

Comparative Tensile Testing of Aluminium and Mild Steel

Posted on January 8, 2020

Abstract

For better consideration of the properties of things or materials and their behavior under pressure, tensile testing forms the basis of the knowledge. Two materials were selected for testing in the lab that is aluminum and Mild steel (with 0.1, 0.4 and 1% of carbon). These were tested thrice for the sake of precision in the readings with the most commonly used apparatus. The properties to be measured included cross-sectional area, Tensile strength, Yield Strength, Percentage reduction in area and Percentage elongation at break. These calculations helped in comparing the materials selected for the experiment and describing their properties regarding malleability and brittleness. The tensile testing of these materials indicated that mild steel was the strongest material among the three, with maximum ultimate tensile strength (451.77MPa). The area reduction was largest in mild steel (62%). Aluminium had a Maximum yield strength of 273.5MPa. Hence concluded that Aluminium and mild steel were revealed to be ductile.

Introduction And Theory

Tensile testing is among the best necessary tests in the field of engineering. It delivers valued facts related to the material under discussion and its concomitant properties. Engineering structures are designed and analyzed based on these properties. Also, fresh materials are developed for the required usage. In tensile testing, a material is exposed to controlled tension while waiting for failure. The outcomes of the test are then utilized to pick the material for use and foretell the behavior of the material under certain circumstances. Properties to be analyzed by tensile testing include elongation, area reduction and tensile strength. Among the two types of tensile testing, Uniaxial is used to measure mechanical characteristics, while Biaxial testing is used for composite materials and textiles. The elements that are tested include metals, paper, adhesives, fabrics, etc. (Ritchie et al., 1973).

The purpose of tensile testing is to check the strength of the material and its susceptibility to tolerate pressure. It could be based on elongation value. It can be used to compare different materials.

The choice of material is the most important step in the process of designing. The right choice of material is the most basic task for a specific design. The tensile test is a customary process in engineering to describe the elasticity variables of elements.

The Selection of the material is the main task of the designing process. Engineering has to decide

which material they are going to use in the design process. The tensile test helps to decide which material the engineer should use to design a particular product. It helps to characterize the plastic and elastic variables that relate to the mechanical behavior of the stuff.

Tensile testing was piloted by Load Frame equipment and analyzed by data acquirement software. Three, unlike materials, were used comprising Aluminium, Mild Steel with different percentages of carbon. The gage section was reduced as the samples were rod-shaped. This is to ensure that greater stresses occur not near the grips but within the gage. The samples were prepared according to the dimensions of the test, according to the ASTM standards.

Materials/ Equipment

The universal testing machine is the most commonly used machine for tensile testing. The machine is adjusted with crossheads for the length and tension of the test specimen. Some machines are hydraulic, and some are electromagnetic. The machine is analyzed by four parameters: Force capacity, Speed, Accuracy, and precision. The most important factor for the functioning of the machine is alignment (Tetelman et al., 1968).

Procedures

Material selection for the sample is one of the most important tasks of the overall design process. Engineers need to decide which material is appropriate for the making of a particular product. The Tensile test helps engineer the selection of a particular material. The test helps to characterize elastic and plastic variables that are linked to the mechanical behaviors of the material.

The procedure involves putting the test sample into the testing instrument and then slowly putting pressure on it until it breaks or fractures. In this process, the change in length is measured against the applied force. The data is analyzed, and the gauge area is measured by the force applied. The measurements of the change of length are used to compute the value of ϵ (engineering strain).

Whereas ΔL represents the gauge length's change, L is the length after applying the force, and L_0 is the initial gauge length. The calculations of the force help to measure the value of σ (engineering stress).

The above graph shows the tensile stress of steel with different compositions of carbon. It shows the expansion of the material when the load is applied to it. The graph shows that the expansion is less at the start but increases significantly when the applied load is more significant than 10000 Newton.

Where F represents the tensile force, and A represents the total area of the material. The machines do these measurements as the force upsurges so that the data points can be plotted in Young's modulus (stress-strain curve).

Results

The comparison was made of the three materials that were tested for tensile strength, i.e., Aluminium, Mild steel with different compositions of carbon. The two materials showed the relation between them in a very precise way.

Cross-Sectional Area:

The cross-sectional area was measured before and after applying force, and it was observed to be almost the same for Aluminium and steel with different percentages of carbon.

Tensile Strength:

The highest tensile strength was found to be of Steel with a different percentage of carbon with a mean value of 176.16MPa with the ultimate tensile strength of value 451.77 MPa.

Yield Strength:

Aluminium showed more yield strength than Mild steel with a different percentage of carbon, with an average of 273.5 MPa.

