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Behaviour of Stress Strain Relationship of Few Metals

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Abstract. The aim of this study is to examine the uniaxial tensile strength of three specimens of mild steel, brass and aluminium is examined. Tension tests enable the determination and prediction of the deformation/deflection response of the material properties and elastic modulus. The values of Young's Modulus for Elasticity (E) for mild steel, brass, and aluminium have been successfully determined from laboratory experiments. Also, the stress and strain of the materials were graphically shown to have good correlations between theory and experimental values and compositions. The results further show that steel is more suitable for structural application than brass and aluminium respectively, because of their high E Modulus rating. It therefore implies that steel can withstand more tension. The result obtained from the study such as tensile strength, yield strength etc. have been recorded. Also, the related theory has been indicated.

Keywords. Stress; Strain; Steel; Aluminium

1. Introduction

Tensile tests of materials are executed to obtain various elastic and plastic material properties such as modulus of elasticity, initial yield strength, ultimate strength, plastic hardening exponent, strength coefficient, etc. A true stress - true strain curve for the required material, focused mainly on plastic properties, is essentially required in order for numerical analyses accompanying large strain and fracture problems such as ship collision, ship grounding (Bridgeman, 1952).

Unfortunately, most engineers are interested in getting only a load-elongation curve from the tensile tests. Even with load-elongation data, however, it is impossible to estimate average true stress-logarithmic true strain data beyond the onset of the diffuse necking. Namely, an average true stress-logarithmic true strain curve estimated from a load-elongation curve is valid only until uniform deformation, viz., before the onset of necking (Ling, 1996). For most engineering steels, a non-uniform deformation field, called plastic instability, starts to develop just after a maximum load. At the same time, flow localization, called diffuse necking, starts at the minimum cross section of the specimen. The stress state and deformation in the necked region are analogous to those in the notch of a circumferentially notched round tensile specimen. For most steels, the load continuously decreases during diffuse necking, which terminates in ductile fracture of the specimen.

Mechanical behavior of metallic type material, such as mild steel, brass and aluminium is generally established by means of uniaxial tension test. Such tension test protocol (ASTM, 2010), which was primarily created only for use in comparison of different steels, establishes the engineering stress and the engineering strain. Figure 1 shows a typical engineering stress-strain relationship for steel (solid line), where the engineering stress was calculated as load divided by the original cross-section area of the sample, and the engineering strain was calculated as change in length divided by the original gauge length. Such calculations, which do not recognize the area changes during increasing loads, are used for convenient of measurements of dimensions and will always show an elastic range (Region-I), strain hardening range (Region-III), and a necking zone (Region IV). However, the stress-strain relationship established on the basis of instantaneous deformed dimensions of the test specimen is known as the true stress-true strain relationship (dash line in Figure 1). For all practical purposes, the engineering relations and the true relations would coincide up to yield point; however, the two relations would diverge beyond this point. Figure 1 shows the qualitative differences between the engineering stress-strain relation and the true stress-strain relation.

Strain, defines quantitatively the degree of deformation of a material. It is measured most commonly with extensometers or strain gauges. During uniaxial deformation, nominal strain (*e*) can be generally expressed as the ratio of change in length to the original length of the specimen. The objective of this investigation is to develop true stress-true strain relationships for metallic materials.

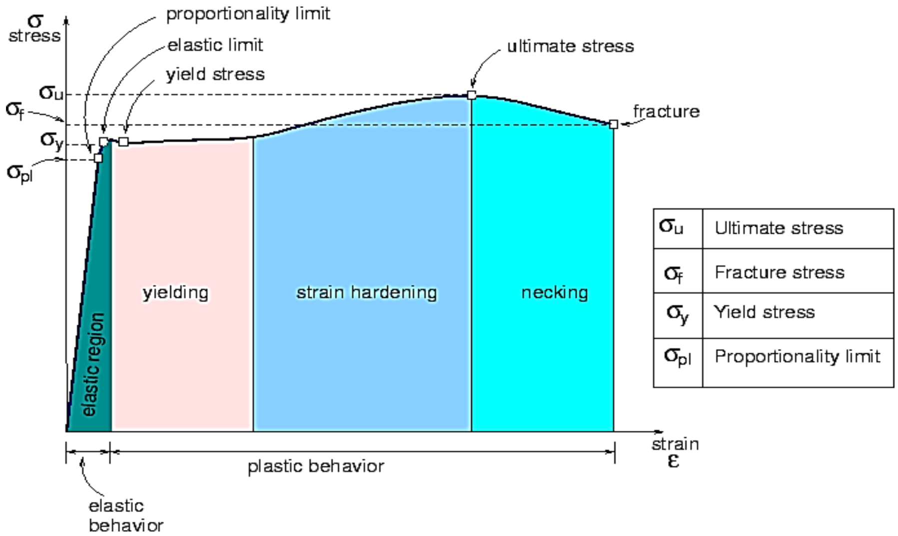

Figure 1. Typical Engineering Stress-Strain Relationship.

