Materials 1 Lab Report

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Abstract

The aim of this laboratory work is to design a strut/bracket assembly for aircrafts. Experiments are carried out to determine mechanical properties of certain materials.The material chosen is Mild Steel. Given the possible condition experienced by the material and the safety factor, the dimensions for the designs of the strut/bracket assembly for aircrafts are obtained to avoid failure by yield or fracture. The diameter of the pin, d ,which is subjected to shear stress should be larger than 14.56mm. The diameter of the rod, D, should be larger than 12.74mm. The thickness of the rod would be 10mm.

1 Introduction

The aim of this laboratory work is to design a strut/bracket assembly for aircrafts. The materials selection comes from a multi-criteria analysis. The components must be designed to avoid failure by yield or fracture. Temperature difference is also a parameter that must be taken into consideration as temperatures may vary from -50C to +85C or even higher in areas close to the engines. Finally, for aeronautical applications, high strength is needed at low weight. When comparing materials it is useful to get their properties from standardised tests. In this lab, three different tests have been performed (tensile test, torsion test and Charpy impact test) on different materials. From these tests, important parameters such as yield strength, toughness and Youngs modulus can be determined in order to choose the most appropriate material to use depending on the external forces and the temperature. Finally, knowing the material properties, dimensions of the assembly can be calculated to avoid damage. Indeed the nominal maximum stress values should be less than the strength of the material (yield stress limit).

2 Experimental Apparatus and Methods

In this lab, different test have been carried out in order to determine the mechanical properties which govern the materials behaviour in response to an applied load:

- Tensile tests on tool steel, mild steel and aluminium.

- Torsion tests on cast iron, mild steel and brass.

- Charpy impact test on tool steel and mild steel at different temperatures.

2.1 Tensile Testing

Tensile test involve pulling a specimen apart and are used to not only produce stress-strain curve but also to ascertain several mechanical properties that are useful in design such as the yield strength, the modulus of elasticity and the breaking stress of a material. The specimen is placed in a pair of grips and a load cell measures the applied force to elongate the specimen. An extensometer attached on the specimen is used to measure accurately the sample elongation excluding the deformation of the machine.

2.2 Torsion Testing

Torsion tests, which are a variation of pure shear tests, involve twisting a specimen whereby the torsional force produces a rotational motion. They will focus on the effects of shear but still enable us to calculate the toughness of a material, the yield shear strength, the shear modulus and understand how fracture occurs in terms of energy. The specimen is placed in between a pair of hexagonal grips. A torsional force is applied by rotating the handwheel until failure. The torque is recorded in function of the rotation angle.

2.3 Charpy impact Testing

Charpy impact tester is used to measure the impact toughness of a material. A notch is cut into the sample, it acts as a stress concentration and a starting point for the fracture. A swinging pendulum hammer is held in place with an electromagnet. When the current in the electromagnet is turned off, the pendulum swings down and breaks the sample. The amount of energy absorbed by the sample is calculated from the maximum swing angles of the pendulum before and after impact.

3 Results

3.1 Tensile Testing

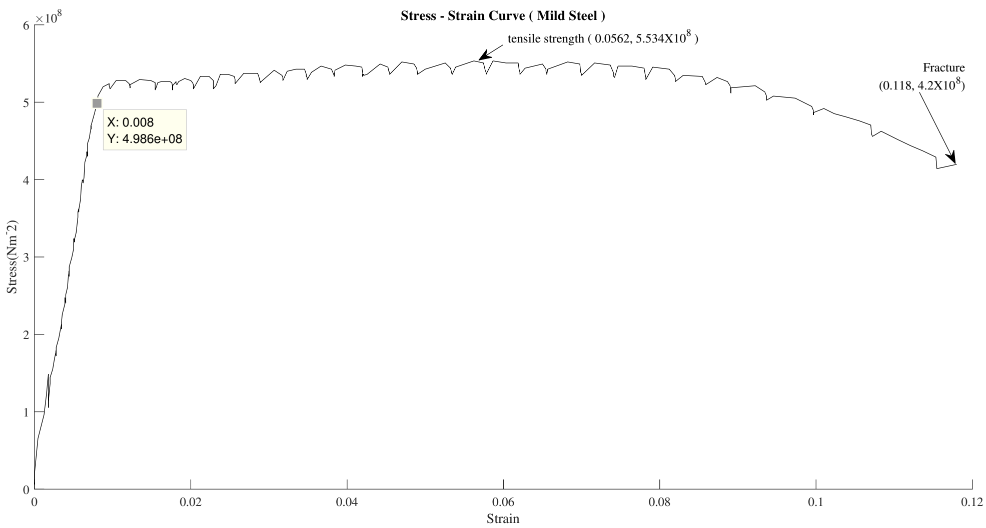

Figure 1: Stress-Strain Curve(Mild Steel)

E=$\frac{4.986X10^8}{0.008}$ = 62.3250GPa

$\sigma_{yield} = \frac{2u}{e_{failure}}$ - $\sigma_{tensile} = \frac{2\times(5.9464\times10^7)}{0.118}$ - $5.534 \times 10^8 = 454MPa$

Toughness, u (area under graph) is calculated with trapezium rule in Matlab.

