Solid Mechanics Coursework

(Three-Point Bending/ Flexural Test)

Zhan RuiXin 710082148

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Outline

The modulus of elasticity is a physical quantity that describes the elasticity of a material. The aim of this experiment is to find the modulus of elasticity of a specimen by machine analysis of the relationship between displacement and loading of the specimen.
In this report, the modulus of elasticity of Mild Steel and Aluminium in the experiments is obtained and compared with the ANSYS results, the errors are analysed and an optimisation method is proposed.

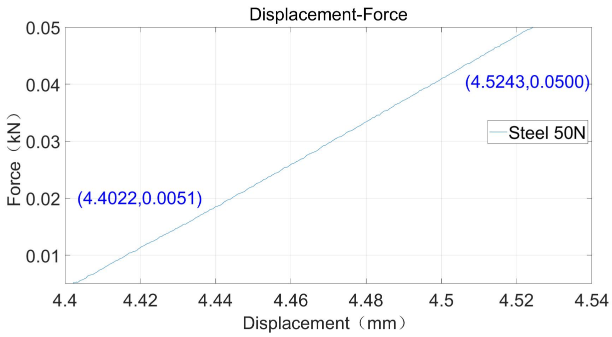
1 Intruction

2 Section A

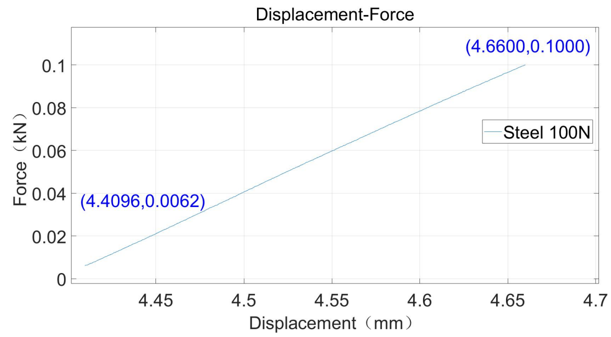
2.1 Results of the experiment

Through the experiments, we obtained data about the bending displacement and force of two materials, Aluminium and Mild Steel, respectively, and obtained Figure 2.1.

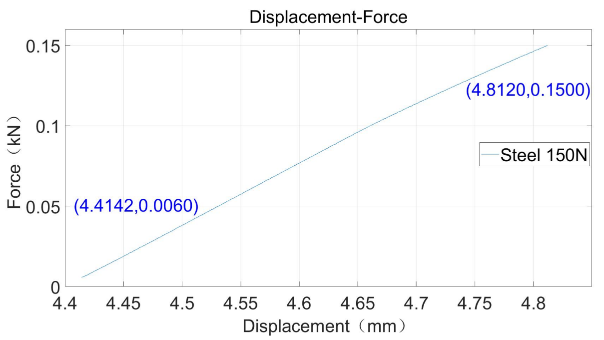
The moment of inertia for the beam of cross-section can be calculated by equation $I = \frac{b \times h^3}{12}$ with the width and height of the experimental sample being constants. I is 4.5×10^{-11}. The results for the modulus of elasticity can be derived from the calculation of equation $E = \frac{PL^3}{48I\delta}$, which can be obtained in Table 1.2 .



