IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 20, Issue 2 Ser. III (Mar. – Apr. 2023), PP 37-41
www.iosrjournals.org

Study the effect of different ellipse sizes on the stress distribution around an elliptical hole in a plate subjected to axial loading using Finite difference analysis.

Md Mesbah Uddin
Department of Mechanical Engineering, Northern Illinois University

ABSTRACT
This study investigates the impact of varying ellipse sizes on the distribution of stress around an elliptical hole in a plate under axial loading, utilizing finite difference analysis. The study aims to understand how the size of the ellipse affects the stress distribution and how it can be utilized to mitigate stress concentrations in real-world engineering applications. The results show that the stress distribution around the hole is heavily influenced by the size of the ellipse, with smaller ellipses leading to higher stress concentrations. This study provides valuable insights into the effect of ellipse size on stress distribution, which can aid in the development of new techniques for stress mitigation in engineering applications.
KEYWORDS*: Finite Difference scheme, stress distribution, Numerical analysis*

Date of Submission: 10-04-2023 Date of Acceptance: 23-04-2023

I. INTRODUCTION

The stress function technique has been extensively used by researchers to analyze stresses in various scenarios, such as circular holes in plates [1], slender holes [2], concentrated loads on straight boundaries [3], and concentrated loads on beams. Uddin [4] initially introduced the formulation of two-dimensional elastic problems, and Idris [5] later utilized it to obtain analytical solutions for different mixed boundary mode elastic problems. Ahmed further extended its use by solving finite difference solutions for mixed boundary value problems of simple rectangular bodies. Dow, Jones, and Harwood found that the finite difference technique was more accurate than the finite element technique in studying stress distribution along the boundary. Akanda [6] later developed a novel numerical scheme that enabled the solution of irregular-shaped elastic bodies with mixed-mode boundary conditions. These advancements have greatly improved our understanding of stress analysis and its application in the design and optimization of engineering structures. Computational techniques to solve numerical analysis such as computational fluid dynamics, finite element method, machine learning, molecular dynamics has become very popular in the last two decades to solve numerical analysis [7,8,9]. This study is an extended work on our previous work [7], focusing on the effect of different ellipse sizes on the stress distribution around an elliptical hole in a plate subjected to axial loading using finite difference analysis.

II. METHOD AND MODELLING

2.1 Governing equations

A new function called displacement potential function *(ψ)* is used to solve the governing equation, which is defined as a function of displacement,

$$u = \frac{\partial^2\psi}{\partial x\partial y} \quad (1)$$

$$v = -\frac{1}{1+\mu}\left[(1-\mu)\frac{\partial^2\psi}{\partial y^2} + 2\frac{\partial^2\psi}{\partial x^2}\right] \quad (2)$$

Putting this value in ψ *(x, y)* it becomes:

$$\frac{\partial^4\psi}{\partial x^4} + 2\frac{\partial^4\psi}{\partial x^2\partial y^2} + \frac{\partial^4\psi}{\partial y^4} = 0 \quad (3)$$

The problem has been simplified to the evaluation of a single function (x,y) from the bi-harmonic equation, while ensuring that the function satisfies the specified boundary conditions at the boundary.

2.2 Geometry and Boundary condition:

Figure 1 illustrates the geometry of the problem, where the material assumed to be perfectly elastic with material properties corresponding to a Poisson's ratio of μ=0.3. However, it's important to note that this methodology can be applied to any type of elastic material. Six different combinations of h and k are used to study the effect of ellipse size on the stress distribution as shown in Figure. 2.

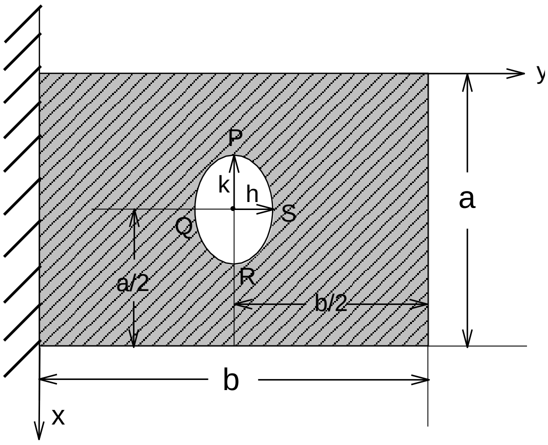


Fig. 1- Geometry of the problem [7]