2. Materials and Method

The tensile test has been performed using Hounsfield Tensometer. The specimens have been tested made of the following material: mild steel, brass, and aluminium. The description of typical test standard specimen is shown in Fig. 2. It has enlarged ends for gripping. The substantial part of the specimen is the gauge section. The cross-sectional area of the gauge section is lesser relative to that of the remaining portion of the specimen so that the deformation and failure will be localized in this region. The gauge length is the region over which measurements are made and is centered within the reduced section. The distance between the ends of the gauge section and the shoulders should be sufficient so that the larger ends do not constrain deformation within the gauge section, and the gauge length should be long enough relative to its diameter. Otherwise, the state of stress will be more complex than simple tension.

The Hounsfield Tensometer is shown in Fig. 3. It is manually operated device and used for small test specimens (Itugha and Jumbo, 2019).As the force is applied to the specimen, the material begins to stretch or extend. The Tensometer applies the force at a constant rate and readings of force applied and deformation are noted until the specimen finally breaks. The readings obtained can be

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plotted on a graph to show the overall behavior of the material. The shape of the graph is very important, and it helps to predict how the material will behave under different loading conditions. Specimen is fit to the test machine. Maximum load is documented during testing. After fracture of the material, final gauge length and diameter is measured. Diameter should be measured from the neck. The necessary data for calculations will be recorded to the Table 1 given below.

Table 1

Description	Standard specimen at nominal diameter		Small specimen at nominal diameter		
	0.500	0.350	0.25	0.160	0.113
Gauge Length	2.00 ±0.005	1.400 ±0.005	1.000 ±0.005	0.640 ±0.005	0.450 ±0.005
Diameter tolerance	±0.010	±0.007	±0.005	±0.003	±0.002
Fillet radius (min.)	0.625	0.25	0.3125	0.15625	0.15625
Length of reduced section (min.)	2.5	1.75	1.25	0.75	0.625

(Values are in inches)

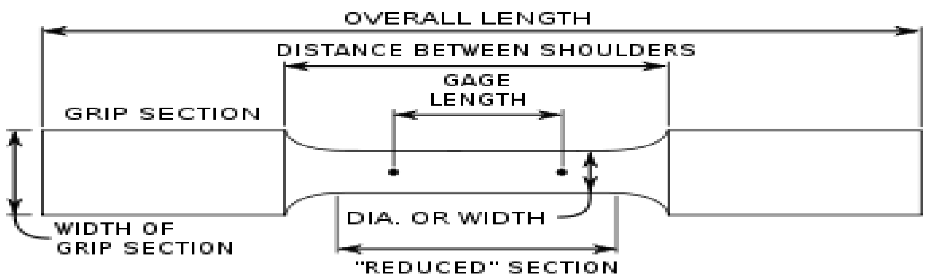

Figure 2. Nomenclature of Standard Test Specimen.

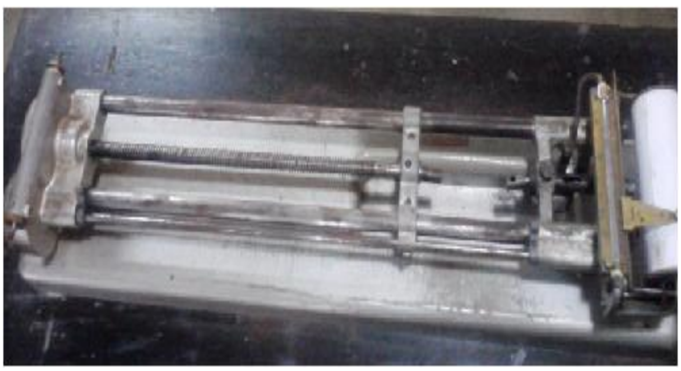

Figure 3. Hounsfield Tensometer.

