SPASCIT 63 The Effect of Heat Treatment on the Torsional Properties of TR1021 Carbon

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The Effect of Heat Treatment on the Torsional Properties of TR1021 Carbon Steel.

Abstracts

Controlled heating and cooling of steels have significant effect on the mechanical properties which is as a result of change in the microstructure. The change in microstructure largely depends on the composition of carbon present and temperature change. This experiment investigates the change in mechanical properties of plain carbon steel with 0.4% carbon content when subjected to heating process and a subsequent rapid cooling in ice cooled water. After the heat treatment procedure, the material is then subjected to a destructive test (Torsion Testing) to check the behaviour of the material before failure. The material failed on getting to a Torque of about 9.8 N-m. The result was compared with another material of same composition without the heat treatment process, a Torque of 25N-m reached and an appreciable plastic region was observed before failure. The non-heat treated material is said to have a considerable level of ductility when compared with the heat treated material which is very hard and brittle hence a martensitic structures.

Keywords: Heat treatment, torsional properties, composition and carbon steel.

1.0 INTRODUCTION

Micro-structural analysis of materials are very important but not enough to ascertain the sustainability of materials when used for engineering purposes therefore, it is necessary to check for mechanical properties after they have been subjected to changes such as heat treatment. According to an investigation by Rajkumar and Gore (2013) on a 1020 Carbon steel and Aluminium, plotting the stress-strain curve and a torque- twist curve reveals that shear modulus depends on specimen dimensions. Previous knowledge in regards to stress-strain curve and torque-twist angle for a normalized 1020 carbon steel specimen is likely to lead us to a remarkable result when the specimen is subjected to a controlled heating and cooling. A non-equilibrium approach can be used to obtain a desired martensitic structure (Bolton, 1989). A martensitic structure presents us with a rearrangement of the lattice orientation, and atoms in a lattice are distorted and the resultant is a very hard and brittle material. There is therefore a change in the micro-structure and mechanical properties of the material when under controlled heating and cooling.

The hardness of steel with medium carbon content is higher when the quenching medium is water compared to a lower hardness value for oil as a medium of quenching. This is simply because water has a faster quenching rate however, this might result into distortion in grain arrangement and cracking (Ismail, Khatif and kecih, 2016).

Jaypuria (2008) investigated the effects of heat on low carbon steel and made conclusions that when ductility is the only criteria of choice, then tempering at high temperature for 2 hours achieves the best results when compared to other tempering experiments.

Joshi, Singh, Ali and Bohra (2014) also studied the effect of heat treatment on steel particularly micro grain structure and made an observations that copper has a significant impact on carbon steel. Further observations were made on the ductile-brittle transition temperature in a standard specimen to be 83°C which was lower than 95°C of the tested specimen implying a rapid temperature activity.

Mechanical analysis can be done to test for tensile, compression, bending and torsion which are vital to ascertain the integrity of engineering materials in general, giving an explicit insight to failure of materials and their suitability for engineering applications.

In torsion, the maximum shear stress is an important factor that needs to be known. This will enable a proper design of rigid shafts that are less prone to failure. The micro-structural analysis of the heated and cooled carbon steel is possible with a scanning electron microscopy.

In this study, an investigation of carbon steel with 0.4 wt % of carbon content were subjected to torsion to ascertain the effect of the temperature on its resistance.

2.0 MATERIALS AND METHODS

This research seeks to compare TR1021 carbon steel specimen used for torsion testing, with a heat treated specimen of TR1021. The heat treatment is to obtain an entirely austenitic structure of the specimen and hence suitable for rapid quenching in a medium. In other to obtain a martensitic structure, a minimum of 0.3% carbon composition in carbon steel is required. TR1021 Specimen used contains 0.4% carbon and therefore suitable for a hardening process.

The hardening process requires heating of TR1021 carbon steel to produce a fully austenitic structure followed by rapid quenching in cold water to obtain a structure that is completely martensitic. The heat treated specimen is then subjected to a torsion test to check for significant changes in the stiffness of the specimen and its resistance to torsion A destructive test is performed on the heat treated specimen, using the SM1001 Torsion testing machine (30NM). Values of shear stress and corresponding shear strain, torque and the corresponding angle of twist are obtained from a synchronized Bench-mounted version of a Versatile Data Acquisition System (VDAS).

Table 2.0: Experimental condition of heat treated sample.

Specimen	Retention Time	Retention Time	Cooling Medium
TR1021	5 Minutes	5 Minutes	Ice Cold Water

Table 2.1 Carbon steel parameters under investigation.