3.2 Torsion Testing

Shear Strain	**Shear Stress [MPa]**
0	0
0.08132780982	270.0720323
0.1626556196	321.2761654
0.2439834295	355.8091854
0.3253112393	381.0540139
0.4066390491	397.4869682
0.4879668589	413.443605
0.5692946687	422.2554791
0.6506224786	433.4489408
0.7319502884	442.9752911
0.8132780982	450.5963714
0.894605908	457.2648166
0.9759337178	462.7424681
1.057261528	468.2201195
1.138589337	474.4122472
1.219917147	477.5083111
1.301244957	483.4622801
1.382572767	486.3201852
1.463900577	492.0359954
1.545228387	495.370218
1.626556196	499.6570757
1.707884006	502.7531395
1.789211816	504.6584096
1.870539626	507.5163147
1.951867436	509.8979023
2.033195246	513.9466012
2.114523055	516.8045063
2.195850865	518.9479351
2.277178675	520.1387289
2.358506485	524.1874278
2.439834295	527.2834917
2.521162104	529.1887617
2.602489914	531.0940318
2.846473344	536.5716833

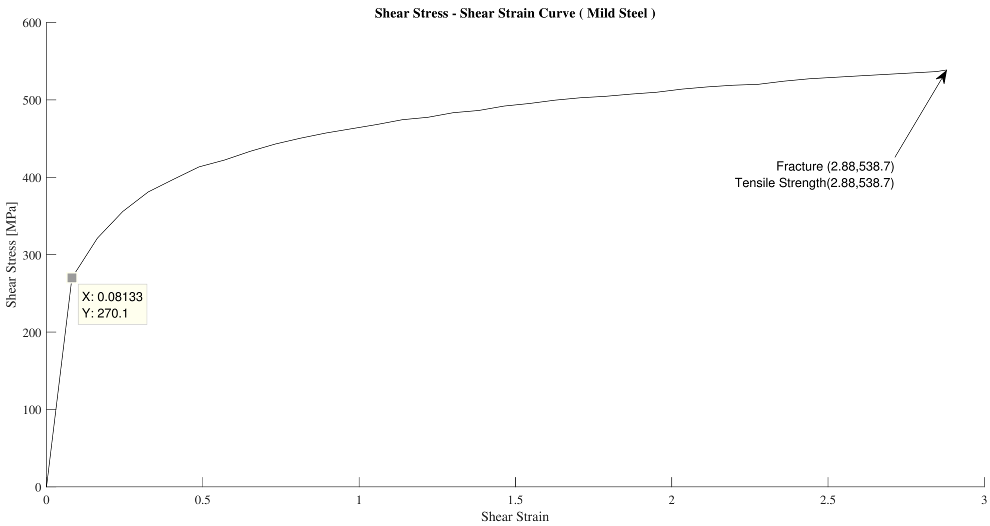

Figure 2: Shear Stress - Shear Strain Graph

G = $\frac{270.1\times10^6}{0.08133}$ = 3.321GPa

$\tau_{yield} = \frac{2u}{e_{failure}}$ - $\tau_{tensile} = \frac{2\times(1.338\times10^3)}{2.88}$ - 538.7 = $390.5MPa$

Tensile toughness, u (area under graph) is calculated with trapezium rule in Matlab.

