# Middle East Technical University

## Department of Metallurgical and Material Engineering

### Mete206 – Materials Processing Laboratory

**Experiment 1:** Tension Test

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## ABSTRACT

Tensile testing was done with the use of screw driven testing machine on dog bone shaped 1040 steel. Many properties of the material were found using the stress-strain graph as well as other graphs. Mainly, Tensile strength was found to have a value of 611.18 MPa, yield strength 404.78 MPa and elastic modulus as 244632.15 MPa. More of the found values can be found from table 1. These values deviate slightly from the real values due to reasons such as slipping and mechanical stiffness effect. From the final shape of the fractured material and ductility calculations the material was considered as relatively strong and ductile.

## INTRODUCTION

One of the most important test that gives one many of the materials mechanical properties is the Tensile test. The tensile test allows the understanding of the range of load that a material can work at and the amount of stress that a material can withstand (Singh, 2012). In normal cases, when a test is done only one type of parameter is obtained. However, in tensile testing the following parameters can be obtained;

- Tensile Strength
- Yield Strength
- Elastic Modulus
- Percent Elongation
- Percent Reduction
- Toughness
- Resilience
- Poisson Ratio

This is one of the reasons as to why tensile strength can be considered as a critical test as it allows one to understand the material. Through the Tensile test one can also know when the amount of stress will cause permanent deformation on the material, known as plastic deformation or when the stress is just enough to change the shape of the material but not enough to permanently deform it, known as the elastic deformation.

The value of Yield Strength is the value of strength that separates plastic deformation and elastic deformation. Therefore, it can be said that yield strength is the stress at which plastic deformation starts (William D. Callister, 2016). This value is critical for engineers as generally an engineer would not want a material to plastically deform meaning that an engineer works in elastic region. In this case the yield strength would be a critical value. There are some difficulties in finding the value of yield strength as in a stress-strain curve it is at the point that the graph deviates from linearity and most often the exact point where this happens is not clear. To overcome this the 0.2% offset method is introduced. It is defined as a line having the slope of young modulus which the intersection of this line with the stress-strain curve gives one the value of yield strength (Pattillo, 2018).

Tensile strength is also an important point which correspond to the place where the necking starts. Up to this point the volume of the specimen can be considered as non-changing however from this point on the volume as well as the cross-sectional area begins to change, leading to a deviation from the true stress and strain curve. One can also define this point as the maximum stress level the material can withstand (William D. Callister, 2016).

Elastic modulus is the slope of the linear portion of the line that is in the elastic region and it can be corelated with the stiffness of a material. It is also used in the Hooke’s law which a relation of stress and strain in the elastic region.

Ductility is one of the parameters that can be derived from the graph and it is represented either by percent elongation or percent reduction in area. By definition it is said to be the amount a material can plastically deform where higher the value the better as the likelihood of a catastrophic failure decreases (Y.H. Zhao, 2011).

The energy parameters that consist of resilience and toughness are the amount of energy a material can have before certain situations. For resilience it is the energy for it to elastically deform and for toughness it is the energy to fracture the material. Both of them are found from the area under the stress-strain curve.

Deviation from true stress and true strain were mentioned in the above paragraphs. In engineering stress-strain curve it is seemed like the strength of the material is decreasing from the point of tensile strength however in reality this is not the case. It is observed as such due to the decrease in the cross-sectional area after necking but the test machine continues to give values as if the cross-sectional area did not change. True stress and strength are related with one other with the following equations up to the point of necking;

$\sigma_t = \sigma\ (1+\varepsilon)$

$\varepsilon_t = \ln\ (l+\varepsilon)$

$\sigma_t = K\ \varepsilon^n_t$ where n and K values are constants.

There can be said of two types of Test machines;

- Screw Driven Testing Machine
- Hydraulic Testing Machine

The experiment was done with the use of screw driven testing machine.

