Methodology for Finding Corrected Stress-Strain Diagram

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Abstract: - Stress-strain diagram is a very useful diagram for finding the physical properties of metals. Especially by the tensile test in Universal Testing Machine (UTM), we can find the load-displacement diagram and there by stress-strain diagram. From this diagram by suitable correction, also we can get the true stress-strain diagram. But, as we know that the Poisson's ratio (μ) for metal is not a constant terms above elastic limit because above the elastic limit the metal expansion is not remain uniform. So, in our current research by finding suitable correction method of finding the true μ value and considering this we can find the corrected stress- strain diagram. For this we made experiments on different metals, namely aluminum, copper & brass and there by finding their respective corrected stress-strain diagram we tried to establish this methodology.

Key-Words: - Physical properties, Universal Testing Machine (UTM), Load-displacement diagram, True stress-strain diagram, Poisson's ratio (μ), Elastic limit.

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1 Introduction

Stress (σ) is defined as the ratio of force to cross sectional area (A) i.e. σ = P/A, where σ is the stress, p is the internal resisting force and A is the cross-sectional area) and Strain(e) is the ratio of change in length to the original length, when a given metal sample is subjected to some external force (Strain = change in length ÷ the original length i.e. $e = \frac{\delta}{L_0}$).

In an UTM or Universal Testing Machine we make the tensile test for metals. An UTM or universal testing machine is referred to as universal because it can be used to perform a variety of static tests, including tensile tests and compression tests, as well as bending test, flexure tests, peel tests, tear tests and other mechanical tests.

The primary use of this testing machine is to create the load-displacement diagram or stress strain diagram. A stress strain diagram or stress strain curve is used to illustrate the relationship between a material's stress and strain. A stress strain curve can be constructed from data obtained in any mechanical test where load is applied to a material and continuous measurements of stress and strain are made simultaneously. Once the diagram is generated, a pencil and straight edge or computer algorithm can be used to calculate yield strength, Young's Modulus, tensile strength or total elongation. The obtained load stress-strain curve can provide the engineers for various designs and determine their tensile strength. Also, It can determine the mechanical properties of the given material and on parameters such as strength, toughness, yield point, etc. It helps in the fabrication of the material.

The important features of the strain stress curves are as below

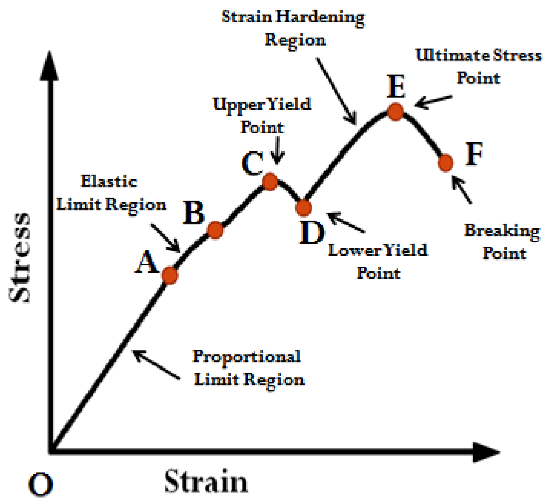


Figure 1: Stress-Strain diagram of a Ductile Metal

A single tensile test can produce a stress-strain graph, which then allows the following properties of a material to be obtained:

- Young's modulus.
- Yield strength.
- Ultimate tensile strength.
- Ductility.
- Poisson's ratio.

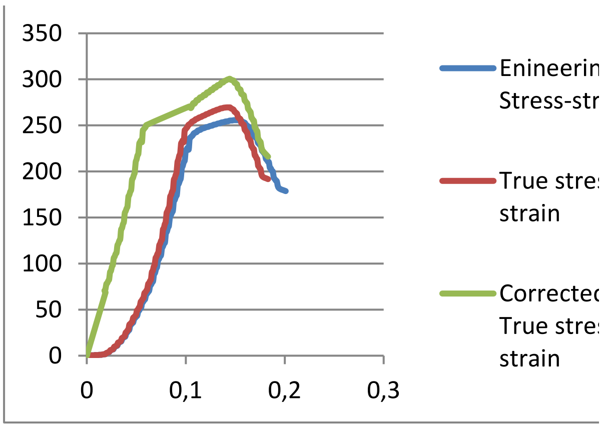
In our current research, after preparing the suitable UTM test pieces (Aluminum, Brass & Copper) we conduct the tensile test and then we get the load displacement data of the respective metals. From this, we consider the Engineering stress-strain curve and then considering true stress and strain we find the true-stress strain curve and then above elastic limit by considering suitable value of Poisson's ratio (μ), finally we find the corrected strain-strain diagram.

