Investigating the Effect of Heat Treatment on the Mechanical Properties of Hot Rolled Low Carbon Steel Rod

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***Abstract* - A study has been carried out to investigate the effect of heat treatment on the some mechanical properties of hot rolled low carbon steel rod. The main aim of this research is to discover the heat treatment process that hot rolled low carbon steel of various dimension could be subjected to that will make it more beneficial to structural work in the construction industries. The heat treatment processes used were annealing and normalizing, it was later subjected to Rockwell hardness test as well as tensile test. The results showed that 8mm rod will require annealing after production for work where ductility and hardness is required while that of 12mm and 16mm will required normalizing but that of 10mm may not need heat treatment. Also, for work involving tensile loading, 8mm, 12mm and 16mm may not require heat treatment after production. Therefore, depending on the type of structural work and dimension of rod to be used in such work, then heat treatment may be recommended.**

Keywords: Heat treatment, annealing, Normalizing, Low carbon steel and specimens.

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INTRODUCTION

Steel is undisputedly the most widely used metallic materials for a wide range of applications. This is because it possesses good mechanical properties such as ductility, tensile strength, hardness and toughness and can be processed relatively cheap in large quantities (Adelegan *et. al.*, 2010). Low carbon steel is a type of steel with increasing structural application for the construction of welded structures such as oil rigs, platforms and pipelines in the oil and gas industries.(Kutelu *et. al.*, 2008). It is also one of the most common types of general purpose steel because it is cheaper than other types of steel (Sanjib, 2009). The processes of heat treatment and alloying have over the years been used by metallurgical engineers to obtain desired mechanical properties in steel. In Nigeria today, process technology and high cost of alloying elements have led to a shift from alloying elements to heat treatment as a means of improving its quality of metals. (Adelegan *et. al.*, 2010). Wolariska *et. al.*, 2007, in their work on the microstructural investigation of low carbon steel after hot deformation discovered that there is non metallic inclusion which influence the microstructure and the types of crack mechanism. The hot ductility investigations were carried out on the low carbon-manganese steel with the addition of boron. Bertinelli *et. al.*, 2006, researched on the production of low – carbon Magnetic steel for the LHC Superconducting Dipole and Quadrupole Magnets. Schindler *et. al.*, 2007, also worked on how the deformation behavior of low carbon deep-drawn steels can be influenced by phase transformation. This was accomplished by determining the phase transformations temperature of a specific Interstitial-free (IF) grade steel micro alloyed by titanium, and quantify the influence of phase composition on its deformation resistance in comparison with a common low carbon deep-drawn steel grade. Also, Visser *et. al.*, 2010, researched on the deformation criterion of low carbon steel subjected to high speed impacts. Campbell (1999), worked on low carbon steel as a special anti-coil break technology that can be smoothen. Also, Omojogberun and Aluko, 2012 investigated the effect of heat treatment on the microstructure of hot rolled low carbon steel during production and operation. This work however researched into the mechanical properties of heat treated hot rolled low carbon steel during production and operations.

2.0 MATERIALS AND METHOD

Hot rolled low carbon steel (mild steel) specimen of dimensions 8mm, 10mm, 12mm and 16mm diameters were used for this researched work. These were collected from the industry and machined to a standard shape of tensile strength specimen. Annealing and normalizing were carried out on these specimens. For each of the dimensions mentioned above there is also the controlled specimen that was not charged into the furnace for heat treatment. The purpose of this was for comparison

2.1 ANNEALING AND NORMALIZING

The specimens mentioned above (8mm, 10mm, 12mm and 16mm) were charged into the furnace, and then heated to a temperature of 800^{o}C. They were soaked for 30 minutes in the furnace since their thickness were below 25mm.The furnace was switch on and the temperature regulated to 800^{o}C. The heating was allowed to reach the maximum temperature, after which the furnace was switched off having attained full homogenization. The specimens were then allowed to slow cool in the furnace. The same process was repeated for normalizing and the cooling was done in the still air instead of cooling in the furnace.