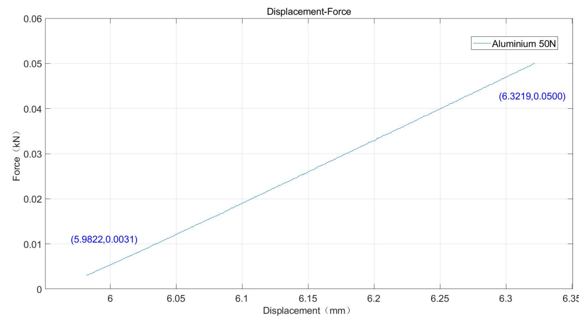
(a) 50N loading Mild Steel



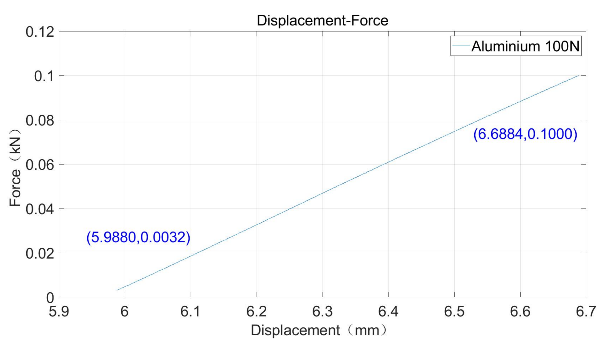
(b) 100N loading Mild Steel



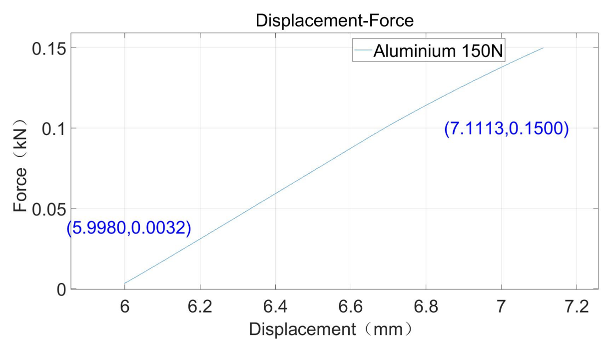
(c) 150N loading Mild Steel



(d) 50N loading Aluminium



(e) 100N loading Aluminium



(f) 150N loading Aluminium

Figure 2.1: Results of experiments with Steel and Aluminium

Table 1.2 Result of Modulus of Elasticity

Modulus of Elasticity	Mild Steel	Aluminium
E_1 (P = 50 N)	171.4815 GPa	64.3056 GPa
E_2 (P = 100 N)	175.5093 GPa	64.5370 GPa
E_3 (P = 150 N)	171.0185 GPa	62.4074 GPa
$E_{exp}=(E_1+E_2+E_3)/3$	172.6698 GPa	63.7500 GPa

2.2 Discussion and summary

The modulus of elasticity of Mild Steel and Aluminium is 172.6698GPa and 63.7500GPa respectively, which shows that the modulus of elasticity of Mild Steel is higher than that of Aluminium, proving that Mild Steel is more rigid and has less displacement under the same load.

The theoretical moduli of elasticity of Mild Steel and Aluminium are 200 GPa and 71 GPa respectively, but the experimental results are smaller.

3 Section B

3.1 Calculation of maximum bending displacement

The experimentally generated modulus of elasticity, Eexp, for each of the two materials can be obtained in Table 1.2 of section A. Also the moment of inertia for the beam is 4.5×10^{-11} which can be obtained in section A. The maximum bending displacements can be calculated by $\delta_{Max} = \delta_c = \frac{PL^3}{48EI}$.

The maximum bending displacements of Mild Steel under different loads can be obtained by Equation 3.1.

$$\begin{cases} \delta_{An\_1} = \frac{P_{50N}L^3}{48E_sI} = \frac{50\times0.1^3}{48\times172.6698\times10^9\times4.5\times10^{-11}} = 0.1341\times10^{-3}m \\ \delta_{An\_2} = \frac{P_{100N}L^3}{48E_sI} = \frac{100\times0.1^3}{48\times172.6698\times10^9\times4.5\times10^{-11}} = 0.2681\times10^{-3}m \\ \delta_{An\_3} = \frac{P_{150N}L^3}{48E_sI} = \frac{150\times0.1^3}{48\times172.6698\times10^9\times4.5\times10^{-11}} = 0.4022\times10^{-3}m \end{cases} \tag{3.1}$$

The maximum Alumlnilum bending displacementsunder different loads can be obtained by Equation 3.2.

$$\begin{cases} \delta_{An\_1} = \frac{P_{50N}L^3}{48E_{Al}I} = \frac{50\times0.1^3}{48\times63.7500\times10^9\times4.5\times10^{-11}} = 0.3631\times10^{-3}m \\ \delta_{An\_2} = \frac{P_{100N}L^3}{48E_{Al}I} = \frac{100\times0.1^3}{48\times63.7500\times10^9\times4.5\times10^{-11}} = 0.7262\times10^{-3}m \\ \delta_{An\_3} = \frac{P_{150N}L^3}{48E_{Al}I} = \frac{150\times0.1^3}{48\times63.7500\times10^9\times4.5\times10^{-11}} = 1.0893\times10^{-3}m \end{cases} \tag{3.2}$$

3.2 Result of maximum bending displacement

The maximum bending displacements for Mild Steel and Aluminium at different loads can be obtained from the calculations in section B, part 1, and the results are shown in Table 2.1.