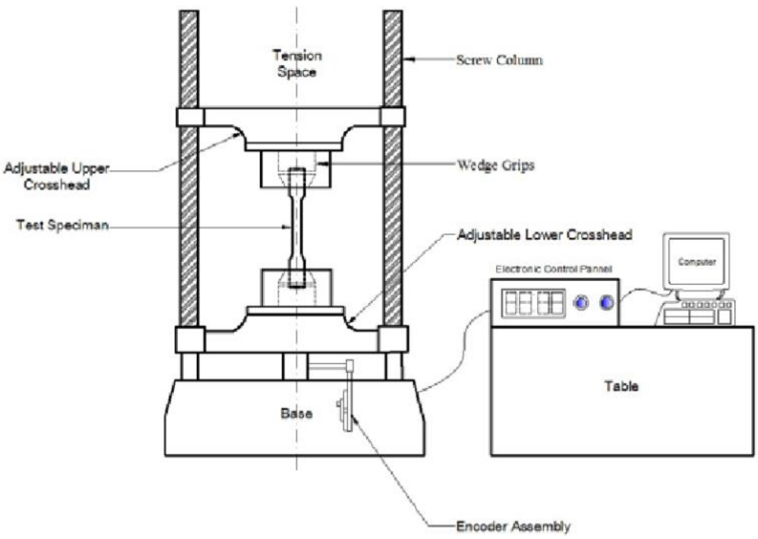


**Figure 1.** Schematic diagram of screw driven testing machine (Chellamuthu, 2012).

# EXPERINMENTAL

Material

- “dog bone” shaped low carbon steel specimen

Equipment

- Screw driven tensile testing machine
- Caliper

Procedure

In the start of the experiment multiple measurements of the diameter of the specimen was taken and the smallest one was noted as the diameter. The initial gauge length was also measured with the help of the caliper. After the initial measurement the specimen was marked with a marker as to allow the machine to get accurate calculations of the elongation. After the preparations the specimen was ready to be put in the tensile machine and it was placed rigidly. The test was done at the rate of 1mm per minute. With the start of the test in the computer that is connected to the testing machine the load- axial strain percent data were able to be seen in real time. After some time, necking was observed on the specimen. Not long after this observation the specimen fractured resulting in a load sound in the process. After the testing the values of gage length and diameter were once again measured and noted which signified the end of the experiment.

# RESULT

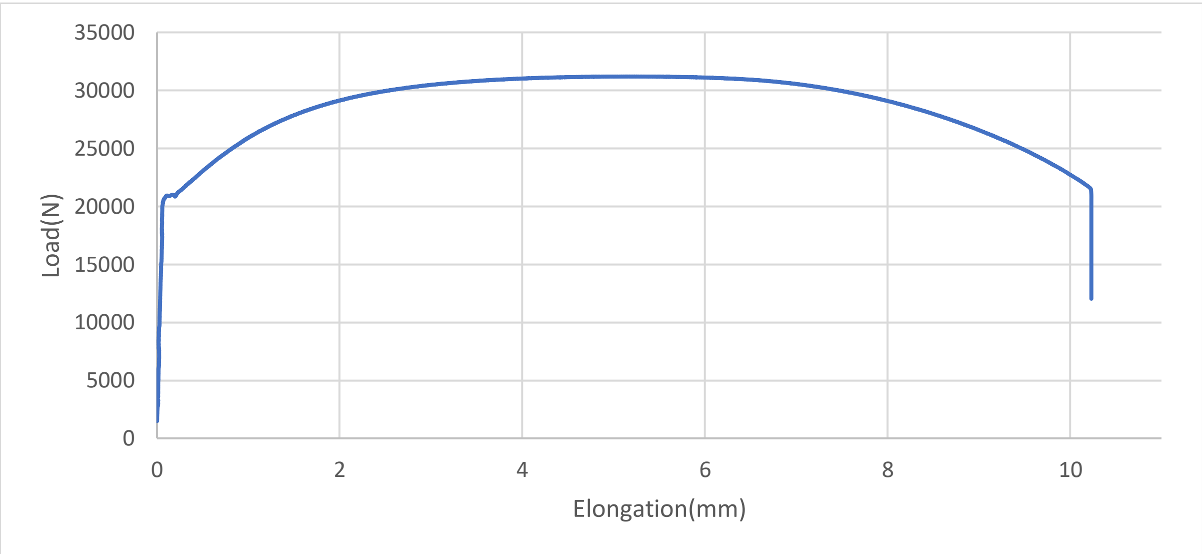


**Figure 2.** Load vs Elongation graph

In figure 2 the graph of load with the unit of newton vs the elongation with the unit of millimeters can be seen. The load was gotten by multiplying the kgf load with 9.81 whereas the elongation was obtained by multiplying strain with the initial gauge length that was measured by the extensometer.

