COMPARATIVE ANALYSIS OF ALUMINUM AND STEEL MECHANICAL PROPERTIES

R.A Abdul Kadir[1)],S. Abdullah[1)],
A.A Mohd Yusuf [2)], K. Md Isa[2)], A.W. Mohd Arhafudin [1)]

[1]School of Mechanical Engineering, College of Engineering, Universiti Teknologi MARA, Bukit Besi Campuses, UiTM Terengganu Branch, Bukit Besi Dungun Terengganu
[2]School of Mechanical Engineering, College of Engineering, Universiti Teknologi MARA, UiTM, Johor Branch., Masai, Johor

rosatikah@uitm.edu.my

ABSTRACT

This research compares and evaluates the mechanical properties of steel and aluminum for lightweight usage in industrial appliances and aircraft parts. Physical and mechanical characteristics, which establish a material's characteristics in terms of strength, hardness, ductility, stiffness, and microstructure analysis, describe its mechanical properties. Producing lightweight industrial appliances and high-performance aviation components is hampered by researchers' and manufacturers' incapacity to choose the appropriate materials. This study aims to compare and evaluate the mechanical properties of aluminum and steel while considering theoretical analysis. According to the experimental findings, steel fractures more quickly during the tensile test because it has a higher tensile strength than aluminum. Steel had a tensile strength of 60.495 MPa while aluminum had a tensile strength of 33.609 MPa. The data points at 8.73E+00 and 4.59E+02 on the graph illustrating the relationship between load and displacement for aluminum demonstrate that the curve initially had a broad linear association before fracturing. As soon as the aluminum cracked, the load decreased. Comparably, the steel load-displacement graph displayed a generally linear connection up until a substantial rise in load, after which there was a displacement and another drop till the point of fracture (7.97E+00, 8.02E+02). The study's findings emphasize how crucial it is to take into account the unique mechanical characteristics of various materials when creating lightweight components. Researchers and manufacturers can improve the performance and efficiency of industrial appliances and aviation parts by making well-informed decisions based on their understanding of these qualities. Because steel fractures more easily during tensile testing, it might not be the best material for these kinds of applications. Aluminum, on the other hand, has a lower tensile strength but a higher ductility.

Keywords: Comparison study, Steel, Aluminium, Ductility

1.0 INTRODUCTION

A material's mechanical and physical properties are determined by its internal structure, including its crystal structure and grain size, as well as its chemical behaviour. The mechanical properties can be significantly affected by processing because it rearranges the internal structure[1]. Heat treatment or metalworking processes may have some slight effects on physical properties including density and electrical conductivity. However, these effects are usually minor[2].

Mechanical and physical properties play a major role in determining which alloy is considered suitable for a given application when multiple alloys satisfy the service specifications. When designing an industrial appliance, engineers often aim to achieve a specific set of performance parameters. Excellent performance in one area may be matched by poor performance in another since many mechanical attributes are interrelated. One may sacrifice ductility in order to achieve more strength, for instance. The selection of the best material for a given application thus necessitates a thorough understanding of the product's surroundings. Aluminum is a common example of a material having several qualities, including low density, non-toxicity, good heat conductivity, resistance to corrosion, and ease of casting, rolling, and shaping. Furthermore, it is not magnetic or sparking[3].

2.0 METHODOLOGY

In this study mild steel and aluminum were used. The tools and equipment used were a universal testing machine (UTM), a scale, standard specimens of dog bone stainless steel and aluminum, a vernier caliper or a micrometer, and a Vickers hardness testing machine refer Figure 1.0 for the experiment flow chart.

