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Effect of Quenching On the Mechanical Properties of Metals (Mild Steel, Copper & Stainless-Steel)

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ABSTRACT

Metals react differently to heat treatment under different temperature and mode of quench. Most engineering equipment and material undergo heat treatment in various form from current conduction to common mechanical stresses. The effect of this indirect minute heat treatment is yet to be fully ascertain. This research work aims at investigating the effect of quenching on the mechanical properties of some metals. Mild-steel, Copper and Stainless materials were cut into different sizes and were subjected to 850 ºC temperature and then quenched in different media. The mechanical properties like tensile strength, hardness and impact were taken before and after heat treatment and quenching. The result was the analysed and compared. The tensile test was carried out to determine modulus of elasticity for metal wire with Searle's apparatus. The ultimate tensile strength for treated and untreated mild steel are 0.637 to 0.441 KN/mm2 and the hardness value was 72.99 to 69.57 Kg respectively. Also the ultimate tensile strength for treated and untreated copper are 0.380 to 0.277 KN/mm2 and hardness value was 41.33 Kg and 38.33 Kg respectively. The ultimate tensile strength for treated and untreated stainless steel are 0.389 to 0.224 KN/mm2 and their hardness value was 51.57 to 48.57 Kg respectively. The experiment revealed that heat treatment will cause an increase in hardness value and the ultimate stress of the three specimen of metal, while the breaking load, yield stress and percentage elongation decreased. as they are heat treated.

Keywords: Quenching, Mechanical Properties, Metals, Mild Steel, Copper & Stainless-Steel

1. INTRODUCTION

Heat treatment is an operation or combination of operations involving heating at a specific rate, soaking at a temperature for a period of time and cooling at some specific rate, with the aim of obtaining a desired microstructure to achieve certain predetermined properties such as physical, mechanical, magnetic or electrical (Manna, 2015) Heat treatment is a combination of time heating and cooling applied to a particular metal or alloy in the solid state in such way as to produce certain microstructure and desired mechanical properties (hardness, toughness, yield strength, ultimate tensile strength, young modulus, percentage elongation and percentage reduction).

Annealing, normalizing, hardening and tempering are the most important heat treatments often used to modify the microstructure and mechanical and electrical properties of engineering materials particularly steels. Annealing is the type of heat treatment most frequently applied in order to soften iron or steel material and refines its grains due to fermite-pearlite microstructure. It is used when elongations and appreciable level of tensile strength are required in engineering materials. In Normalizing, the material is heated to the austenitic temperature range and this is followed by air cooling. This treatment is usually carried out to obtain a mainly pearlite matrix, which result into strength and hardness higher than in as received condition. It is also used to remove undesirable free carbide present in the as-received sample. Mild steel is normally hardened and tempered to improve their mechanical properties, particularly their strength and wear resistance. In hardening, the steel or its alloy is heated to a temperature high enough to promote the formation of austenite, held at that temperature until the desired amount of carbon has been dissolved and then quench in oil or water at a suitable rate.

Also in harden condition, the steel should have 100% martensite to attain maximum yield strength, but it is very but it is very brittle and thus, as quenched steels are used for very few engineering applications. By tempering, the properties of quenched steel could be modified to decrease hardness and increases ductility and impact strength gradually. Mechanical tests (as opposed to physical, electrical, or other types of tests) often involves the deformation or breakage of samples of material (called test specimens or test pieces).

2. MATERIALS AND METHODOLOGY

In considering the effect of temperature and quenching on the mechanical properties of metals. Three different metals were investigated, these metals are copper, mild steel and stainless steel. The following test stated below were carried out on the materials before and after heat treatment:

1. Hardness test
2. Tensile test and
3. Impact test

2.1 Hardness test

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration (Gordon, 2013). It is referred to as the resistance to bending, abrasion or cutting. The hardness of the materials was tested after heating and the readings were tabulated for comparison.

2.2 Tensile test

The tension test is the commonly used test for determining "static" (actually quasistatic) properties of materials. The tensile test is carried out to determine modulus of elasticity for metal wire with Searle's apparatus.

Digital Innovations
& Contemporary Research in
SCIENCE & ENGINEERING
Vol. 4 No. 4, Dec. 2016

2.3 Impact test

An impact test signifies toughness of material, that is, ability of material, to absorb energy during plastic deformation. Static tension test of unmatched specimens do not always reveal the susceptibility for a metal to brittle fracture. This important factor is determined by impact test. Toughness take into account both the strength and ductility of the materials. Several engineering materials have to withstand impact or suddenly applied loads while in service. Impact strengths are generally lower as compared to strength achieved under slowly applied loads.