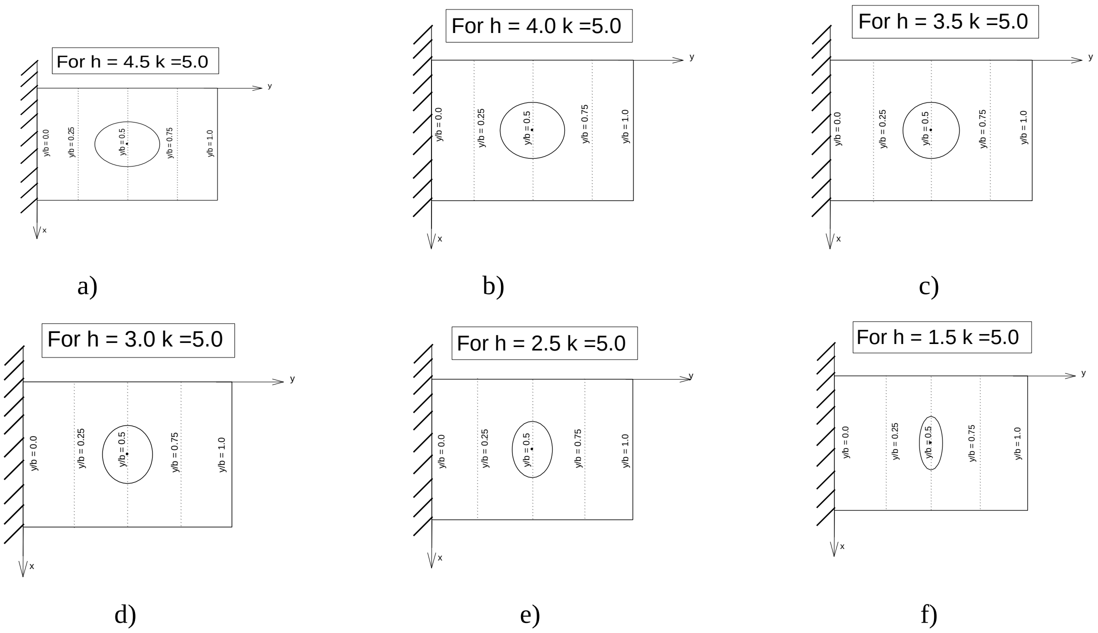


Figure. 1- Geometry of the problem used in this study. a) h=4.5, b) h=4, c) h=3.5, d) h=3, e) h=2.5 and f) h=1.5

The boundary AB is fixed (Figure.3) so there is no displacement, and the boundary conditions are un=0.0, ut=0.0. The right boundary CD has a uniform tensile load and the boundary conditions for every nodal point are $\sigma_n /E = 3\times10^{-4}$, $\sigma_t /E = 0.0$, where E is the modulus of elasticity and equals 200GPa. The top and bottom boundaries AD and BC are free from stress with boundary conditions $\sigma_n /E = 0.0$, $\sigma_t /E = 0.0$. The surface of the internal hole has no external load, so the boundary conditions are $\sigma_n /E = 0.0$, $\sigma_t /E = 0.0$. Stress and displacement distribution are obtained from the computer program's output, and five different sections are analyzed to study the hole's effect on the plate.