Table 2.1 Result of the maximum bending displacements

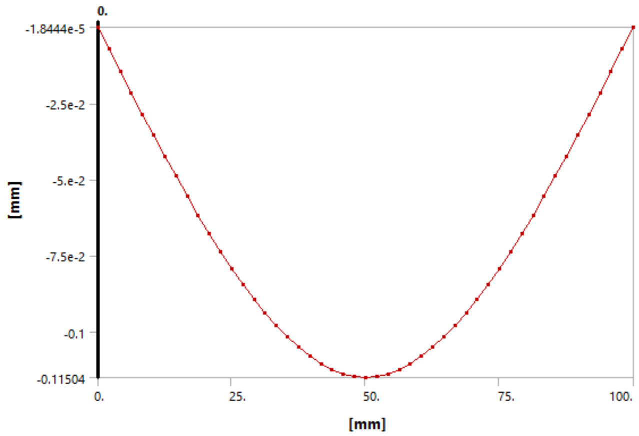
Bending Displacement	Mild Steel	Aluminium
δ_{AN_1} (P = 50 N)	0.1341 mm	0.3631 mm
δ_{AN_2} (P = 100 N)	0.2681 mm	0.7262 mm
δ_{AN_3} (P = 150 N)	0.4022 mm	1.0893 mm

4 Section C

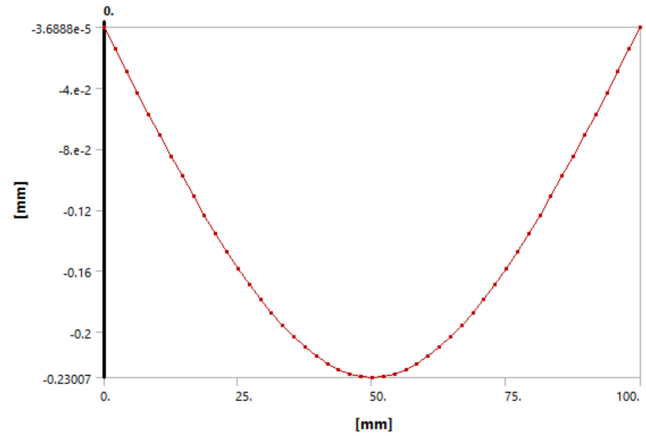
4.1 Displacement versus Position curves obtained from ANSYS

Displacement versus Position curves for different stress conditions can be obtained by modelling and simulation analysis in ANSYS.

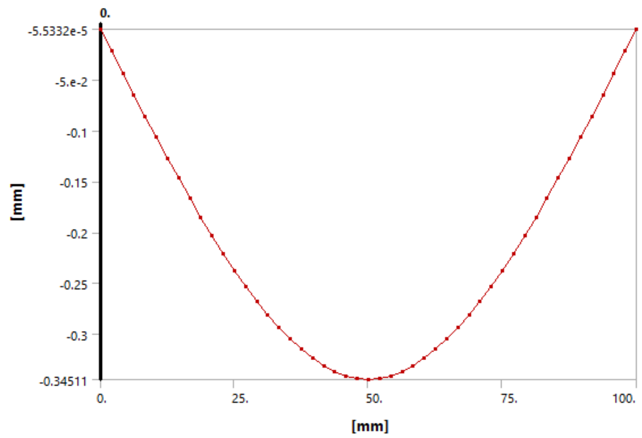
Figure 4.1 shows the Displacement versus Position curves for Mild Steel.



