Investigation of Mechanical Properties of ST 145 Steel and Aluminum Alloys for Shaft Making Materials

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ABSTRACT
Steel material has resistance to rust and strong magnetic properties, as well as resistance to loads. Aluminum is of high strength and corrosion resistance. Most of the technical equipment is under rotary dynamic load pressure. The component that receives the most dynamic load is the shaft. The shaft receiving the shipment can be a fixed load, a shock load, or a combination of the two packs. Shaft fatigue failure will be more visible when experiencing shock loads. This shock load can occur during the initial movement, braking, gear shifting, or external shock load. Fatigue results in fractures that look brittle and without deformation in the fracture. The manufacture of the shaft requires a mechanical test, including stress, strain, and hardness factor. This study, comparing the mechanical properties between ST 145 steel and aluminum alloy (Al-Si), in which the two materials have high strength. The purpose of this study was to determine whether the ST 145 steel and aluminum alloy meet the requirements as a shaft material in terms of mechanical aspects. The test material sample is in the form of a specimen using ASTM standards—research by testing steel and aluminum material with a diameter of 6 mm. Mechanical testing resulted in the maximum stress of steel 85,124 kg / mm2, and aluminum 19.05 kg / mm2; the ultimate steel strain was 8.03% and aluminum 7.796%. The hardening factor of steel was 0.771, and aluminum was 0.243.

***Keywords:** Aluminum, Al-Si, Gears, Shafts, Steel.*

1. INTRODUCTION

Construction requires a material with specifications and properties that are specific to each part. The material must have strong and elastic properties because it must not be broken when there is standard or excessive loading [1]. In general, making the shaft of metal material, where this component has the most complex stress [2]. Even though we have predicted metals' mechanical properties in the manufacturing process, we need to know the absolute and accurate value of the metal's mechanical properties by carrying out automated tests [3].

This test aims to determine the mechanical properties of the material to find out its advantages and disadvantages. The tensile test is a method for testing the strength of a material by applying axial force loads. The test results are significant for measuring a material's resistance to static forces and product design because it produces material strength data [4]. These properties are the strength and elasticity of the metal.

The manufacture of shafts usually uses steel metal or aluminum alloy. This study will test the ST 145 steel material and aluminum alloy (Al-Si) because these metals have high tensile stress properties.

2. BACKGROUND

2.1. Engineering Stresses And Strains

Technical stress and strain refer more to the average pressure and tension; this is because, at the time of drawing, the specimen diameter assumption does not change; in reality, it is not.

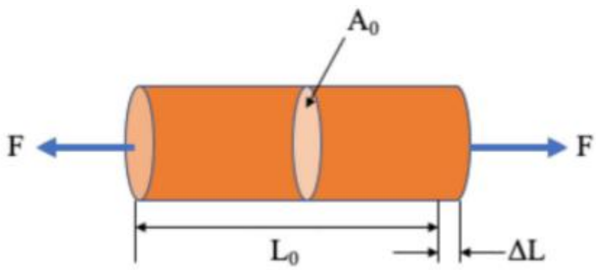

Figure 1. Stress-strain

The material experiences stress, namely the ratio of the power to the cross-sectional area of the rod.

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

where,
P = the maximum force on the force scale, kg
Ao = 1/4 π (Do)^2
= the cross-sectional area of the specimen, mm^2
Do = the initial diameter of the sample, mm

The strain is the deformation or displacement of material that results from applied stress.

$$\varepsilon = \frac{L-L_o}{L_o} \quad (2)$$

where,
ε = a strain, %
L_o = original length , mm
L = length after load is applied (mm).

2.2. *True Stress and Strain*

Due to the shrinking of section area and the ignored effect of developed elongation to further elongation, actual stress and strain are different from engineering stress and tension. A technical stress and strain curve is not a stress and strain curve. This condition is due to the reduction of the cross-sectional area when the drawdown occurs.