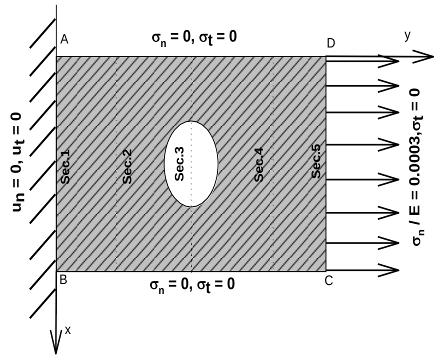
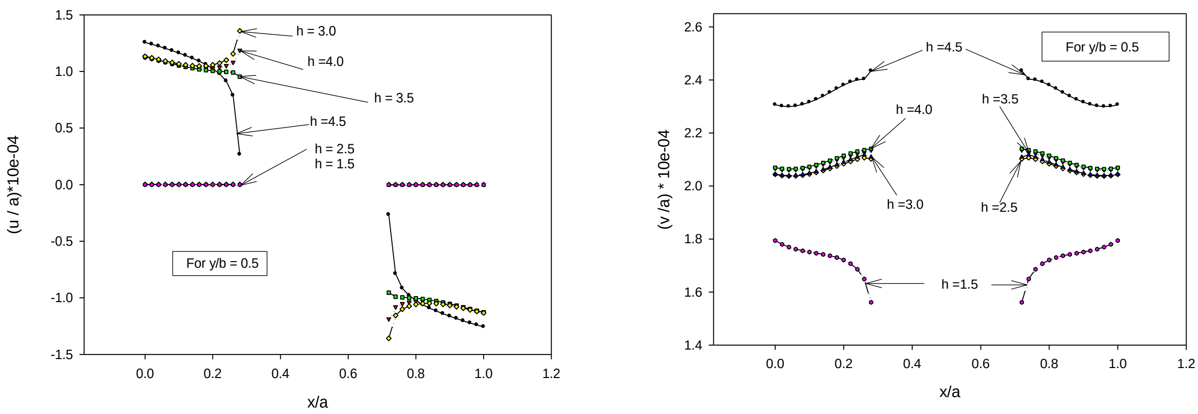


Figure 3- Boundary Conditions applied for the problem(b). The body is divided into 5 sections. (Sec 1: y/b=0, Sec 2: y/b=0.25, Sec 3: y/b=0.5, Sec 4: y/b=0.75, Sec 5: y/b=1.0) [7]

III. Results and discussions

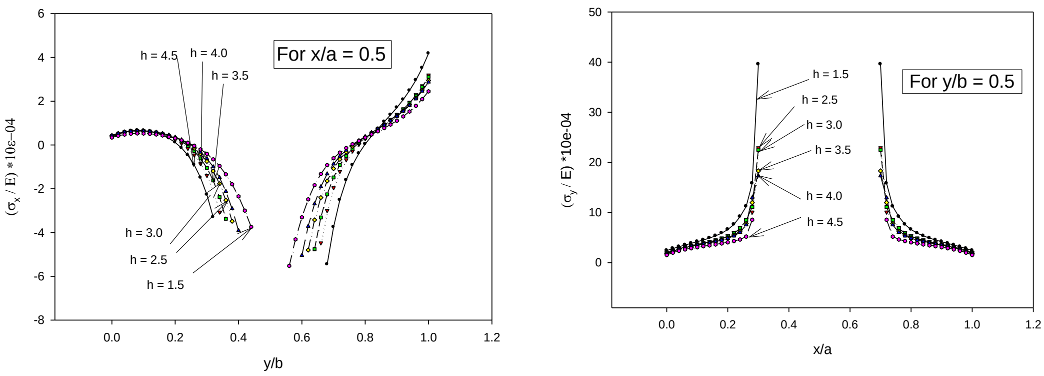
Figure 4 shows the distributions of u and v for the different ellipse sizes. In this problem, a larger hole size is used to study the deflection of an ellipse-shaped beam. The deflection is measured at the critical section of the centerline for different ellipse sizes. Then, the major axis of the ellipse is narrowed to study the change of deflection along the x-axis. Negative deflection is identified from the bottom to the top section and positive deflection from the top to the bottom section. The distribution of deflection along the centerline is shown in Figure 4 (a). It is observed that higher values of "h" result in higher deflection. When the major axis of the ellipse is narrowed, the deflection ratio decreases, and for the thinnest section (h=1.5), the deflection approaches zero. The distribution of deflection is symmetrical from the centerline. The deflection "v" of an ellipse decreases as the size of the ellipse increases due to less material flow. This is because higher material flow results in less deflection, and the two have an inversely proportional relationship. In Figure 4 (b), the deflection of "v/a" for various ellipse sizes is shown, and as the major axis decreases, the deflection also decreases, which is expected. Since the section is at the center, the graph is symmetric.



(a) (b)

Fig. 4- Stress distribution of u (a) and v(b) in different 5 ellipse size

In Figure 5, the distribution of σ_x and σ_y for different ellipse size is plotted against the distance from the left boundary. In Figure 5 (b), it can be observed that the primary stress along the vertical axis initially reduces and then increases after the hole section. This is because there is less material flow, and higher material flow results in lower stress. The stress distribution follows this pattern.