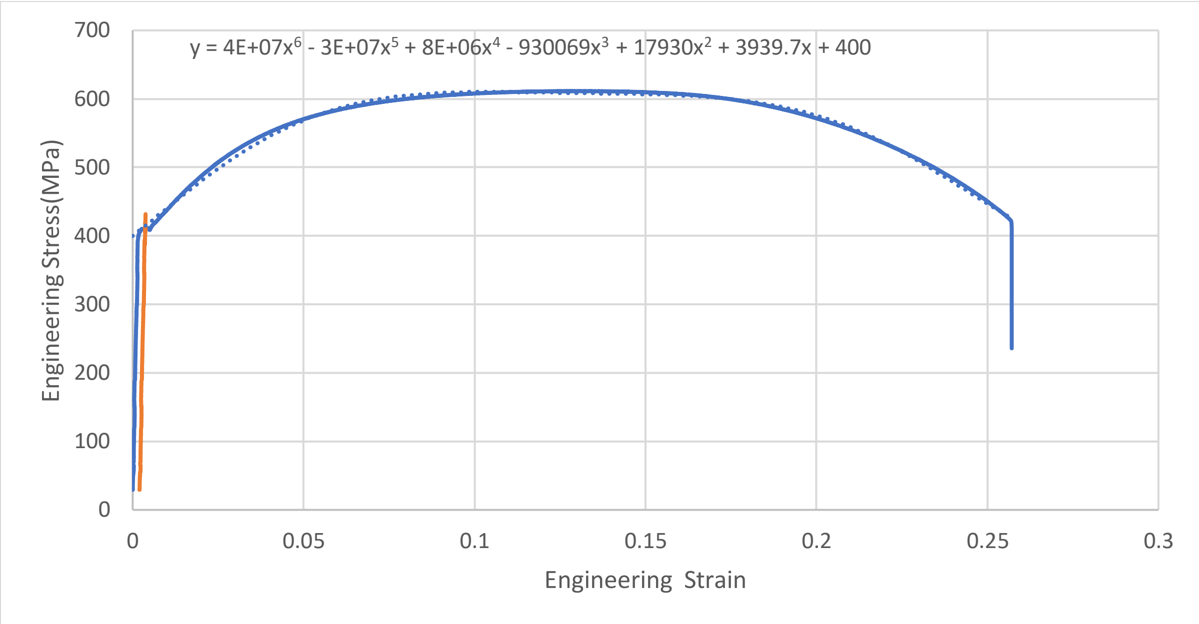


**Figure 3.** Engineering Strain vs Engineering stress graph with the addition of a 0.2% offset curve

In figure 3 the behavior of strain-stress curve can be observed. As mentioned in the introduction many properties of the material can be determined with this curve and the 0.2% offset method to determine the yield strength and the trendline and its equation used to determine the area under the stress-strain curve can also be found can also be seen in figure 3.

| | |
|---|---|
| Yield Strength | 404.78 MPa |
| Young Modulus | 186503.07 MPa |
| Tensile Strength | 611.18 MPa |
| Fracture Stress | 411.4 MPa |
| Yield Strain | 0.0037 |
| Strain at onset of neck | 0.1368 |
| Fracture strain | 0.2571 |
| Percent Elongation | %22.66 |
| Percent reduction in area | %88.61 |
| Resilience | $0.75*10^6$ J/m$^3$ |
| Toughness | $96.28 * 10^6$ J/m$^3$ |
| Poisson Ratio | 2.92 |

**Table 1.** Material properties obtained from the stress-strain curve

The materials properties can be found from table 1.

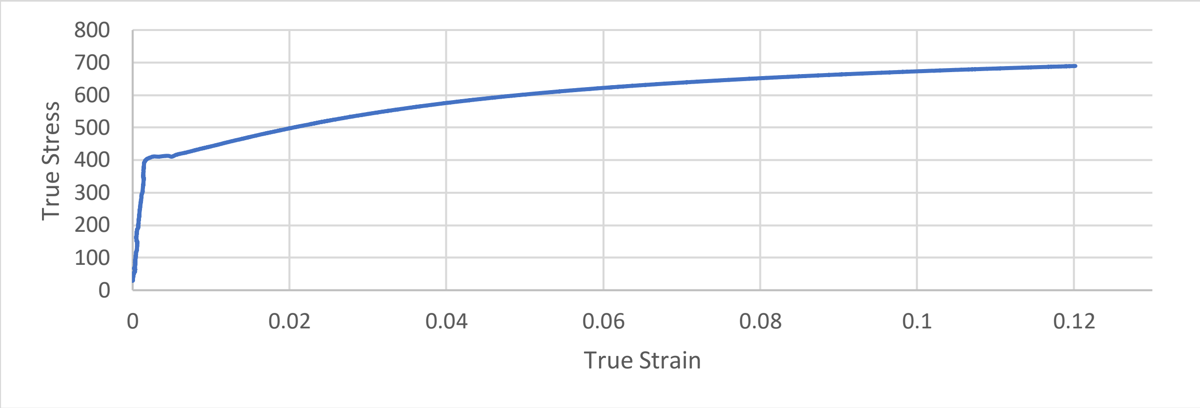


**Figure 4.** true strain vs true stress graph

True stress vs true strain graph cab be seen in figure 4.