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2.2 HARDNESS AND TENSILE TEST

After the heat treatment, the hardness of the treated specimens were measured by means of a micro-hardness tester and tensile test of the specimens were carried out for both the test piece and the control piece using universal tensile testing machine and the results are as plotted on graphs of tensile stress against tensile stain.

3.0 RESULT AND DISCUSSION

From table 1, it was observed that the hardness of 8mm annealed specimen increased while that of normalized specimen decreased compared to the hardness of the controlled specimen while the reversed was the case for that of 12mm and 16mm specimen but for the 10mm specimens, the hardness reduced for both the annealed and normalized specimen.

Figure 1, 2 and 3 represents the graph of tensile stress against tensile stain for 8mm annealed normalized and controlled specimen respectively. Point A in each of the graph represents the lower yield point, B, the ultimate tensile strength and C the rupture point respectively for all graphs. The tensile stress at point A is 620MPa for both the annealed and normalized specimen with a corresponding tensile strain value of 0.76 and 0.8 while the control specimen has a value of 650MPa and a strain of 0.85. At point B, the tensile stress is 470MPa and 480MPa for annealed and controlled specimen with a corresponding strain value of 1.03 and 1.07 respectively but for the controlled specimen the tensile stress is 570MPa and a strain of 1.09. At point C, which is the rupture point the tensile stress is 250MPa for both annealed and normalized specimen with a corresponding strain value of 1.03 and 1.07 while the control specimen has a value of 300MPa and 1.09.

Figure 4, 5 and 6 are the graphs of tensile stress against tensile strain for 10mm annealed, normalized and controlled specimens. The values of their tensile stresses and strains are 620MPa, 680MPa, 590MPa and 0.59, 0.65, 0.65 respectively for the lower yield point. The tensile stress is 500MPa (for annealed and normalized specimen) and the corresponding strain 0.88, 0.92 for both the ultimate tensile strength and rupture point. The controlled specimen has 590MPa and 0.86 at point B and 310MPa and 0.86 at point C respectively.

Figure 7, 8 and 9 are the graphs of tensile stress against tensile strain for 12mm annealed, normalized and controlled specimen, the values of the tensile stress and their corresponding strain at the lower yield point are 610MPa, 690MPa, 720MPa and 0.65, 0.59, 0.65 respectively while the values at ultimate tensile strength are 490MPa, 580MPa 720MPa and 0.98, 0.82,0.85 respectively. At their rupture point, the results are 280MPa, 310MPa, 350MPa and strain values are not different from those of their ultimate tensile strength.

Figure 10, 11 and 12 are the graphs of tensile stress against tensile strain for 16mm annealed, normalized and controlled specimen, the value of the tensile stress and their corresponding strain at the lower yield point are 480MPa, 450MPa, 510MPa and 0.57, 0.65 0.65. Also, the value of their tensile stress and the corresponding strain at the ultimate tensile strength are 350MPa, 330MPa, 400MPa and 0.84, 0.94, 0.95 respectively, while those at the point of rupture are 200MPa, 180MPa, 200MPa with the strain remaining unchanged compared to that at the ultimate tensile strength.

CONCLUSION AND RECOMMENDATION

From the discussion of results, the hardness of 8mm annealed specimen increased while that of normalized specimen decreased but the reversed was the case for 12mm and 16mm specimen although the hardness of 10mm normalized and annealed specimen decreased indicating that annealing the 8mm specimen will be required where the material is needed for work in which both ductility and hardness is required while that of 12mm, 16mm and above as the case may be will required normalizing after production however, the case of 10mm specimen, heat treatment may not be necessary but where hardness and toughness is required then, quenching of the specimen can be carried out after production.

