Stress Concentration of a Curved Plate under Bi-Axial Loading

Zechariah Gajadhar
Vaughn College of Aeronautics and Technology, Flushing, NY, United States, zechariah.gajadhar@vaughn.edu

Advisor: Yougashwar Budhoo, PhD
Vaughn College of Aeronautics and Technology, Flushing, NY, United States, yougashwar.budhoo@vaughn.edu

ABSTRACT

In a typical undergraduate Mechanics of Materials curriculum, Stress Concentration is taught at an intermediate level. Students usually analyze the Stress Concentration of a flat plate which has some discontinuity like a circular hole or fillet. Using given formulas and tables, the Stress Concentration Factor can also be determined. However, if the plate is curved what occurs to the localized stress at the discontinuity? An example of this can be seen on an aircraft window. This paper will endeavor to compute what the stress is at this discontinuity and also establish a stress concentration factor chart for undergraduate use.

1. INTRODUCTION

Stress concentration in regions of discontinuity is very important and its consideration is critical when designing complex structures. The purpose of this paper is establish a simple graphical approach to determine the stress concentration factor in a curved plate/shell with a discontinuity. Not only will the stress concentration chart for curved plate under uniaxial loading be developed, but also that for biaxial loading will be developed. This plate will serve as representation of an aircraft fuselage where the discontinuity represents the window cutouts.

2. MODELING

A flat plate 6-in x 12-in x 0.25-in with a center hole with diameter ranging from 0.3 inches to 3 inches was modeled in a finite element analysis (FEA) software. The plate was assigned material properties of aluminum. A uniaxial load of 100 lbs was applied to the plate. The average stress in the plate was calculated using equation (1) while the maximum stress was obtained in the vicinity of the hole from the finite element mode. Using equation (2), the stress concentration factor was obtained. The reason for this is to first establish the validity of the FEA model. After validation of the model, a curved plate was modeled as shown in fig. 2 with same dimensions as the flat plate.

$$\sigma_{avg} = \frac{P}{(L - h_d) \times t} \quad (1)$$

Where:

P = Axial Force
L = Length of Plate
h_d = Hole Diameter
t = Thickness of Plate

$$K = \frac{\sigma_{max}}{\sigma_{avg}} \quad (2)$$

The angle of curvature, θ, will be varied and the stress concentration factor be found for various center hold diameters. The final step of the paper will be to establish the relationship between stress concentration factor under a biaxial loading and different angle of curvature, θ.

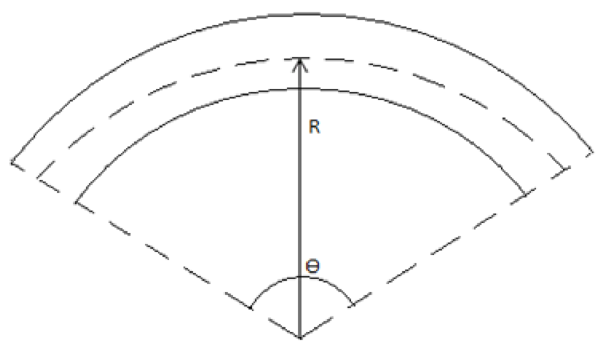

Figure 1: Curved plate

3. NUMERICAL ANALYSIS

Fig. 2 shows the model of the flat plate that was used for the preliminary work. The software used in in this analysis was CATIA. The element used for meshing was tetrahedron. and the mesh size after a mesh convergence study was chosen to be 0.1-in.

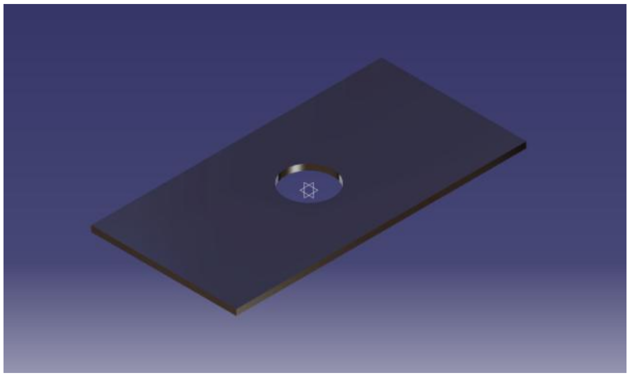

Figure 2: Model of the plate

Since it was not possible to apply loading at both ends of the plate, one end had a fixed boundary condition, while loading was applied on the opposite end. It can be seen in fig.3 that the maximum stress is around the region of discontinuity. It could also be seen that the stress distribution in the plate was symmetric. This means that a quarter model of the plate could be used in the analysis if needed.

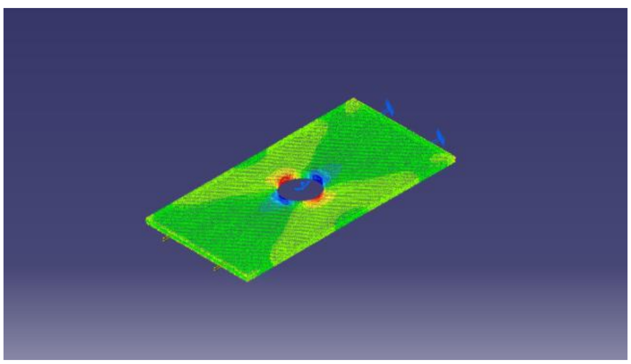

Figure 3: Aluminum Plate with a 2-in diameter hole

After varying the diameter, the stress concentration graph was obtained in fig 4. The graph was matched very closely to the stress concentration charts which currently exists [1,2] with less than 5% error.

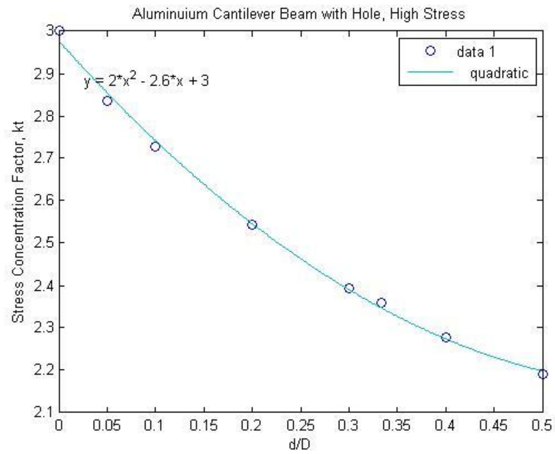

Figure 3: Stress Concentration Factor Graph obtained for Flat Plate

4. FUTURE WORK

The next phase of this paper would be obtain stress concentration for a curved plate under uniaxial and biaxial loading.

REFERENCES

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