Material Test Specimen	Gauge test section	% of composition in Specimen
TR1021	6mm	0.4

3.0 RESULTS

Table 3.0: Angle of Twist against Torque. (Heat Treated Material)

Angle of twist $\varphi(^\circ)$	**Torque** (N/m)	**Material Description**	**Specimen gauge Length (mm)**	**Initial specimen Diameter (mm)**
1.00	0.10	TR1021/MT	50	6
16.47	9.65	TR1021/MT	50	6
27.63	3.93	TR1021/MT	50	6
27.87	0.10	TR1021/MT	50	6
28.77	0.10	TR1021/MT	50	6
30.09	0.10	TR1021/MT	50	6
30.09	0.10	TR1021/MT	50	6
30.09	0.10	TR1021/MT	50	6
30.09	0.10	TR1021/MT	50	6
30.09	0.10	TR1021/MT	50	6

Figure 3.1: Graph of Torque against Angle of Twist (non-heat Treated Material)

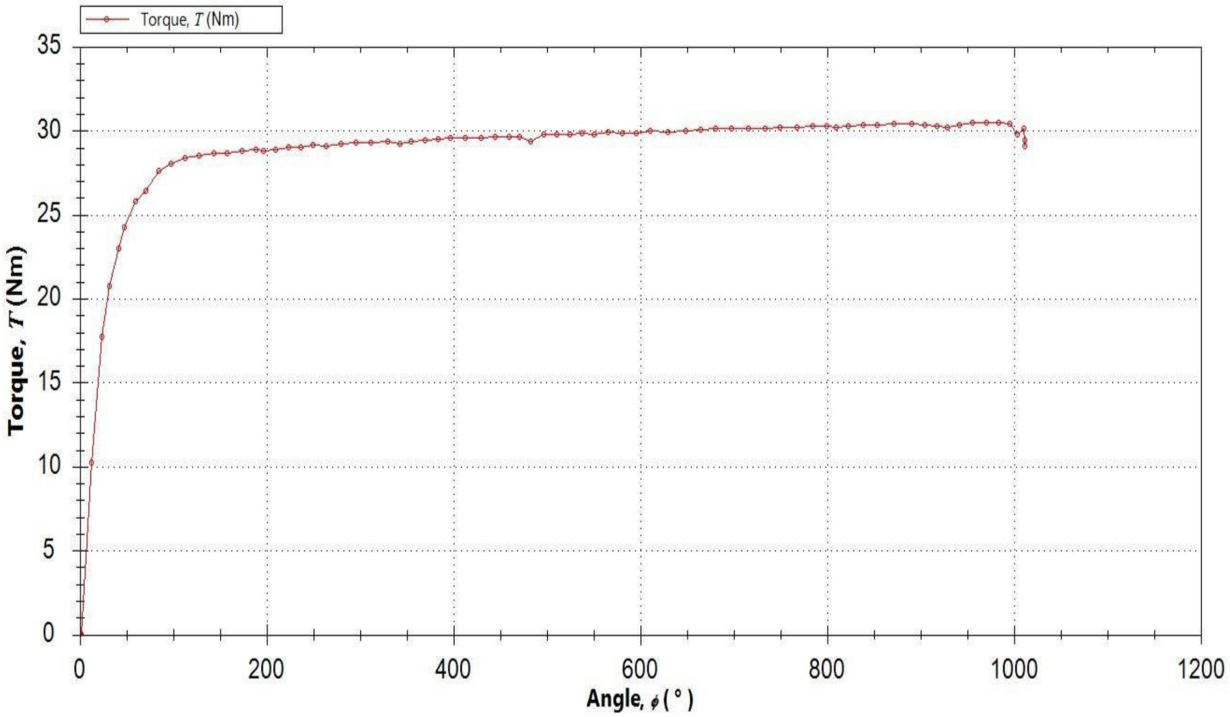
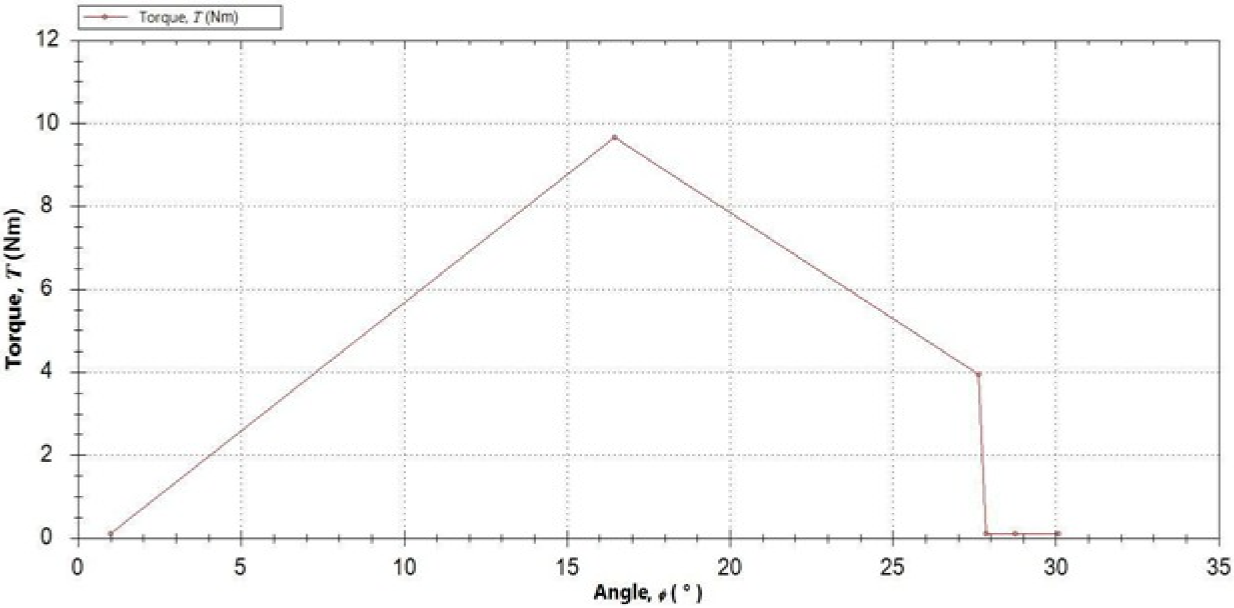