3. Results and Discussions

The tensile test has been performed on all material studies to determine the engineering stress-strain curve. The experimental results for each specimen are presented in Tables 2-4. The curve obtained

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from the test then was converted to true engineering stress-strain curve. Fig.4 shows the plotted stress strain curve for mild steel, aluminum and brass. From the graph, it is observed that mild steel has greater tensile strength compared to brass and aluminum. Aluminum has the least tensile strength. Also, it is observed that mild has shown maximum ductility property compared to brass and aluminum. Mild steel and brass have marginal difference in ductility property.

Fig.5 shows the typical tangent modulus curve for mild steel, brass and aluminum. The tangent modulus is advantageous in describing the elastic behavior of materials that have been stressed beyond the elastic region. When a material is plastically deformed there is no longer a linear correlation between stress and strain. The tangent modulus quantifies the "softening" or "hardening" of material that generally occurs when it begins to yield. The tensile test has been performed on all material to determine the engineering stress-strain curve. The experimental results for all specimens are presented in Table 4. The curve obtained from the result of the test, was then converted to true engineering stress-strain curve. Fig.4 shows the stress strain curve for mild steel, aluminum and brass. From the graph, it is observed that mild steel has greater tensile strength compared to brass and aluminum. Aluminum has the least tensile strength. Also, it is observed that mild has shown maximum ductility property compared to brass and aluminum. Mild steel and brass have marginal difference in ductility property. Fig. 5 shows the typical tangent modulus curve for mild steel, brass and aluminum. The tangent modulus is very helpful in elucidating the behavior of materials that have been stressed beyond the elastic region. When a material is plastically deformed there is no longer a linear relationship between stress and strain. The tangent modulus quantifies the "softening" or "hardening" of material that generally occurs when it begins to yield.

Table 2. Specimen- Mild Steel

δ(m)	P(N)	e	ε	ε_p	H/E	slope	σ(MPa)	A(mm^2)	L(m)	T/E
0	0	0	0	0	0	0	0	31.35	0.0481	1
0.00025	13.33221	0.005198	0.00518	0	1	1.53	0.42748	31.1879007	0.04835	1
0.001	59.58562	0.02079	0.020488	0	1	1.53	1.950051	30.5559271	0.04935	1
0.00175	98.21457	0.036383	0.03565	0	1	1.53	3.328236	29.5094912	0.0511	1
0.0025	129.9113	0.051975	0.050664	0	0.452274	0.691979	4.617737	28.1331157	0.0536	0.47648
0.0035	142.7845	0.072765	0.07023	0.019566	0.187315	0.286592	5.406728	26.408669	0.0571	0.241378
0.00475	136.0438	0.098753	0.094173	0.043509	0.150815	0.230747	5.58002	24.3805174	0.06185	0.200507
0.006	130.0396	0.12474	0.11755	0.066886	0	0	5.851172	22.2245394	0.06785	0
0.00725	117.363	0.150728	0.14037	0.089706	-0.0582	-0.08905	5.845056	20.079028	0.0751	-0.09455
0.0085	102.6538	0.176715	0.16272	0.112056	-0.18844	-0.28832	5.691131	18.0375	0.0836	-0.35526
0.01	83.04829	0.2079	0.18888	0.138216	-0.33414	-0.51123	5.154944	16.1104167	0.0936	-0.76777

Table 3. Specimen- Brass

δ(m)	load(N)	e	ε	T/E	ε_p	H/E	slope	σ(MPa)	A(mm^2)	L(m)
0	0	0	0	1	0	0	0	0	32.86	0.05116
0.000636	44.59735	0.012432	0.012355	1	0	1	1.729929	1.374086	32.456	0.051796
0.001273	75.17839	0.024883	0.024578	0.585073	0.012223	0.511045	0.884071	2.373246	31.6774572	0.053069
0.002122	93.01733	0.041478	0.040641	0.380292	0.028286	0.281773	0.487448	3.053802	30.4595129	0.055191
0.003183	99.38838	0.062217	0.060358	0.307299	0.048003	0.216008	0.373678	3.45115	28.7986257	0.058374
0.004033	105.7594	0.078831	0.075878	0.347318	0.063523	0.251204	0.434565	3.926098	26.9375387	0.062407
0.005306	110.8563	0.103714	0.098681	0.406519	0.086326	0.307175	0.531392	4.465202	24.8267094	0.067713
0.005943	114.6789	0.116165	0.109899	0.380292	0.097544	0.281773	0.487448	5.024588	22.8235443	0.073656
0.007641	117.2273	0.149355	0.139201	0.340687	0.126846	0.245232	0.424235	5.669074	20.6783888	0.081297
0.00849	115.9531	0.16595	0.153536	0.347318	0.141181	0.251204	0.434565	6.193051	18.7231	0.089787
0.009764	114.6789	0.190852	0.174669	0.353935	0.162314	0.257221	0.444974	6.791066	16.8867312	0.099551