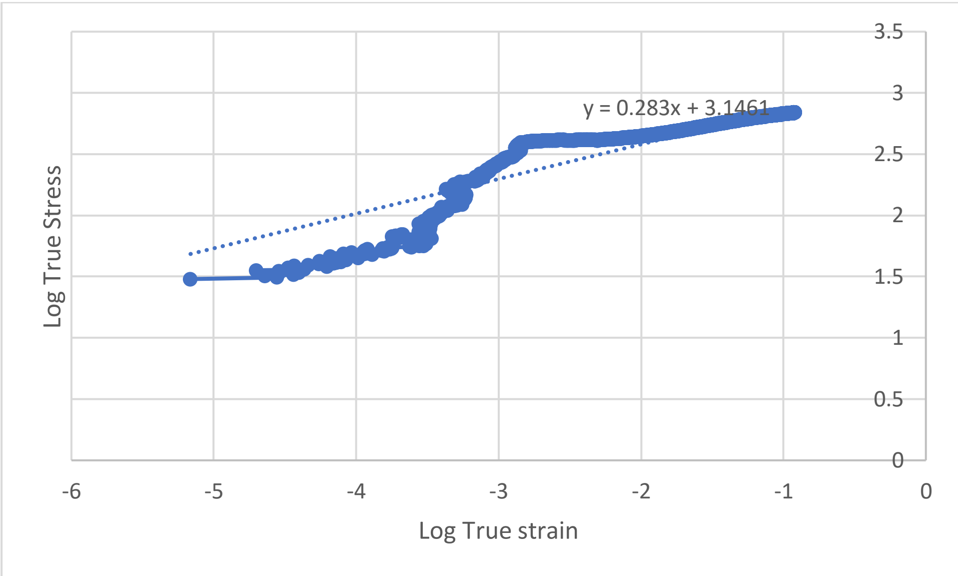


**Figure 5.** log true strain vs log true stress graph

# DISCUSSION

In figure 2 the load vs elongation graph can be seen. The Testing machine gives the values of load in the unit of kgf and axial strain percent which we divided by 100 to get strain. From these given values by the machine, to transform it into load in the unit of newton, kgf value is multiplied by 9.81. and since strain is elongation divided by initial gage length the elongation can be obtained by multiplying strain with initial gage length. After these calculations figure 1 was obtained. To determine the mechanical properties of the material with this graph would be wrong as this graph is geometry dependent. Therefore, to overcome this load is transformed into engineering stress and strain is used instead of elongation. Load is transformed into engineering stress by dividing the load to initial cross-sectional area and the resulting values are of the unit MPa. In figure 3 the stress-strain graph can be seen. From this graph we can determine the mechanical properties of the material. It must first be noted that there can be seen a upper and lower yield point in the point of yield strength as our metal has low carbon composition and this can be seen on low carbon steels.

Yield strength was derived using the 0.2% offset method and the value of 404.78 MPa was noted. The actual value for 1040 steel is found to be 415 MPa. There is some difference between the real value and the value that has been found. This can be because of slipping in the machine or may be because of machine stiffness effect.

Young Modulus which is the slope of the linear part in the elastic region is found to be 186503.07 MPa and the real value is 190-210 GPa. The value was found by selecting two point in the middle of the elastic region and with the use of the two point the slope was found which equals to the young modulus. When regression calculation was done using the data analysis add-on on excel the value of 244632.15 was found. One can see that this value is very different from the real as well as the value that has been calculated by using two points. This can be attributed to the fact that there were adjustment errors as well as slipping at the start of the tensile strength which can be considered as the reason for the very off value obtained using regression calculations. The slope which is the young modulus was found as following;

$$\frac{\sigma 2 - \sigma 1}{\varepsilon 2 - \varepsilon 1} = \frac{291.34 - 169.74}{0.001132 - 0.00048} = 186503.07\ MPa$$

Tensile strength was found by looking at the data to find the point where the increase stopped and decrease started. Tensile strength represents the place the necking starts and it has been found to have a value of 611.18 MPa. It can be considered as relatively close to the real value of 620 MPa.