Also, from the graph of tensile stress against tensile strain the 8mm, 12mm and 16mm heat treated specimen yielded earlier compare to their controlled specimen indicating that where the material will be used for tensile loading then only the 10mm rod is essentially necessary to be heat treated while the 8mm, 12mm and 16mm may not be heat treated after production. Therefore, depending on the type of structural work and the dimensions to be used in such work heat treatment may be recommended.

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TABLE 1: HARDNESS TEST CONDUCTED ON THE SPECIMENS (ROCKWELL HARDNESS)

S/N	SPECIMENS	READING I	READING II	READING III	READING IV	AVERAGE
1.	Annealing (8mm)	261.8000	273.7000	264.7000	269.9000	267.7000
	Normalizing (8mm)	243.6000	218.3000	208.9000	201.1000	217.9800
	Control (8mm)	217.5000	217.6000	225.4000	236.7000	224.3000
2.	Annealing (10mm)	277.9000	214.1000	215.3000	227.9000	233.8000
	Normalizing (10mm)	262.9000	248.1000	288.6000	258.3000	264.4800
	Control (10mm)	330.9000	302.1000	280.70000	258.6000	293.0800
3.	Annealing (12mm)	170.6000	168.8000	173.7000	167.8000	170.2300
	Normalizing (12mm)	190.2000	153.8000	197.5000	186.8000	182.0800
	Control (12mm)	176.4000	168.5000	189.6000	170.5000	176.2500
4.	Annealing (16mm)	163.9000	157.1000	162.6000	165.5000	162.0800
	Normalizing (16mm)	183.4000	173.2000	186.0000	165.4000	177.0000
	Control (16mm)	172.3000	162.2000	154.7000	161.5000	162.6800
5.	Billet	239.5000	220.8000	236.4000	217.1000	228.4500

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LOAD: 490.3MN DWELL TIME 10 SECONDS

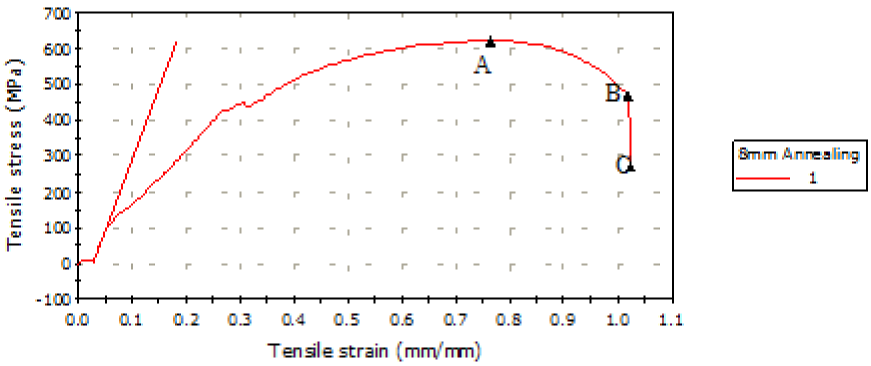

Figure 1: A graph of tensile stress against tensile strain for 8mm annealed specimen.

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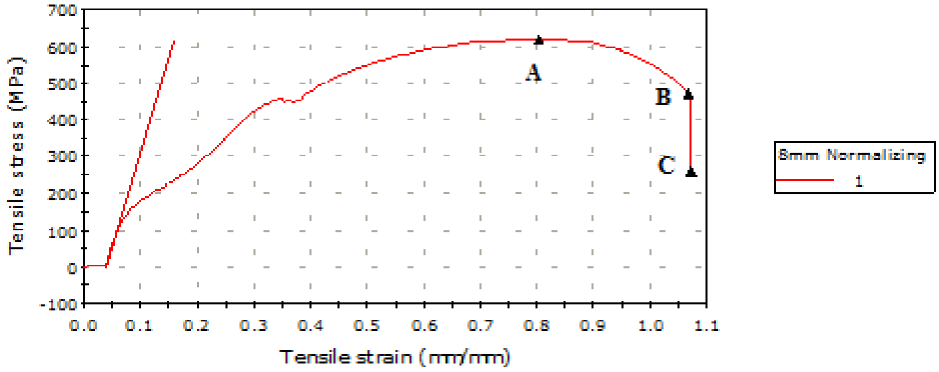