The effect of strengthening the work is equal to reducing the cross-sectional area at the UTS point. After the formation of necking, the sample undergoes heterogeneous deformation, so the equations above are not valid. The equation for calculating pressure and tension is as follows:

$$\sigma = \frac{P \times L_1}{A_o \times L_o} \quad (3)$$

where,

L_1 = length is after breaking, mm.

$$\varepsilon = Ln\left[\frac{L-L_o}{L_o} + 1\right] \quad (4)$$

Modulus of Elasticity

$$Y = \frac{F \times L}{A \times \Delta L} \quad (5)$$

where,
F = a force, kgf
L = specimen lengt, mm
A = specimen area, mm^2
ΔL = changes in length,mm.

2.3. *A Stress-Strain Curve*

One can think of the curve representing the relationship between stress and strain in any form of deformation to be a stress-strain curve. One obtains by gradually applying a load to the test coupon and measuring the deformation to determine the stress and strain. These curves reveal many of a material's properties, such as Young's modulus, the yield strength, and the ultimate tensile strength.

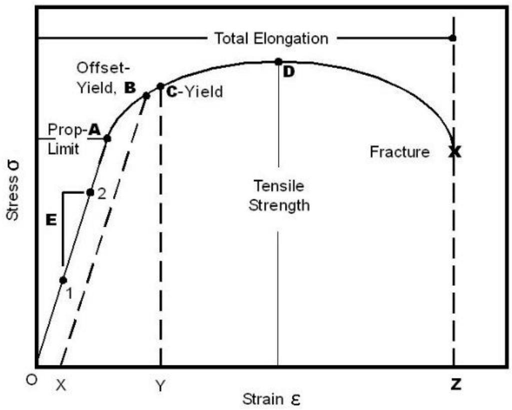

Figure 2. A stress-strain curve

3. METHODOLOGY

In this research, we will test:

1. using ST 145 steel and aluminum alloy (Al-Si), which are typical for shaft manufacture
2. material with a diameter of 6 mm and a length of 37 mm.
3. using the ASTM E.8 standard.
4. tensile strength, strain, and hardness factor.

The purpose of the tensile test is to determine the tensile stress and strain on the material for making the shaft. This test uses a tensile testing machine by clamping the sample firmly and continuously giving a load of 1000 kgf for aluminum and 5000 kgf for steel until the sample breaks. In tensile testing machines, the existing output data is the relationship between the pulling force (F) and the change in specimen length (Δ1). The magnitude of the difference in the measured pulling force on "loadcells" while Δl uses an extensometer. The relationship between the pulling power and the length change then obtains the technical stress and strain parameters, actual stress and tension, and the strain hardening factor.

4. RESULT AND DISCUSSION

4.1. *Specimen Testing Results*

Testing using a tensile test device produces a broken specimen, as in Figure 3 and Figure 4.

Figure 3. Testing results of aluminum specimens

Figure 4. Testing results of steel specimens

A tensile test is used to test a material's strength by applying an axial force load. The results obtained from tensile testing are significant for engineering and product design because they produce material strength data. The test results are the characteristics of steel and aluminum materials, such as tensile strength, yield strength, ductility, modulus of elasticity, and tensile hardening factor. The fracture results show that the fault's location is not in the middle of the material on the test specimens. The composition of the material that is not homogeneous is the material that grips the handle, not one axis/tilt, which causes cracks so that the tensile testing machine needs to be calibrated [7]. The strength between steel and aluminum is that steel is more rigid than aluminum, but aluminum is more ductile than steel. The fracture results from the tensile test indicate these conditions.

The mechanical test results are as shown in Figure 5 and Figure 6.

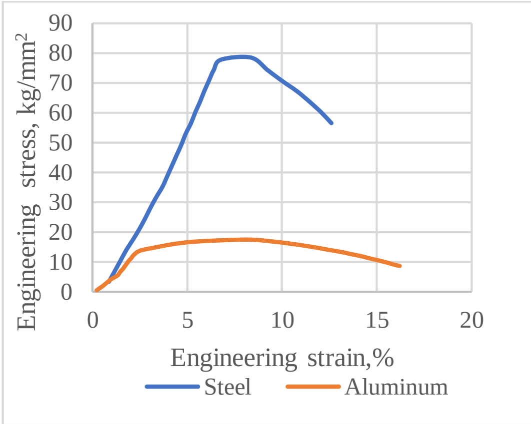

Figure 5. Engineering strain vs. engineering stress

Figure 5 shows that the engineering stress increases as the engineering strain is more significant, ultimately reaching the maximum stress for aluminum 19.05 kg / mm2 and steel 85,124 kg/mm^2. As the pressure approaches its peak, the stress severity increases sharply and results in fatigue fracture [5].