Table 4. Specimen- Aluminum

δ(m)	P(N)	e	ε	T/E	ε_p	H/E	slope	σ(MPa)	A(mm^2)	L(m)
0	0	0	0	1	0	0	0	0	33.99	0.05197
0.000312	20.45362	0.006003	0.005986	1	0	1	3.478816	0.605367	33.78716	0.052282
0.000546	33.22936	0.010506	0.010451	1	0	1	3.478816	0.993762	33.4379553	0.052828
0.001092	59.88787	0.021012	0.020794	1.095246	0.010343	0.459498	1.598509	1.828037	32.7607622	0.05392
0.001638	61.79918	0.031518	0.031032	0.61904	0.020581	0.216465	0.753041	1.943683	31.7948864	0.055558
0.002262	63.7105	0.043525	0.042605	0.494911	0.032154	0.16586	0.576996	2.08538	30.5510256	0.05782
0.0028	64.98471	0.053877	0.052476	0.378123	0.042025	0.121948	0.424235	2.230094	29.1398928	0.06062
0.00351	62.43629	0.067539	0.065356	0	0.054905	0	0	2.266702	27.5449914	0.06413
0.004212	56.06524	0.081047	0.07793	-0.4856	0.067479	-0.12249	-0.42612	2.16909	25.8473603	0.068342
0.00499	45.87156	0.096017	0.091683	-1.1095	0.081232	-0.24181	-0.84121	1.90429	24.088533	0.073332
0.005772	33.12946	0.111064	0.105318	-1.92144	0.094867	-0.35581	-1.23778	1.483573	22.3308594	0.079104

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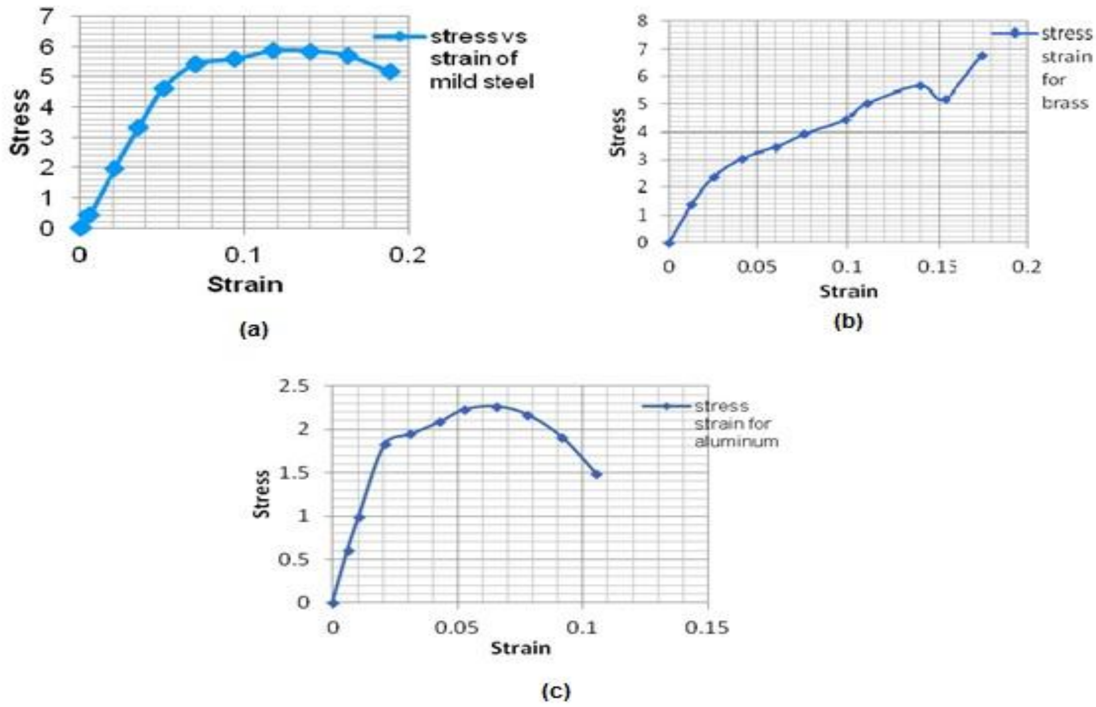

