ISSN No:-2456-2165

Stress and Deflection Analysis of Cantilever Beam by Numerically

Daw Thanda Aye [1st]
Department of Engineering Physics[1st]
Technological University (Toungoo)[1st]
Toungoo,Myanmar

Daw Aye Myint Thwe[2nd]
Department of Engineering Physics[2nd]
University of Technology (Yatanarpon Cyber City)[2nd]
Pyinoolwin, Myanmar

Abstract:- This study focus on the stress and deflection of a cantilever beam under 5kN load. It consists of a finite element model to the rectangular-shaped cross-section. The area of this beam is 0.2 x 0.3 m and the length is 1 m. For this purpose, a cantilever beam with the only deflection in one direction is used. The whole study, modeling, and behavior of structural cantilever beam for loading and boundary conditions are performed on the Solidwork.

Keywords:- *Finite Element Model, Stress, Deflection, Solidwork.*

I. INTRODUCTION (*HEADING 1*)

Beam Structure has been widely used in various mechanical, civil and aerospace industries for various applications. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment. A beam is a member subjected to loads applied transverse to the long dimension, causing the member to bend. Types of beams are depending on their support. They are cantilever beam, simply supported beam, overhanging, continuous beam and fixed ended beam. This study based on basic engineering physics. The stress and deflection of a beam are very important for engineers and scientists. In this paper, the theory of stress, deflection, numerical analysis of three-dimensional strength is studied.

II. THEORY OF CANTILEVER BEAM

Cantilever beam can be defined as a beam with one fixed support and one free end. The beam distributes the load back to the support where it is forced against a moment and stress. Cantilever beam allows the certain of a bay window, balconies, and some bridges. The stress analysis and deflections can be obtained by Bernoulli – Euler's equation. The various load applied the cantilever beam can be divide into two types. They are point load, uniformly distributed load.

III. BASIC EQUATION OF STRENGTH FOR CANTILEVER BEAM

The strength of the cantilever beam consists of three parameters. They are stress, deflection, and strain that are approached the engineering physics. These parameters are as follow:

A. Stress

The force of resistance per unit area, offered by a body against deformation is known as stress. The external force acting on the body is called the load or force. The load is applied to the body while the stress is induced in the material of the body. A loaded member remains in equilibrium when the resistance offered by the member against the deformation and applied load are equal.

Mathematically stress is written as,

$$\sigma = \frac{P}{A} \quad (1)$$

Bending stress at the fixed end,

$$\frac{\sigma}{y} = \frac{M}{I} \quad (2)$$

where, σ = stress (N/m^2)
P = load (N)
A = Area of cantilever beam (m^2)
M = bending moment (Nm)
I = second moment of inertia (m^4)
y = distance from neutral axis (m)

B. Deflection

Deflection is the movement of a beam or node from its original position due to the forces and loads being applied to the member. It is also known as displacement. It can occur in beams, trusses, frames, and any other structure. To calculate the deflection of the cantilever beam can be used in the following equation.

Mathematically deflection is written as,

$$\delta = \frac{PL^3}{3EI}$$

where, P = External force or Load (N)

L= length of the cantilever beam (m)

E = Young's Modulus of Alloy Steel (N/m^2)

I = Moment of Inertia (m^4)

(3)

C. *Strain*

A single force acts on a body, it undergoes some deformation. It is called strain. To calculate the strain of the cantilever beam can be used in the following equation. Mathematically strain is written as,

$$\varepsilon = \frac{\Delta L}{L} = \frac{L - L_0}{L_0}$$

where, ΔL = Difference between final length and original length (m)

L = Original length (m)

(4)

IV. NUMERICAL SIMULATION

Alloy steel is used as a model to analyze the strength enhancement in SolidWorks. It is based on the finite element method (FEM). FEM is a numerical method for solving problems of engineering includes structural analysis, heat transfer, and fluid flow. This simulation was separated five steps as follow:

- Creating Geometry
- Defining Subdomain
- Defining boundary condition
- Meshing
- Solving and Visualization

A. *Creating Geometry*

The geometry of the cantilever beam was defined and created in the physics module. This geometry was drawn in three dimensions (3D). This study is used in the point load at the end of the middle of alloy steel. Fig. 1 shows the detailed geometry of the cantilever beam model.

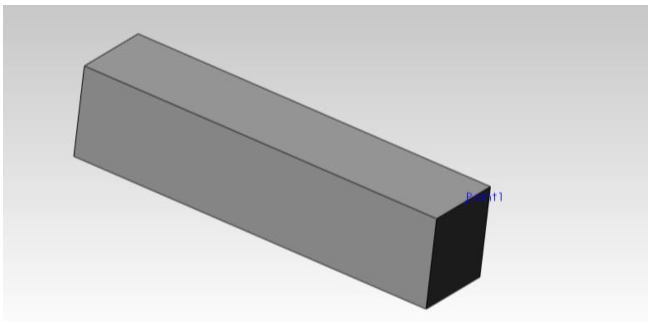

Fig 1:- Geometry of Cantilever Beam

B. *Defining Subdomain*

A subdomain is defining the properties of the material. In this study, the cantilever beam material is alloy steel. The value of yield strength is 6.20422 x 10^8 N/m^2 and the young's modulus of the alloy steel is 21 x 10^{10} N/m^2.