2.4 Calculation for tensile test

i. Ultimate Tensile Stress

$$UTS = \frac{load}{cross\ sectional\ area} x\ 100$$

2.5 Percentage elongation for 10mm mild steel rod quenched in water

i. $$\%\ e = \frac{final\ guage\ lenght - origin\quad guage\ lenght}{original\ guage\ lenght} x\ 100$$

3. RESULTS AND DISCUSSIONS

3.1 Mild steel specimen

Table 3.1: Tensile test on mild steel heated to 850 °C and quenched in water

S/N	Type of Specimen	(mm) Original diameter	(mm) Original gauge length	(mm) Final diameter	(mm) Extension	(KN) Max.load	(KN) Breaking load	(KN/mm²) Yield stress	(%) Elongated	(KN/mm²) UTS
1	Mild steel	10	50	8	13	49	36	0.416	26.00	0.624
2	Mild steel	10	50	7.9	13.2	50	36.6	0.425	26.40	0.637
3	Mild steel	10	50	8	12.9	48	35.3	0.407	25.80	0.611

Table 3.1 shows that when mild steel is quenched in water, the final in diameter during tensile test is 8mm and an extension of 13.2mm. The maximum load is 50KN and with breaking load of 36 KN. The yield stress is 0.416 KN/ mm^2, the elongated percentage is 26.40% and the ultimate tensile strength is 0.637 KN/mm^2. The hardness value was 72.99 Kg.

Tensile test on 10mm mild steel rod without undergo heat treatment

S/N	Type of Specimen	(mm) Original diameter	(mm) Original gauge length	(mm) Final diameter	(mm) Extension	(KN) Max. load	(KN) Breaking load	(KN/mm²) Yield stress	(%) Elongated	(KN/mm²) UTS
1	Mild steel	10	50	7.5	13.5	52	38	0.662	27.00	0.441
2	Mild steel	10	50	7.5	13.5	52.3	38	0.666	27.00	0.441

The result of 10mm mild steel that was not heat treated shows a final diameter of 7.5mm, an extension of 13.5mm and a maximum load of 52 KN. The breaking load is 38 KN, yield strength of 0.666 KN/mm^2, ultimate strength of 0.441 KN/mm^2 and 27 % elongation. The hardness value was 69.57 Kg Comparing the mild steel of 10mm diameter, treated and quenched in water to the untreated, their final diameters under tensile test are 13.2mm and 7.5 mm respectively. The extension was 13mm to 13.5mm. A maximum load of 50 KN to 52 KN, breaking load of 36 KN to 38 KN, yielding strength of 0.416 to 0.666 KN/ mm^2, an elongated percentage of is 26.40 to 27 %, the ultimate tensile strength of 0.637 to 0.441 KN/mm^2 and hardness value was 72.99 to 69.57 Kg. Quenching of mild in water at 850 ^{0}C increases the hardness value and ultimate stress, but decreases the maximum load, breaking load, elongation percentage and yield stress

3.2 Copper

Table 3.3: Tensile test on copper quenched by water

S/N	Type of Specimen	(mm) Original diameter	(mm) Original gauge length	(mm) Final diameter	(mm) Extension	(KN) Max. load	(KN) Breaking load	(KN/mm^2) Yield stress	(%) Elongated	(KN/mm^2) UTS
1	Copper	12	60	12	11.0	41	29	0.241	18.333	0.362
2	Copper	12	60	11.5	11.5	43	31	0.253	19.167	0.380
3	Copper	12	60	12	11.0	42.6	32	0.251	18.333	0.377

Copper quenched in water has a final diameter under tensile load of 11.5mm, an extension of 11.5mm and a maximum load of 43 KN. The breaking load was 32 KN, yield stress of 0.253 KN/mm^2, ultimate tensile stress of 0.380 KN/ mm^2, yield stress of 0.253 KN/mm^2 and 19.17 % elongation. The hardness value was 41.33 Kg

Table 3.4: Tensile test on copper quenched by oil

S/N	Type of Specimen	(mm) Original diameter	(mm) Original gauge length	(mm) Final diameter	(mm) Extension	(KN) Max. load	(KN) Breaking load	(KN/mm^2) Yield stress	(%) Elongated	(KN/mm^2) UTS
1	Copper	12	60	11.50	11.50	42	30	0.248	19.167	0.3713
2	Copper	12	60	11	12.0	31	31	0.183	20.0	0.274
3	Copper	12	60	11.50	11.50	40	28	0.236	19.167	0.354

When copper was quenched in oil the final diameter under tensile was 11.50mm, with an extension of 11.50 mm and a maximum load of 42 KN. Breaking load was 31 KN, yield stress of 0.248 KN/mm^2, ultimate stress of 0.371 KN/mm^2 and 20% elongation.