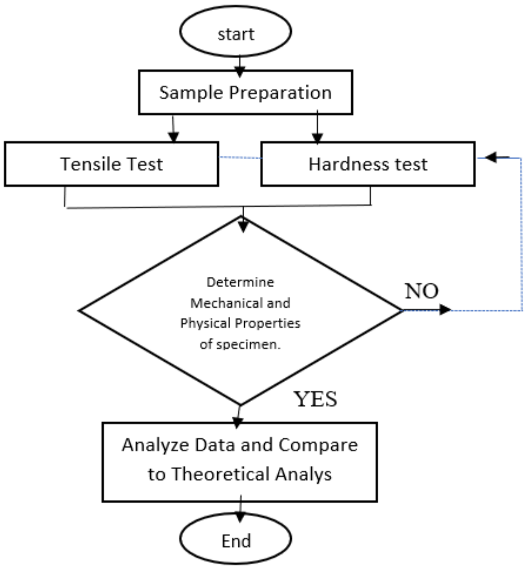


Figure 1: Flow Chart for Tensile Test and Hardness Test

The tensile test is a destructive test that measures the tensile strength, yield strength, Young's modulus, and elongation of a material[4]. The specimen is subjected to a gradually increasing tensile load until it fractures. The load and elongation data are recorded at regular intervals[5].The stress is calculated as the load divided by the cross-sectional area of the specimen. The strain is calculated as the change in length of the specimen divided by the original length of the specimen. Young's modulus is the ratio of stress to strain in the elastic region of the stress-strain curve. The elongation is the percentage increase in length of the specimen after fracture[6].While for Vickers hardness test is a non-destructive test that measures the hardness of a material[7]. The specimen is subjected to a load by a diamond indenter. The size of the indentation is used to calculate the hardness of the material. The Vickers hardness number (VHN) is calculated as follows:

VHN = 1.854P/d^2

where:
P = Load applied in kg
d = Average length of the diagonal L in mm

3.0 RESULTS AND DISCUSSION

After performing the tensile test on the standard dog bone specimen. The mechanical properties of both samples as shown in Table 1. From the table it shows that steel has a higher tensile strength than aluminum, thus it fragmented more quickly during the tensile test. (60.495 Mpa compared to 33.609 Mpa for aluminum)

The information below indicates that steel has a stronger tensile strength while aluminum is a versatile material with a number of advantages and widely recognized for being both flexible and lightweight which is suitable for aviation components.

Table 1: Mechanical Properties of Aluminum and Steel

Properties	Aluminium	Steel
Max. Force	659.911	1187.827
Tensile Strength	33.609	60.495
Elongation, mm	8.76	8
Elongation, %	35.04	32
Area	19.635	19.635
0.2% Offset Yield Force	652.578	714.501
0.2% Offset Yield Strength	33.235	36.389
Upper Yield Load	469.879	593.161
Lower Yield Load	469.879	593.161
Upper Limit	0	0
Lower Limit	0	0
Exhaust Time	28.2	25.9
Gauge type	0	0

Figure 2 shows how both specimens fractured. Physical qualities like yield and tensile strength are determined by the load displacement relationship between two rough surfaces of steel and aluminum in contact. From the graph, indicates that steel can withstand higher load compared to aluminum but the aluminum have higher ductility due to the face-centered cubic (FCC) structure, commonly known as a repeating crystal structure, is found in aluminum[8]. This structure has the benefit of having slip systems, which quickly bend when force is applied. In contrast to steel, which has a body-centered cubic (BCC) structure, aluminum is more ductile for this reason.

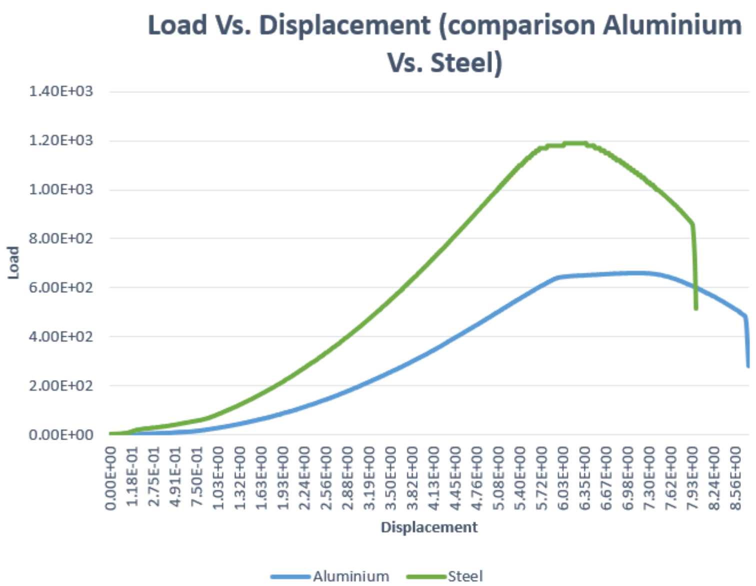


Figure 2: Load vs Displacement for aluminium and steel

a)

b)

