum plate has a little effect on the natural frequency. The contour elastic displacement is shown that the elastic deformation moreover elastic strain is increasing away the supporting sides of plate. This result give advantage for using aluminum plate with any shape of holes in application where vibration occur, without take consider there effect on the vibration performances.

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