C. *Defining boundary condition*

Fig. 2 described the boundary conditions of the cantilever beam. The left-hand end (1) is defined as the fixed and the right-hand end (2) is defined as the point load 5kN. This simulation used the finite element method. The governing equation is as follow:

$$\{U\} = [K] / [f] \qquad (5)$$

where, U = finite element matrix

K = stiffness of element

f = force

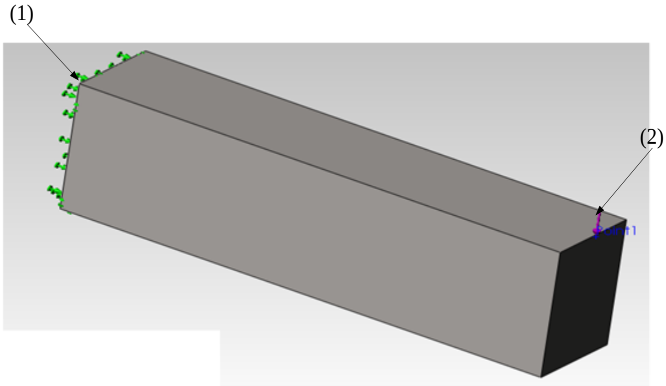

Fig 2:- Boundary condition in three dimensional cantilever beam

$$[Stress] = [A] \times [B] \times \{U\} \qquad (6)$$

where, A = elasticity of element

B = strain of element

Boundary	Condition	Governing Equation
1	Fixture	[f] = 0
2	Load	[f] = 5 kN

Table 1:- Boundary Setting of Structural Analysis

This study is calculated the finite element matrix based on each mesh grid. The detailed boundary condition is shown in table 1.

D. *Meshing*

In meshing of the cantilever model, create a solid mash to run the analysis. It is the triangular shape solid mash is formed. The total numbers of mesh elements are 10808 and vertex are 16439. The created triangular shape solid mash is shown in fig 3.

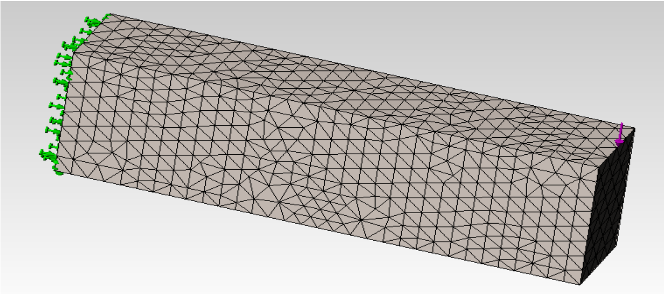

Fig 3:- Mesh properties

E. Solving and Visualization

Fig. 4 shows the result of maximum stress. It described the maximum stress is lower than the yield strength.

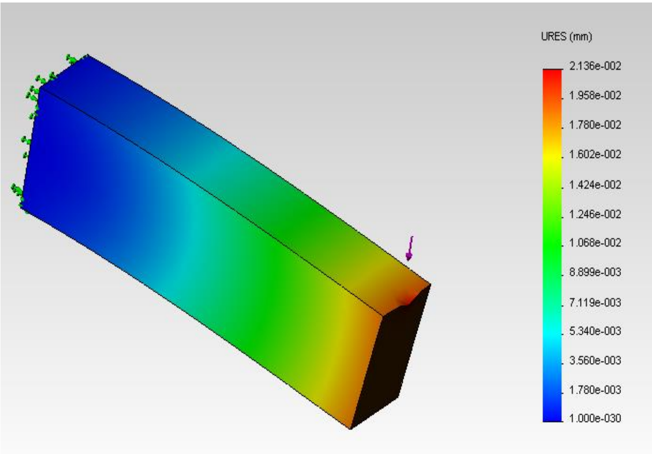

Fig 4:- Maximum stress of cantilever beam

The details results show the fig. 5. It includes the value of stress along the length of the cantilever beam. The maximum stress is 1.9823 x 10^6 N/m^2 by simulation. Theoretically, the value of stress is 1.67 x 10^6 N/m^2 by using equation (2).

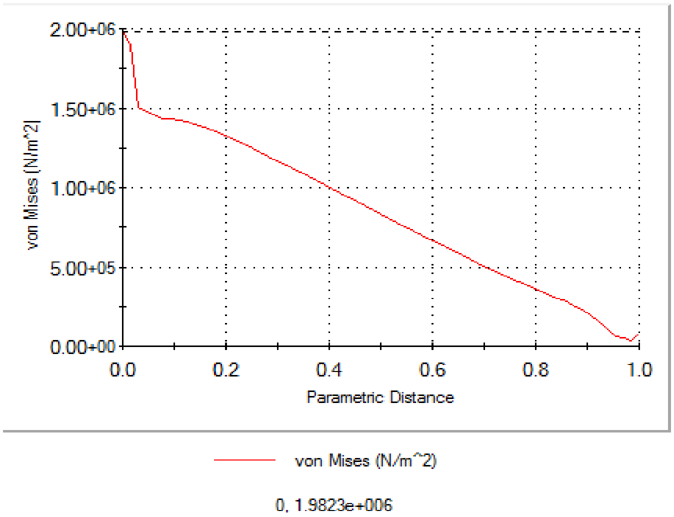

Fig 5:- Maximum stress of cantilever beam with a line graph

The result of the deflection of the cantilever beam described the fig. 6. The maximum deflection is 2.136 x 10^{-2} mm.