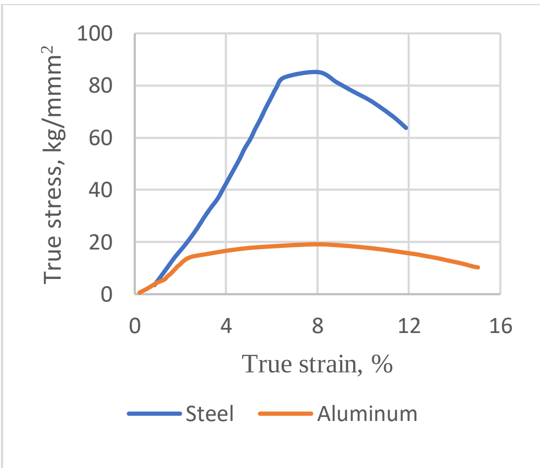

Figure 6. True strain vs. stress

Figure 6 shows the actual stress increases when the real strain is more excellent. It is also interesting to observe that as the applied strain increases, the actual stress is almost constant for aluminum [6].

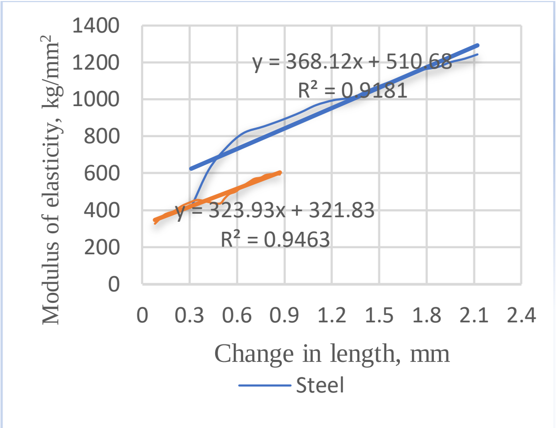

Figure 7. Change in length vs. modulus of elasticity

With the same change in length, steel has a greater modulus of elasticity than aluminum. This condition describes a material's stiffness, which means that the smaller the shape occurs when particular stress is applied [9].

Table 1. Mechanical strength of steel ST 145 and aluminum (Al-Si)

Characteristics	Steel ST 145	Aluminum (Al-Si)
Broken stress (kg/mm^2)	63.7	10.3
Modulus of elasticity (kg/mm^2)	1218.4	488.5
Percentage of strain (%)	11.9	15.1
Length after breaking (mm)	40.3	42.6
Material Constants	680.1	36.5
Hardening factor	0.771	0.243

The stress applied to the components continuously causes the stress to fracture. The fracture stress of aluminum is 10,281 $kg/mm^{2,}$ and for steel 63,757 kg/mm^2, this result is better than [7,8].

5. CONCLUSIONS

The mechanical properties of steel are better than aluminum, namely engineering stress, actual stress, engineering resistance, true strain, and fracture stress. While the mechanical properties of aluminum are better than steel in terms of length after breaking, hardening factor, and percentage of strain. Mechanical properties of ST 145 steel and aluminum alloy, namely:

1. The highest engineering stress is 79.7 kg/mm^2 for steel and aluminum 18.8 kg/mm^2
2. The highest engineering strain is 13.1 % for steel and aluminum 16.3 %
3. The maximum of true stress is 83.2 kg/mm^2 for steel and aluminum 20 kg/mm^2
4. Full of true strain is 11.8 % for steel and aluminum 15.6 %
5. The maximum modulus of elasticity are 1218.4 kg/mm^2 for steel and aluminum 488.5 kg/mm^2
6. Material hardness factor for steel are 0.771 and aluminum 0.234

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