Fracture Stress can also be found as 411.4 MPa from the stress-strain graph.

It is important to note that machine stiffness effect and the slipping's are a source for error but another error source can be the approximation error.

Yield strain, Strain at onset of neck and fracture strain can be found on table 1. The stress-strain curve can be said to exist in three different sections which are elastic region that is up to the yield strength, uniform plastic region which is up to the necking point determined by tensile strength and the non-uniform plastic deformation region that comes after necking up to fracture point.

There are two ductility parameters that has been found and noted in table 1.

Percent elongation was found by;

$(L_f - L_i)/L_i * 100$

$= (49.43-40.3)/40.3 * 100$

Which gave us a value of %22.66.

Percent reduction in area was found by;

$(A_i - A_f)/A_i * 100$

$= (51.02-5.81)/51.02 * 100$

Which gave the value of %88.61

To determine the resilience,

½ * Yield strength * Yield strain was used

$= ½ * (404.78)*(0.0037) = 0.75$ MPa $= 0.75 * 10^6$ J/m$^3$

To determine toughness as it can be seen from figure 3 the trendline and its respective equation was obtained. This equation was used to be used in an integral calculation to determine the area under the graph which is equal to the toughness of the material. The lower bound was chosen as 0 and the upper bound as the fracture strain which is equivalent to 0.2571. Therefore, the toughness is found as $96.28 * 10^6$ J/m$^3$

Poisson ratio was found by the equation $(\Delta d/d_i)/(\Delta L/L_i)$ and 2.92 was obtained. The expected value is 0.3 and 2.92 is impossible for a poisson ration we can conclude that since the poisson ration is found from the elastic region the final values after fracture and before the testing are not dependable values to determine poisson ratio.

Figure 4 shows the true stress and true strain curves. These values were calculated by the equations;

$\sigma_t = \sigma (1+\varepsilon)$

$\varepsilon_t = \ln (l+\varepsilon)$

$\sigma_t = K \varepsilon^n_t$

but it is important to note that these equations hold up to the point of necking which is determined by tensile strength. Therefore, it can also be seen that the graph in figure 4 goes only up to the point of Tensile strength.

From figure 5 the strain hardening constant is found as 0.283 which is inside the range of what is expected which is between 0.1 and 0.5. To examine the graph an linear graph is expected however as it can be seen the graph does not match this description. It can be the result of the error while the data was taken.

**Figure 6.** Side view of the specimen after fracture

**Figure 7.** Top view of the specimen after fracture

The cup and cone structure of the broken specimen after fracture can be observed from figure 6 and 7. This shows that the material is ductile as if it were brittle it would snap and have a relatively flatter surface as opposed to this case.

## CONCLUSION

From this experiment, the importance of the tensile test is understood as with only a single test many mechanical properties are found. However, the test is not without disadvantages as to the tensile test the specimen needs to be of a particular shape and in the case of ceramics or for some other materials it might not be so easy to give shape. Our specimen was 1040 steel and from the values obtained from the test it can be said that this steel is relatively strong while also still being ductile. The values that has been found slightly deviated from the real values and this was related to the slipping's and the mechanical stiffness effect. All in all Tension test is a very critical testing and is a necessary for designing and working with materials.

## REFERENCES


Singh, R. (2012). *Applied Welding Engineering Processes, Codes, and Standards.* Butterworth Heinemann.

William D. Callister, D. G. (2016). *Fundamentals of Materials Science and Engineering.* Wiley.

Pattillo, P. (2018). *Elements of Oil and Gas Well Tubular Design.* GPP.

Y.H. Zhao, E. L. (2011). *Nanostructured Metals and Alloys Processing, Microstructure, Mechanical Properties and Applications.* Woodhead Publishing.

Chellamuthu, S. (2012). Experimental study on tensile behavior of multi wall carbon nanotube reinforced epoxy composites. *Journal of Applied Sciences Research*, 3253-3259.


## APPENDIX

- Pa = J/$m^3$

| | |
|---|---|
| Initial gage length mesured by caliper (mm) | 40.3 |
| Final gage length measured by caliper (mm) | 49.43 |
| Initial diameter mesured by caliper (mm) | 8.06 |
| Final diameter mesured by caliper (mm) | 2.72 |
| Initial gage length mesured by extensometer (mm) | 39.8 |

**Table 2.** Properties of specimen