3.3 Charpy Impact Testing

Diameter(mm)	Temperature(°C)	Initial Angle Position (°)	Final Angle Position (°)	Energy Lost to Friction and Air Resistance (J)	Energy Lost to Fracture (J)
3.31	2	100	2	0.04	2.7
3.2	-76.4	100	91	0.04	0.32

3.4 Summary of results

Table 1: Results from the Tensile Test

Material	Yield Strength,$\sigma_Y(MPa)$	Young Modulus,E (GPa)
Tool Steel	339.84	73.781
Mild Steel	510	119.77
Aluminium	221	80

Table 2: Results from the Torsion Test

Material	Toughness ($\mathrm{MJ}m^{-3}$)	Shear Yield,$\tau_Y(MPa)$	Shear Modulus,G (GPa)
Cast Iron	8.62	103	13.6
Mild Steel	1338	390.328	3.321
Brass	163	357	0.667

Table 3: Results from the Charpy Impact Test

Material	Specimen Temperature (°C)	Energy lost to Fracture (J)
Tool Steel	21.3 -76.6	1.64 0.12
Mild Steel	23.0 -76.4	2.70 0.32

4 Discussion

4.1 Tensile Testing

Table 4: Theoretical values for the Tensile Test Materials[1–6]

Material	Yield Stength,$\sigma_Y(MPa)$	Young Modulus,E (GPa)
Tool Steel	1650	210
Mild Steel	247	200
Aluminium	7 - 11	70

According to the data obtained, Mild Steel seems to have the highest yield strength and Young's Modulus value. However, in comparison to the theoretical values, Tool Steel should have the highest yield strength among the three and similar Young's Modulus with Mild Steel. Overall, the data do not agree well with the theoretical value, so the result the data gave is not expected. During the application of tensile stress, the apparatus itself elongates relatively much to the specimen, which might have affected the data.

4.2 Torsion Testing

Table 5: Theoretical value for the Torsion Test Materials[7–12]

Material	Shear Yield,$\tau_Y(MPa)$	Shear Modulus,G (GPa)
Cast Iron	180 - 610	41
Mild Steel	143.26	80
Brass	235	40

Toughness is the energy required to break the material. The temperature of the specimen is warm after fracture at the break point. The yield shear stress and the shear modulus does not agree well with the theoretical value. Maybe the recording angle interval is too large, resulting in limited data collected and inaccuracy of calculations.

4.3 Charpy Impact Testing

Materials at low temperature seems to be more brittle than at high temperature. It takes lower energy to fracture the material at lower temperature.

4.4 Materials Selection

For critical structural integrity, Mild Steel should be used. It has the highest yield strength, so it can withstand high stress before achieving plastic strain. It has high toughness so a lot of energy is required to fracture the material at normal temperature as shown in the Charpy Impact Test. Even at low temperature, it can accommodate more energy before fracture occurs than Tool Steel.

Table 6: Density of Materials[5, 13–16]

Material	Tool Steel	Mild Steel	Brass	Cast Iron	Aluminium
Density(kgm^{-}3)	7715	7850	8400	7300	2700

The table above shows that all the materials' density are around the same range except for Aluminium. It is important to choose materials with low density so it does not have to support much of its own weight, Aluminium has the lowest density of all, which seems to be an optimum choice. However, its Young modulus value and yield strength is too low and is unsafe to use in building a structure. Criteria of a material such as strength, toughness and ductility is dominant in structural integrity. The material must be ductile so it does not fracture shortly after the point of yield strength. In the case of overload of stress, the material will show sign of plasticity and repair can be carried out.

4.5 Design

$$\frac{F\times S_f}{\frac{\pi\times d^2}{4}} < \tau_Y, \qquad d^2 > \frac{4F\times S_f}{\tau_Y\pi}, \qquad d^2 > \frac{4\times5\times10^4\times1.3}{390.328\times10^6\pi}, \qquad d > 14.56mm$$

$$\frac{F\times S_f}{\frac{\pi\times D^2}{4}} < \sigma_Y, \qquad D^2 > \frac{4F\times S_f}{\sigma_Y\pi}, \qquad D^2 > \frac{4\times5\times10^4\times1.3}{510\times10^6\pi}, \qquad D > 12.74mm$$

5 Conclusions

Tensile Test, Torsion Test, Charpy Impact Test are carried out on Tool Steel, Mild Steel, Aluminium, Cast Iron, Brass. Data are collected from experiment and analyzed and calculated to provide the mechanical properties of the materials involved. The most suitable metal selected according to the mechanical properties is Mild Steel. Given the possible condition experienced by the material and the safety factor, the dimensions for the designs of the strut/bracket assembly for aircrafts are obtained. The diameter of the pin, d ,which is subjected to shear stress should be larger than 14.56mm. The diameter of the rod, D, should be larger than 12.74mm. The thickness of the rod would be 10mm.The values in the design are to avoid possible failure by yield or fracture. If theoretical values are taken into consideration, it shows that Tool Steel would be the most suitable material for structural integrity due to its high yield strength, relatively low density, and high Young Modulus value. This shows possible inaccuracy with the experiment as the data do not correspond well with the theoretical values.

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