(a) (b)

Fig. 5- Stress distribution of σ_x (a) and σ_y (b) in different ellipse size

In Figure 6, the distribution of $\boldsymbol{\tau_{xy}}$for different ellipse size is plotted against the distance from the left boundary The shear stress value is very small and does not vary much for all sections, except for a slight increase in the middle section that returns to normal after the hole ends.

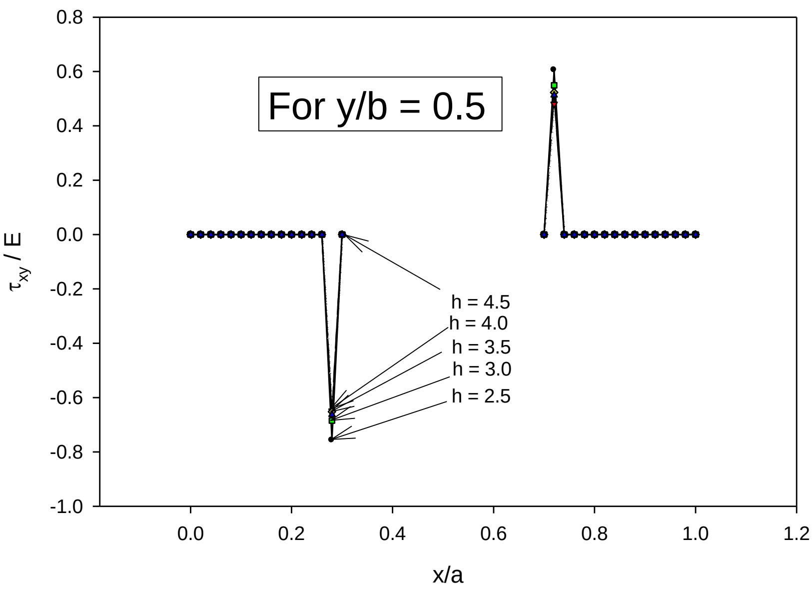


Fig. 4- Stress distribution of τ_{xy} in different ellipse size

ACKNOWLEDGMENT

We would like to thank the Department of Mechanical Engineering and Department of Naval Architecture and Marine Engineering at Bangladesh University of Engineering Technology.

REFERENCES

[1]. H. L. Cox, "The elasticity and strength of paper and other fibrous materials," 2nd ed.), John Wiley & Sons, 2005.

[2]. M. Tuna and P. Trovalusci, "Stress distribution around an elliptic hole in a plate with 'implicit' and 'explicit' non-local models," in Composite Structure, vol. 256, 113003, Jan. 2021.

[3]. S. K. Deb Nath and M. A. Salam Akanda, "A finite difference solution of a steel plate with an internal hole using the displacement potential approach," in Journal of Strain Analysis, vol. 44, no. 8, pp. 713–728, 2009.

[4]. M. W. Uddin, "Finite difference solution of two-dimensional elastic problems with mixed boundary conditions," M.Sc. Thesis, Carleton University, Canada, 1966.

[5]. A. B. M. Idris, "A new approach to the solution of mixed boundary value elastic problems," M.Sc. Thesis, Bangladesh University of Engineering and Technology, Bangladesh, 1993.

[6]. M. A, S Akanda, S. R. Ahmed, M. R. Khan, and M. W. Uddin, "A finite difference scheme for mixed boundary value problems of arbitrary shaped elastic bodies," in Advances in Engineering Software, vol. 31, no. 3, pp. 173-184, 2000.

[7]. M. M. Uddin, "Finite Difference Analysis of Stress Distribution Around an Elliptical Hole in a Plate Subjected to Axial Loading", IJMDES, vol. 2, no. 4, pp. 1–4, Apr. 2023.

[8]. Uddin, Md. Mesbah, "Studying the Scratching Behavior of Nb/NbcNanolaminate Using Molecular Dynamics Atomistic Simulations," Northern Illinois University ProQuest Dissertations Publishing, 27999015, 2020.
[9]. Ahamed, Sabber, Uddin, M Mesbah "Estimating Uncertainty of Earthquake Rupture Using Bayesian Neural Network". ArXiv:1911.09660 [Physics, Stat], November. https://arxiv.org/abs/1911.09660v2.

Md Mesbah Uddin. "Study the effect of different ellipse sizes on the stress distribution around an elliptical hole in a plate subjected to axial loading using Finite difference analysis." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 20(2), 2023, pp. 37-41.