(a) 50N loading Steel



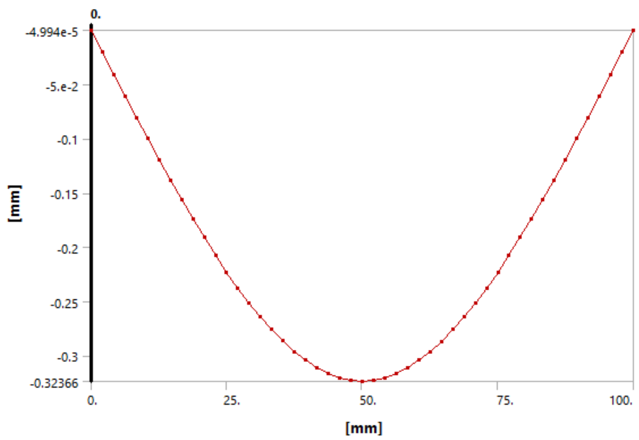
(b) 100N loading Steel



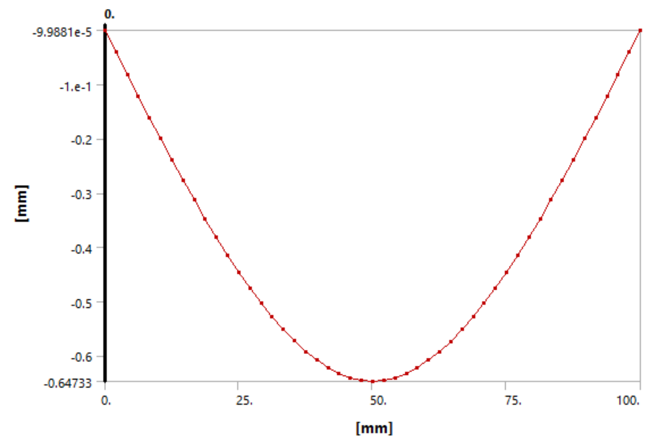
(c) 150N loading Steel

Figure 4.1: Displacement versus Position curves for steel

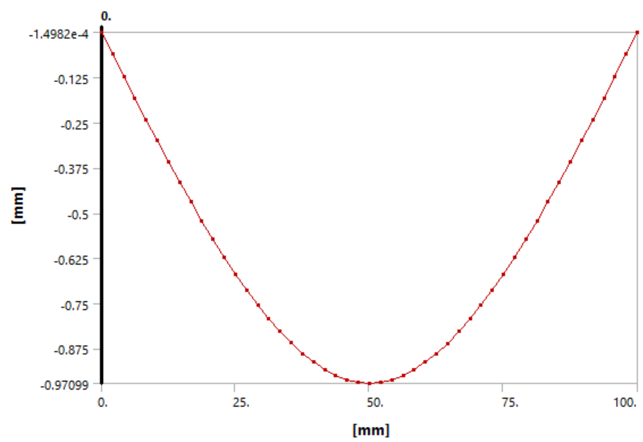
And Figure 4.2 shows the Displacement versus Position curves for Aluminium.



(a) 50N loading Aluminium



(b) 100N loading Aluminium



(c) 150N loading Aluminium

Figure 4.2: Displacement versus Position curves for Aluminium

4.2 The maximum bending displacements from simulation

The result of the maximum bending displacements from simulation in ANSYS can be obtained from the Figure 4.1 and Figure 4.2 in Section C first part. So the data show in Table 3.1.

4.3 Discuss and summarise the FEA results

In section C the displacement versus Position curves and the theoretical values of the maximum bending displacements for both Mild Steel and Aluminium are obtained by finite element analysis.

Table 3.1 Result of the maximum bending displacements from ANSYS

Bending Displacement	Mild Steel	Aluminium
δ_{FE_1} (P = 50 N)	0.11504 mm	0.32366 mm
δ_{FE_2} (P = 100 N)	0.23007 mm	0.64733 mm
δ_{FE_3} (P = 150 N)	0.34511 mm	0.97099 mm

Section D will compare the bending displacements obtained from the experiment δ_{AN} and FEA results δ_{FE}.

5 Section D

5.1 Compare and discuss δ_{AN} and δ_{FE}

Comparing two maximum deflections, δ_{AN} and δ_{FE} can find that:the experiments' result is bigger than the result from FEA. The difference rate for Mild Steel is approximately 16.55%, and for Aluminum is about 12.18%. Therefore, the difference rate of Aluminium is relatively smaller, which may be due to the bigger modulus of elasticity of Mild Steel. These data can be obtained from Table 5.1 and 5.2.

Table 5.1: Difference of Mild Steel

Loading	Difference	Difference rate
50N	0.01906 mm	16.5681%
100N	0.03803 mm	16.5298%
150N	0.05709 mm	16.5426%
Average		16.55%

Table 5.2: Difference of Alminium

Loading	Difference	Difference rate
50N	0.03944 mm	12.1856%
100N	0.07887 mm	12.1839%
150N	0.11831 mm	12.1845%
Average		12.18%

5.2 Error analysis and optimisation

There are a number of possible reasons for the errors in Part I of Section D.

1. Metallic materials are affected by the shape memory effect. The specimen used in the experiment has been used repeatedly, and the shape has changed. In finite element analysis, ANSYS does not consider the loss of specimen, which is a real problem.

2. Uneven density distribution of specimen or insufficient material purity. The specimen's purity will undoubtedly impact the physical properties and, thus, the experimental results.

3. The load direction is not perpendicular to the specimen surface. This results in generating a partial force perpendicular to the specimen surface, which reduces the displacement under the same load.

4. The friction between the support structure and the specimen surface can impact the experiment.[1]

So, there are some methods can optimise this experiment and get more accurate data.

1. Multiple experiments to reduce the effect of data errors.

2. Calibration of the machine before the start of the experiment to prevent Instrumental Error caused by the load not being perpendicular to the specimen surface and by the machine's initial values being inaccurate.

3. Experimentation with new and higher purity parts and completion of three load tests using different specimens.

4. Use a smoother support structure or a smoother specimen to reduce the effect of friction.[1]

6 item

References

[1] Research on the Effects of Friction Coefficient on Three-Point Bending by Finite Element Analysis [J] . Zhai, Xiangguo,Zhang, Fu,Zhao, Hongwei,Li, Cong,Xu, Zhaoxin,Hao, Xin,Zhu, Zhongwei,Xu, Xiuquan. Journal of Computational and Theoretical Nanoscie . 2015 (12)