Figure 3.2: Graph of Torque against Angle of Twist (Heat treated specimen TR1021)



4.0 DISCUSSION

The graphical illustration in figure 3.0 shows the result of Torque against displacement. For the first test sample that was not heat treated, a considerable plastic region of the material was observed as seen on the graph. The peak torque reached was 30.09Nm with a significant high value of twist angle of 1000 $\phi(^\circ)$. This is an indication that the material is ductile and possesses fine grain. This could be adduced to carbon content present in the test sample which could be ferrite in nature. To verify this, a microstructure study can be done which is beyond the scope of our present study. Also, from literature, ductile or plastic deformation is said to be dependent on stress, temperature, and the rate of straining the material. Since no heat treatment (work hardening/hardening) was performed on the first test sample, at temperature below re-crystallization, then there is no distortion in the grain arrangement which in turn confirm the ductile character of the sample under investigation.

Similarly, from the graphical illustration in figure 4.0 above shows the result of torque against displacement. For the second test sample that was heat treated, when subjected to torsion, the test sample snapped off without appreciable plastic deformation. It was noted that the rapidly quenched or hardened test sample after heat treatment was done is hard and brittle. The peak torque of 9.8Nm was reached at a corresponding value of twist angle of 16.5 $\phi(^\circ)$ as the test sample could not resist twist beyond this limit. The hypothesis of rapid cooling of steel having a composition greater than 0.3 % carbon forming a martensitic structure is however verified from this study.

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5.0 CONCLUSION

In view of the above, it can be concluded that the first specimen TR 1021 with 0.4 wt % carbon (non-heat treated) showed substantial plastic deformation hence it is a ductile material. While the second specimen (heat treated) TR 1021 with 0.4 wt % of carbon shows it is hard and brittle due to the rapid cooling of the test sample in chilled water which led to quick transformation from austenitic structure to martensitic structure. Therefore heat treatment can be used to change or alter the mechanical behaviour of materials to suit a particular use.

REFERENCE

Rajkumar, D.P and Gore, P.N. (2013). Review the effect of specimen Geometry on Torsion Test Results. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(12). ISSN: 23198753.

Bolton, W. (1989). Engineering Materials Technology. Butterworth-Heinemann Newnes: Lineacre House, Jordan Hill, Oxford. ISBN: 0750605189.

Ismail, N.M., Khatif, N.A and Kecih, M.A. (2016). The Effect of Heat Treatment on the hardness and impact properties of Medium carbon steel. *IOP Conference*. DOI: 10.1088/1757-899X/114/1/012108.

Jaypuria, S.K. (2008) Heat Treatment of Low Carbon Steel. Department of Engineering National Institute of Technology.

Joshi, V., Singh, S., Ali, S., Bohra, S. and Kumar, S. (2104). A Review on the Effect of Heat Treatment process on Microgram structure of steel. *International Journal of Engineering Science Invention*. 3(5). PP. 46-52.