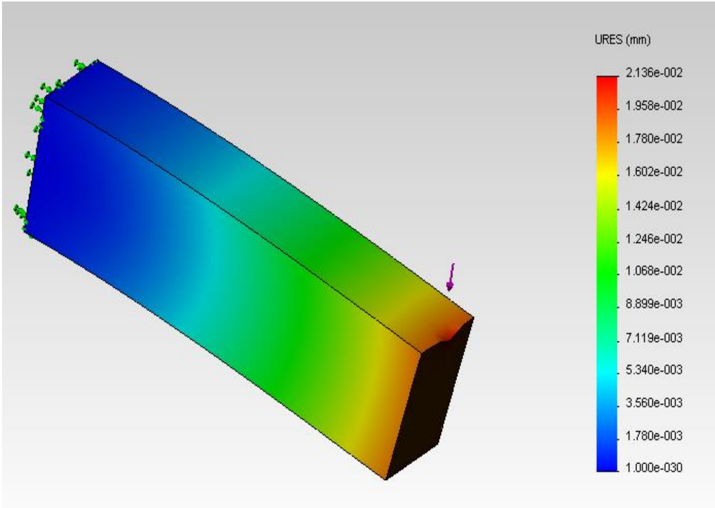

Fig 6:- Deflection of the cantilever beam

Fig.7 shows the detailed result of the deflection of cantilever beam along with the length. The maximum value of deflection is 0.0189381 mm in simulation. By theoretically, the value of deflection is 0.0185 mm by using equation (3).

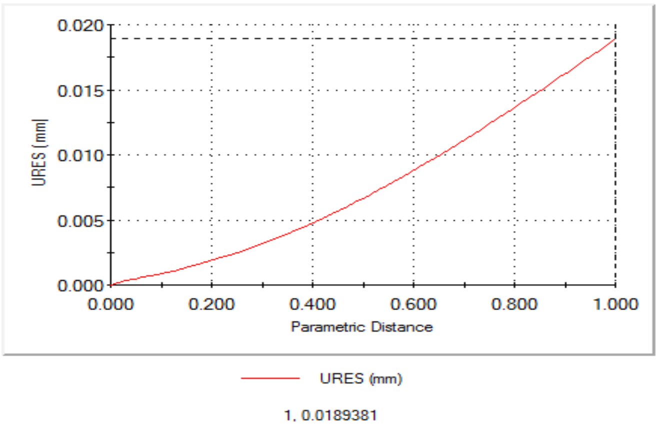

Fig 7:- Deflection of a cantilever beam with a line graph

The maximum strain of the cantilever beam described the fig.8. The value of the defection beam is 0.00002137.

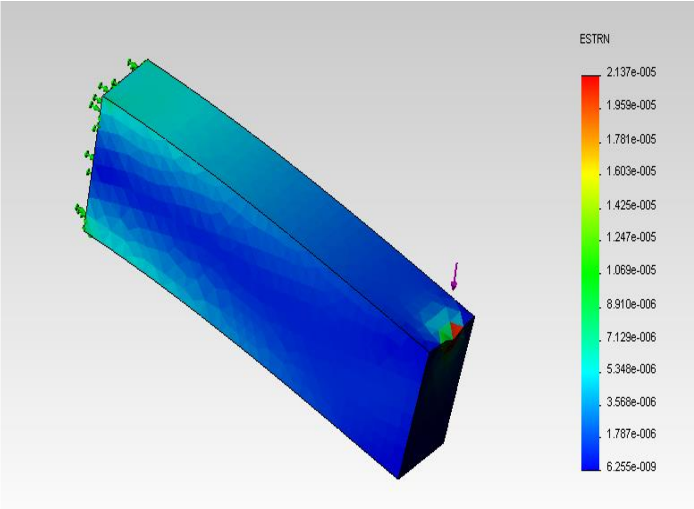

Fig 8:- Maximum strain of cantilever beam

V. RESULTS AND DISCUSSION

Based on the result, the maximum value of stress is 1.98×10^6 N/m^2, the deflection is 0.0189 mm and the strain is 0.00002137 in simulation. On the other hand, the value of stress is 1.6×10^6 N/m^2, the value of deflection is 0.0185 mm by theoretically.

VI. CONCLUSION

The strength analysis of cantilever beam used Solid Work. It is based on the finite element method. In a theoretical method, it used the Bernoulli – Euler's equation. Therefore, the deviation percentage of these two results was under 20%. This study can be solved by the real-world problem.

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