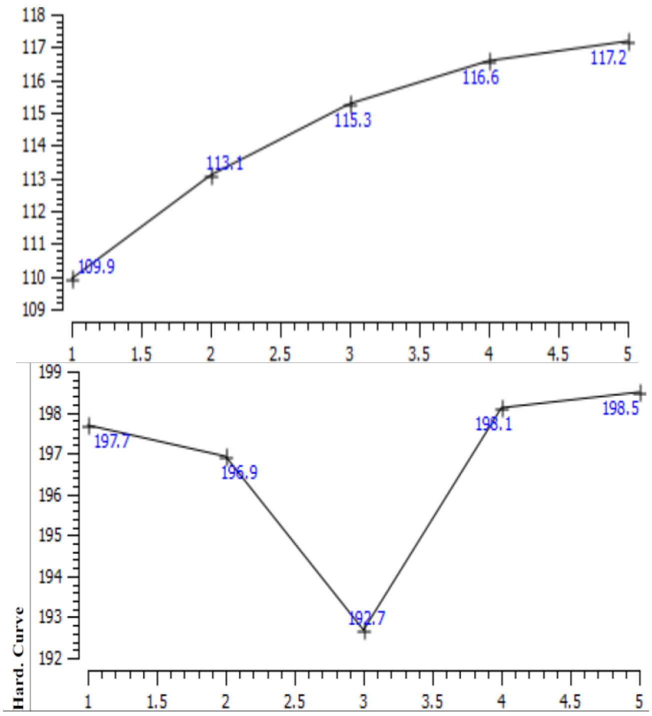
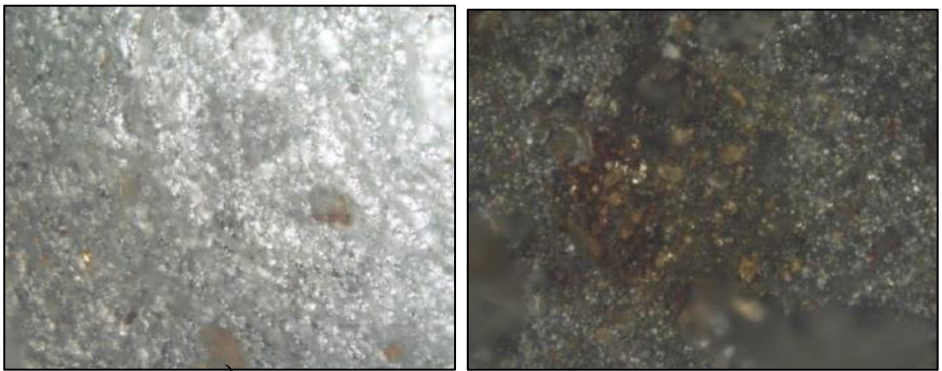


Figure 3: Hardness test result a) aluminum b) steel

While for hardness test for both aluminium and steel it shows that steel is harder than aluminium. Steel's crystalline structure, which enables it to resist large axial loads before fracture, is the reason for this. However, aluminium has a wide range of applications in products like aerodynamics and some automobiles that call for low-density materials[9]. Due to its higher rates of ductility than steel, aluminium has lower Young's Modulus values than steel, which affects how much a structural component deflects[10].

Besides that, from microstructural analysis it shows that aluminium is a soft, silvery metal with a face-cantered cubic crystal structure, a hallmark of ductile metals as shown in Figure 3. Atomic mobility and the presence of concentration gradients during processing are additional factors that affect the microstructures that are generated in materials in addition to their chemical composition and structural characteristics[11]. The microstructure of steels can occur in a variety of ways depending on a wide range of factors, including alloying components, rolling configuration, cooling rates, heat treatment, and other post-treatments. Due to these factors, the microstructure of the steel can be made up of a variety of materials, including ferrite, cementite, austenite, pearlite, bainite, and martensite, depending on how the steel is formed [11]. So, aluminium is more suitable material for aviation's part due to aluminium has the optimum properties and lightweight material.



a) b)

Figure 3: Microstructure analysis a) Aluminum b) Steel

4.0 CONCLUSIONS

The experiment's findings show that steel is more durable than aluminium. Steel's crystalline structure, which permits it to bear large axial loads without cracking, makes this possible. Nonetheless, aluminium is used in numerous applications that call for low-density materials, such as certain car parts and aerodynamics. Because of its higher rates of ductility, which affect how much a structural component deflects, aluminium has lower Young's Modulus values than steel. Thus, aluminium has the best properties for lightweight materials and aviation components, it is consequently a better material.

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