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Cantilever Beam: A New Approach

[1] **Iulia Tomozei,** [2] **Tiberiu Axinte,** [3] **Mihai Cazacu**
[1, 2] Research and Innovation Center for Navy, Constanta, Romania
[3] Ovidius University, Constanta, Romania

Corresponding Author: **Tiberiu Axinte**

Abstract
The paper presents an efficiency study of the cantilever beam. The cantilever beam has a rectangle cross-section. These beams have two ends: a fixed end and a free one. The studied beam is from 1060 aluminum alloy (Al-1060 alloy). The chemical and physical properties of Al-1060 alloy are also presented. The bending stresses from cantilever beam are studied with the help of MATLAB program. Finally, the extreme values of principal stresses from cantilever beam are determined.

Keywords: Beam, Cantilever, Stress, Bending, Aluminum

1. Introduction

A beam is a component that is designed to support transverse loads. These transverse loads act only perpendicular to the longitudinal axis of the beam, (Nastasescu *et al.*, 2022) [1].

The beams are used in various areas such as: constructions, shipbuilding, innovative technologies, research, etc.

The main types of beams which are used in practice are: cantilever beam, simply supported beam, overhanging beam, fixed beam and continuous beam, as shown in Fig 1 below.

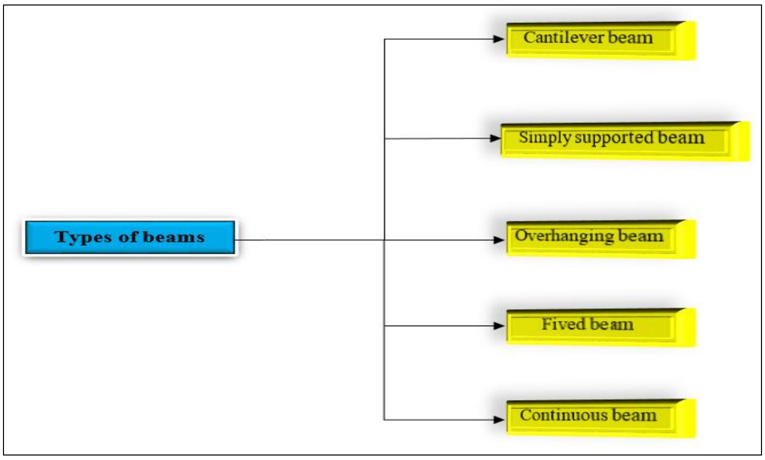
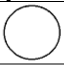
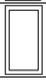
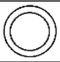
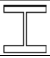


Fig 1: Types of beams

The table below shows the six cross-sectional shapes are most commonly used: circular cross-section, square cross-section, I – cross section, hollow square cross-section, hollow square cross-section, hollow circular cross-section and H-shape cross-section.

Table 1: Symbol of cross-section from cantilever beam

Description	Symbol
Circular cross-section	
Rectangle cross-section	
Hollow rectangle cross-section	
Hollow circular cross-section	
H-shape cross-section	
I-shaped cross-section	

The beam is a structural element that has the role of increasing the load-bearing capacity or avoids bending of a structure, (Dragan *et al.*, 2012) [2].
The cantilever beams has two ends: fixed end and free end, as shown in Fig 2 below.

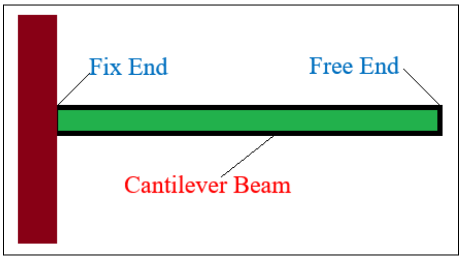


Fig 2: Ends of the cantilever beam

2. Study of Cantilever Beam

According to the Timoshenko theory, there are two hypotheses:

- The longitudinal axis of the unloaded cantilever beam is straight.
- The applied load in free end to the cantilever beam act transverse to the longitudinal axis.

In this paper, the cantilever beam is made of Al-1060 alloy, because this type of material is very highly durable and has exceptional corrosion resistance due to its alloying elements. Moreover, this material has a relatively low density compared to steel. As well, it can withstand large amounts of stress, (Lyubcheva *et al.*, 2012) [3].
The tables below show the chemical and mechanical proprieties of aluminum alloy 1060.

- Chemical properties for Al-1060 alloy.

Table 2: Chemical properties →Al-1060 alloy

Component	Symbol	Composition (%)
Aluminium	Al	99.60
Silicon	Si	0.24
Copper	Cu	0.05
Zinc	Zn	0.05
Vanadium	V	0.04
Manganese	Mn	0.03
Titanium	Ti	0.02
Magnesium	Mg	0.02

- Physical properties for Al-1060 alloy.

Table 3: Physical properties → Al-1050 alloy

Designation	Symbol	Value	Unit
Density	ρ	2700	kg/m^3
Shear strength	τ	$48.3 \cdot 10^6$	N/m^2
Young's modulus	E	$69 \cdot 10^9$	N/m^2
Poisson's ratio	υ	0.33	-
Yield strength	σ	$27.6 \cdot 10^6$	N/m^2

At the right end of the beam, the vertical force F acts, as presented in Fig 3.