Figure 4. Typical Stress Strain Curve for (a) mild steel, (b) aluminum and (c) brass

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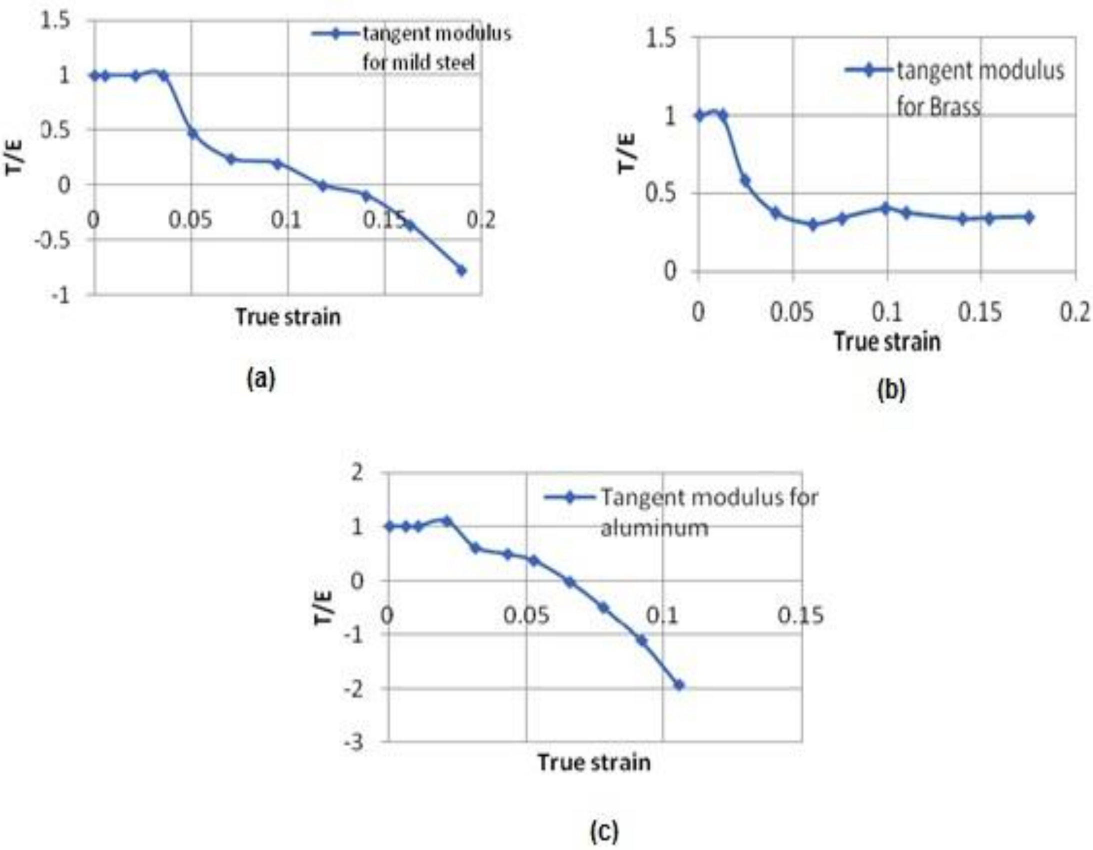

Figure 5. Typical Tangent Modulus Curve for (a) mild steel, (b) aluminum and (c) brass

4. Conclusion

The tensile tests are the methods of investigation of the mechanical properties of the specimens. They are particularly interesting and allow a predictive approach of the behavior of the alloy in fraction. This test is the best known for material testing. It makes it possible to determine the tensile strength, one of the essential characteristic values of a material. The fracture point also makes it possible to measure the tenacity of the material. This work has allowed us to better know the tensile test for the various materials and the deformation operation, the elongation, the stresses, and we need to know them also of all the mechanical characteristics. It is also concluded that the mild steel is stronger than the materials tested by the tensile test, which indicates the fragility of the material and the Young's modulus on the strength of the materials. According to the results obtained it can be said that the higher the modulus of elasticity and the higher the tensile strength.

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