2 The Suitable Methodology

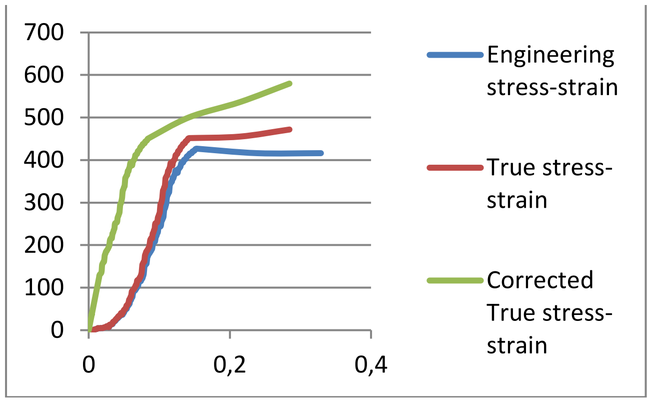
1. Sample Dia. d_0 =…………..mm
2. Sample Gauge Length L_0 =…………..mm
3. UTM Test Data : Load vs Displacement (P vs δ)
4. Take the value of μ for the respective materials.
5. Calculate : Nominal/Engineering Stress, $\sigma_n = \frac{P}{\pi/4\ {d_0}^2}$
6. Find Strain : e = $\frac{\delta}{L_0}$
7. Plot σ_n vs e
8. Correct the above Graph (Take the both of value of σ_n or e from 0).
9. Find the Proportional Limit in terms of σ_n ($\sigma_n \geq \sigma_{n_p}$)
10. Find, True strain ϵ = ln(1+ e)
11. Find, True stress $\sigma_t = \frac{\sigma_n}{2-e^{\mu \ln(1+\frac{\delta}{L})}}$, where $\sigma_n \leq \sigma_{n_p}$
12. Plot σ_t vs ϵ
13. Find E (Modulus of Elasticity) from Graph.
14. Find T from Graph for $\sigma_t > \sigma_{t_p}$
15. Find $\eta = \frac{1}{2} - (\frac{1}{2} - \mu)\frac{T}{E}$
16. If $\eta > \frac{1}{2}$, make $\eta = \frac{1}{2}$
17. Find corrected $\boldsymbol{\sigma_t}$
18. Repeat steps 11 to 14 until η converges.

3 Corrected stress-strain diagram for different metals

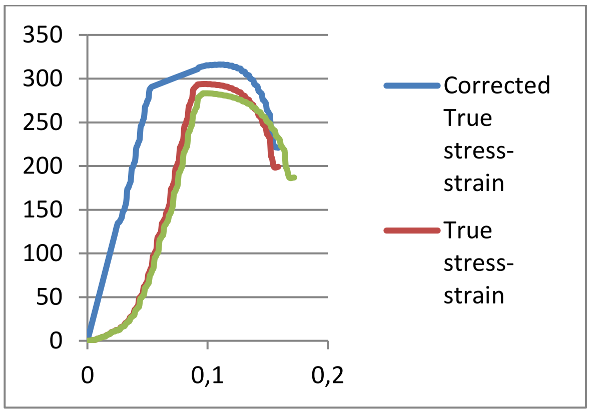
Aluminum



Brass



Copper



4 Discussion

When an external load is applied on the material, it will undergo changes in the dimensions and change in shape will take place. As a result, strain will be induced in the material. The change in dimensions or the shape is referred to as “deformation”. Deformation of metals may be-

i) Excessive Elastic Deformation (EED)

This type of deformation is temporary. It is the deformation taking place within the elastic zone. Under the influence of external load the material will undergo changes. As the magnitude of the load is increased the deformation becomes more and more and reaches a maximum value corresponding to the yield point. Higher the load higher is the deformation and is referred to as excessive deformation.

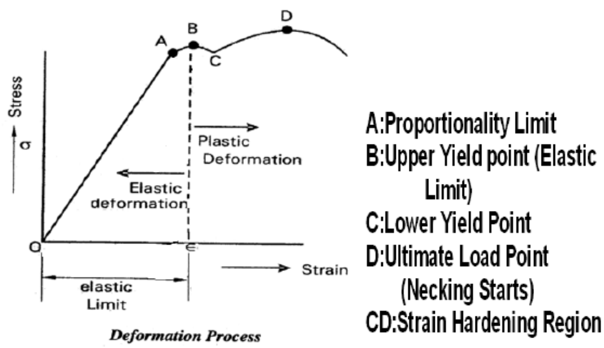


Fig. Deformation Analysis

ii) Excessive Plastic Deformation(EPD)

This type of deformation is permanent in nature. It is the deformation taking place beyond the elastic zone. Under the influence of external load the material will undergo changes. As the magnitude of the load is increased the deformation becomes more and more and reaches a maximum value corresponding to the ultimate point. Higher the load higher is the deformation and is referred to as excessive deformation. Beyond point B, is plastic deformation and the changes are permanent and the material cannot recover its strain free state. Once the external load is removed the material will not recover its free state. It will have induced strain in it.

iii) Necking

Beyond the ultimate load the material undergoes deformation even without increasing the external load. The ultimate load point (D) is called as the point of instability. From point C to D the material shows increasing resistance to deformation. The material will show continuous decrease in the cross section (when tensile load is applied) and reaches a very low value called as necking. Beyond which it cannot offer any resistance at all. Once necking is initiated the material fails at any moment. Once necking has been initiated, fracture propagates faster even when the load is reduced and separation occurs and the material breaks.

5 Conclusions

We were able to successfully tensile test Aluminum, Brass & Copper using the universal testing machine, from the data obtained we were able to successfully obtain the young's modulus, ultimate tensile strength and yield stress values of the two metals. By comparing the values of the two metals we can see that Copper has higher values in all of the three properties which means it is stronger and more ductile than Aluminum.

This experiment of tensile testing showed us how exactly a tensile test is performed and how to obtain he relevant properties of materials such as Aluminum and it has the highest ductility, demonstrating that not only did the material have a high yield strength but it also had the greatest amount of deformation and this was visible during testing as the material shrank and developed bumps through the whole testing.

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