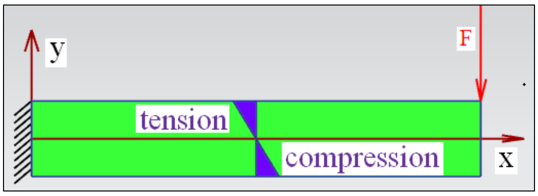


Fig 3: Vertical force F

The rectangle cross-section of the cantilever beam has the characteristics, (Francalanza *et al.*, 2014) [6]:

- h-depth.
- b-breadth.

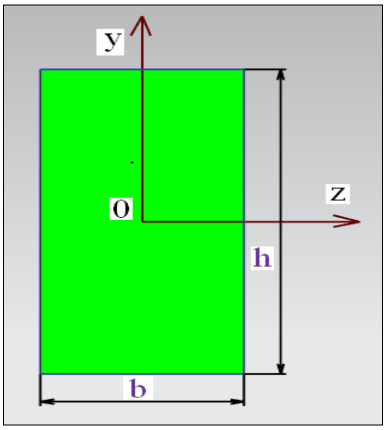


Fig 4: Rectangle cross-section

In Fig 5, the bending stress of this beam has been studied by means of a twenty-three lines subroutine in MATLAB software. The calculation of stresses, however, can be made using a lot of engineering technologies, according to, (Nutu, 2021) [4].

```
clear all
close all
clc
% Bending stress calculations
% Imputs
F = 3*10^3   % Load                    [N]
d = 0.1 % Length of beam               [m]
b = 0.005 % Breadth                    [m]
h = 0.006 % Depth                      [m]
% Moment of inertia
I = b*h^3/12
% Bending stress
M = F*d
y = linspace(-h/2,h/2,100)
Bs = M*y/I
MaxBs = h*M/(2*I)
% Plotting of the bending stress
figure(1)
plot(Bs,y)
figure(2)
a = [MaxBs 0 0 0 -MaxBs]
b = [h/2 h/2 0 -h/2 -h/2]
patch(a,b,'magenta')
```

Fig 5: Cantilever beam → Matlab

The equations for the determination of bending stress, are:

$$I = \frac{b \cdot h^3}{12} \quad (1)$$

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

Where:

I → moment of inertia (cross-section of the rectangle).
b → breadth (cross-section of the rectangle).
h → depth (cross-section of the rectangle).
M → bending moment.
σ_b → bending stress.

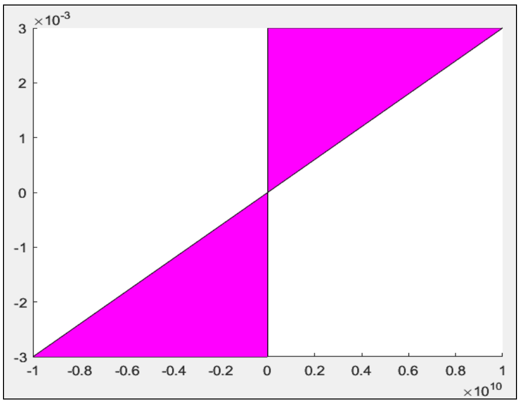


Fig 6: Diagram of bending stress

The bending stresses outcomes are presented in the diagram from Fig 6, (Sadowski *et al.*, 2009) [5].

Additionally, a cantilever beam has been drawn in 3D, according to Fig 7.

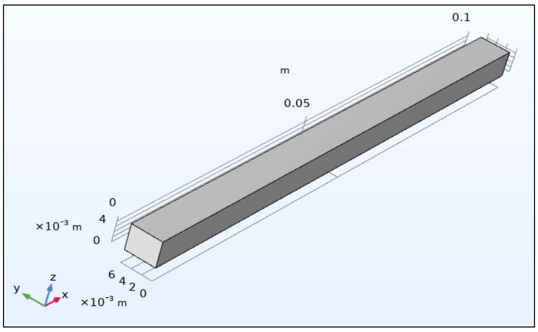


Fig 7: Cantilever beam

As shown in Fig 8, the minimum value of the principal stresses is 1.91·10 N/m^2, whereas the maximum value of the principal stresses is 2·10 N/m^2, (Farrugia *et al.*, 2018) [7].

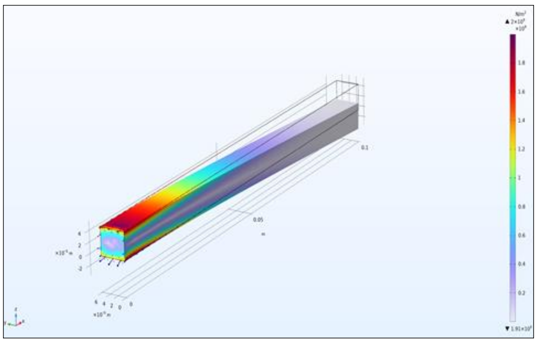


Fig 8: Principal stresses

3. Acknowledgement

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4. Conclusions

From the viewpoint of deflection of a cantilever, Al-1060 alloy beam has the largest deflection. The next one in row from the viewpoint of deflection is the brass beam whereas the steel beam, has the smallest deformation.

The cantilever beam of Al-1060 alloy is used in: constructions, bridges, plants such as cranes, shelving and furniture.

Students and researchers can study a cantilever beam at various forces and pressures for different types of material, such as: brass, steel or iron.

The advantages of cantilever beams are:

- Their fabrication is rather simple
- On the opposite side, these beams do not require support.
- Due to their depth, cantilever beams are very rigid.
- Like all beams, they generate a negative bending moment which counteracts the positive bending moment of back spans.

In the future, we want to analyze a cantilever beam used in shipbuilding industry, made from steel EH3.

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