The above table shows the maximum amount of load that aluminum can hold and the expansion of aluminum when the maximum load is applied.

$$\text{Tensile Stress} = 7519 / 5.06 = 1485.9$$

Reduction In The Area:

When pressure force is applied to the materials, the highest reduction in area was found to be 62% in mild steel with different percentages of carbon.

$$\text{Tensile Stress of Steel with 0.1\% carbon} = 7950 / 4.90 = 1622$$

$$\text{Tensile Stress of Steel with 0.4\% carbon} = 13317 / 5.01 = 2658$$

$$\text{Tensile Stress of Steel with 1\% carbon} = 18331 / 5.02 = 3651$$

Elongation At Break:

The force was applied to check the elasticity; the minimum was found in aluminum with a value of 17%.

Discussion

The Carbon fibres and their composite materials have more tensile strength and more modulus of elasticity as compared to other materials. All of them break up in a brittle manner, and the curve remains linear until the material breaks or fractures without any bending of the curve at the high loads. Therefore, there will be no everlasting modifications in the original shape in this test, and hence, there will be no ductility.

The Young's Modulus (Stress-strain graph shown below) shows that aluminum material has more plastic deformation as compared to steel with different percentages of carbon materials, and the higher percentage elongation reflects this result. After having fractures on its surface, the surface of aluminum turns out to be very rough and irregular. The two halves of the fractured material have shown the cup and the cone shape which are inclined at the angle of 45 degrees on the surface of the fractured material surface. In the uniaxial tensile test, the orientation has represented that the angle of the principle shared the stress and the surface of the material obeys this principle. Crystalline boundaries slip into each other before the fracture due to the shear stress(Verbridge et al., 2006).

Conclusion

The Characteristics of ductile materials, a common property of aluminum, aluminum material has more toughness and hardness as compared to steel, with different percentages of carbon material, which is represented by the larger area in the stress-strain graph shown above. Although it is smaller than that of copper material, the plastic area of the steel sample is large enough that it is deliberated as to have some ductile properties. The fractured surface has a cup and cone geometry at a much lesser context as compared to that of the aluminum material. The steel material has a more necking region than that of the aluminium material. It results in the reduction of the overall area of the fracture as shown in the below figure. Mild Steel material shows a rapid transition, whereas aluminum shows a gradual transition. Necking is also a property of a ductile material.

The Experimental value of Modulus of Elasticity obtained is nearly one order of magnitude lesser as that of the values in the engineering material. This is around 176 GPA for mild steel and 105 GPA for aluminum material. The Yield Strength for mild steel is aluminium 31.9 Mpa and 273 Mpa, respectively. The calculation of the Modulus of the material by using a uniaxial tensile stress experiment is not considered accurate, and its value is calculated by the natural frequency of the material with the help of an oscillation test. The main reason for this is because:

- Noticing the small movements and motions of the material are inexact due to the inaccuracy of the measuring tools.
- The features, for example, creep, could take part in the strain.
- When applying large forces, the tools could start flexing, and the movement of the tools and instruments is being read inaccurately as a movement of the material/sample.

The above graph shows the tensile stress of aluminum. It shows the expansion of the material when the load is applied to it. The graph shows that the expansion is less at the start but increases significantly when the applied load is greater than 7000 Newton.

The final readings of the tensile stress taken are very near to that of the theoretical values. The difference in the reading of the theoretical and practical values for the Young Modulus has suggested very little confidence in the results. In conclusion, copper could be considered as a more Ductile material as steel with more toughness and steel is deliberated to have a more tensile stress and higher yield with the equal modulus.

Bibliography

Jen, S.-H., Bertrand, J.A., George, S.M., 2011. Critical tensile and compressive strains for cracking of Al₂O₃ films grown by atomic layer deposition. J. Appl. Phys. 109, 084305.

Kim, S., Dealy, J.M., 2002. Gross melt fracture of polyethylene. I: A criterion based on tensile stress. Polym. Eng. Sci. 42, 482-494.

Naaman, A.E., Homrich, J.R., 1989. Tensile stress-strain properties of SIFCON. Mater. J. 86, 244-251.

Ritchie, R.O., Knott, J.F., Rice, J.R., 1973. On the relationship between critical tensile stress and fracture toughness in mild steel. J. Mech. Phys. Solids 21, 395-410.

Tepfers, R., 1979. Tensile fatigue strength of plain concrete, in Journal Proceedings. Pp. 919-934.

Tetelman, A.S., Wilshaw, T.R., Rau, C.A., 1968. The critical tensile stress criterion for cleavage. Int. J. Fract. 4, 147-156.

Verbridge, S.S., Parpia, J.M., Reichenbach, R.B., Bellan, L.M., Craighead, H.G., 2006. High-quality-factor resonance at room temperature with nano-strings under high tensile stress. J. Appl. Phys. 99, 124304.