Table 3.8: Tensile Test on 12 mm Copper Rod without undergoing Heat Treatment

S/N	Type of Specimen	(mm) Original diameter	(mm) Original gauge length	(mm) Final diameter	(mm) Extension	(KN) Max. load	(KN) Breaking load	(KN/mm²) Yield stress	(%) Elongated	(KN/mm²) UTS
1	Copper	12	60	7.3	12	46.6	34	0.412	20.00	0.275
2	Copper	12	60	7.5	12	47	34	0.416	20.00	0.277

The copper that was not heat treated has a final diameter of 7.5mm under tensile load, with an extension of 12mm and a maximum load of 47 KN. The breaking load was 34 KN, yield stress of 0.416 KN/mm², ultimate tensile stress of 0.277 KN/mm² and 20% elongation. The hardness value was 38.33 Kg. The comparison of 12mm diameter treated copper to the untreated under tensile load was a final diameter of 11.50mm to 7.30 mm. The extension was 11.5mm to 12mm. A maximum load of 43 KN to 47 KN, breaking load of 32 KN to 34 KN, yielding strength of 0.253 to 0.416 KN/ mm², an elongated percentage of is 19.79 to 20 % and the ultimate tensile strength of 0.380 to 0.277 KN/mm². The hardness value for quench is 41.33 Kg and that of unquenched is 38.33 Kg.
Quenching of copper in water at 850 ºC increases the hardness value and the ultimate stress, but decreases the elongation percentage, yield stress, breaking load and maximum load.

3.3 Stainless steel

Table 4.5: Tensile test on stainless steel quenched by water

S/N	Type of Specimen	(mm) Original diameter	(mm) Original gauge length	(mm) Final diameter	(mm) Extension	(KN) Max. load	(KN) Breaking load	(KN/mm²) Yield stress	(%) Elongated	(KN/mm²) UTS
1	Stainless steel	12	60	12	8	44	26	0.259	13.333	0.389
2	Stainless steel	12	60	12	8.5	43	26	0.253	14.167	0.380
3	Stainless steel	12	60	12	8	44	26	0.259	13.333	0.389

The stainless steel quenched in water has a final diameter of 12mm under tensile load, an extension of 8mm and maximum load of 44 KN. The breaking load was 26 KN, yield stress of 0.259 KN/mm2, ultimate tensile stress of 0.389 KN/mms and 14.167 % elongation. The hardness value was 51.57 Kg.

Table 3.8: Tensile Test on 12 mm stainless steel without undergoing Heat Treatment

S/N	Type of Specimen	(mm) Original diameter	(mm) Original gauge length	(mm) Final diameter	(mm) Extension	(KN) Max.load	(KN) Breaking load	(KN/mm²) Yield stress	(%) Elongated	(KN/mm²) UTS
1	Stainless steel	12	60	11.9	9	38	30	0.336	15.00	0.224
2	Stainless steel	12	60	11.9	9.5	38	30	0.336	15.83	0.224

The unquenched stainless steel under tensile load has a final diameter of 11.9mm, an extension of 9.5mm and a maximum load of 38 KN. The breaking load was 30 KN, a yielding stress of 0.336 KN/mm^2, ultimate tensile stress of 0.224 KN/mm^2 and 15.83 % elongation. The hardness value was 48.57 Kg.

Comparing the quenched stainless steel of 12mm diameter in water to unquenched, the final diameter under tensile load was 12 mm to 11.9 mm. An extension of 8.5mm to 9.5mm. A maximum load of 44 KN to 38 KN, breaking load of 26 KN to 30 KN, yielding strength of 0.259 to 0.336 KN/ mm^2, an elongated percentage of is 14.16 to 15.83 % and the ultimate tensile strength of 0.389 to 0.224 KN/mm^2. The hardness value was 51.57 to 48.57 Kg.
Quenching of stainless steel in water at 850 ⁰C increases the hardness value and ultimate stress but decreases the breaking load, yield stress and the elongation percentage

5. CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

The experiment revealed that heat treatment will cause an increase in hardness value and the ultimate stress of the three specimen of metal, while the breaking load, yield stress and percentage elongation decreased. as they are heat treated.

5.2 Recommendation

Further work can be carried out by varying the temperature and the diameter of the specimen. Also more media can be used to quenched. Also wilder test should include their heat and electrical conductivity and rate of corrosion.

REFERENCES

1. Lawrence H.Van Vlank (1985). 'Element of Materials Science and Engineering, Addison Publishing Company, US 1985
2. Agrava,B.B "Introduction to Engineering Materials First Edition
3. Tata Mc Graw (1989) Material Engineering. Hill Publishing Company ,Limited., New Delli:1989
4. Adegbola A.A.(2005) "Basic of Materials & Properties. Debo Publication and Printing House, Ibadan, Premier Education, pp58-88
5. Er.R.k. Rajput (2008) "Strength Of Materials (Mechanics of Solids) S Chand and Company Limited, New Delhi 2008)
6. R.K. Rajput (2008) "Engineering Materials (Including Construction Materials) S.Chand and Company Limited,,Ramnagar, New Delhi 2008
7. Krauss G. (1980) Principles of Heat treatment of steel, Journal of American Society for Metals (1980) PP. 209-219
8. Higgins R.A (2004) "Engineering Metallurgy", Published by Vinva Books Private limited, Sixth Edition.
9. Washington(2018) "Mechanical properties and performance of materials". http://courses.washington.edu/me354a/chap5.pdf.