Figure 2: A graph of tensile stress against tensile strain for 8mm normalized specimen

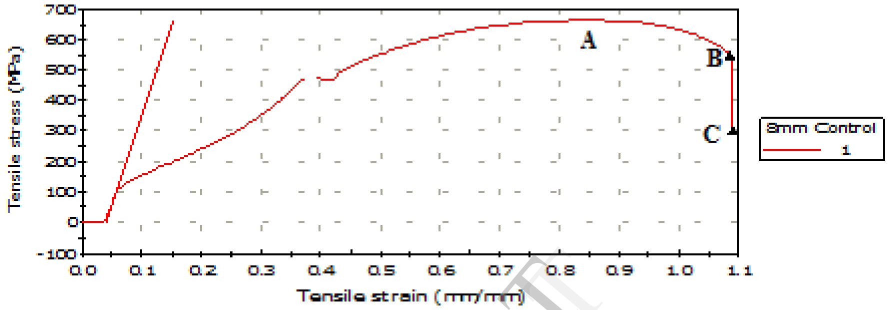

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Figure 3: A graph of tensile stress against tensile strain for 8mm control specimen

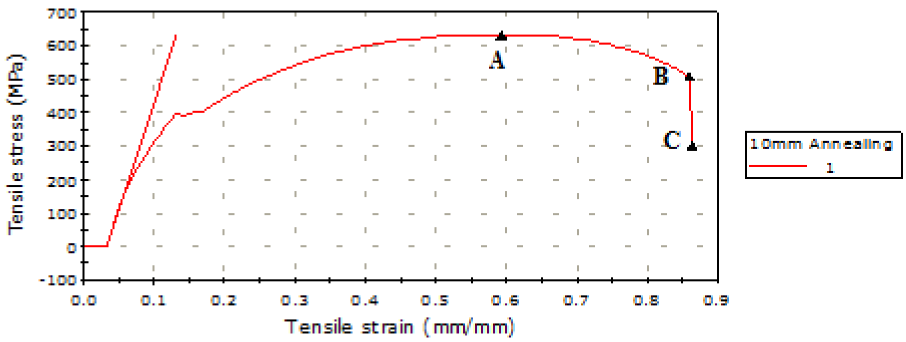

Figure 4: A graph of tensile stress against tensile strain for 10mm annealed specimen

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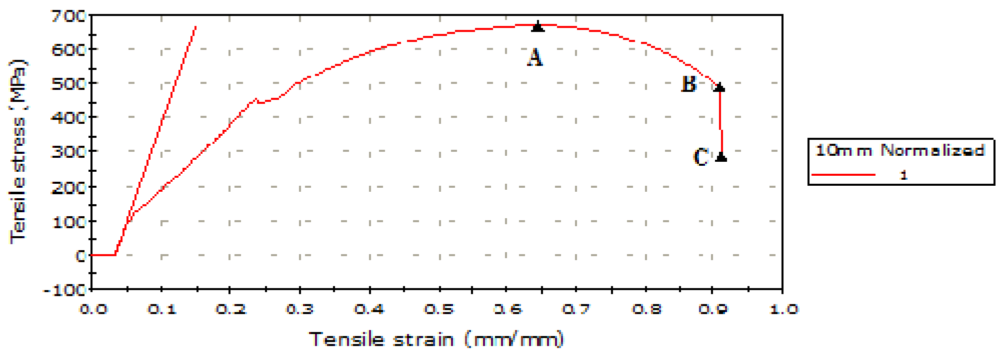

Figure 5: A graph of tensile stress against tensile strain for 10mm normalized specimen.

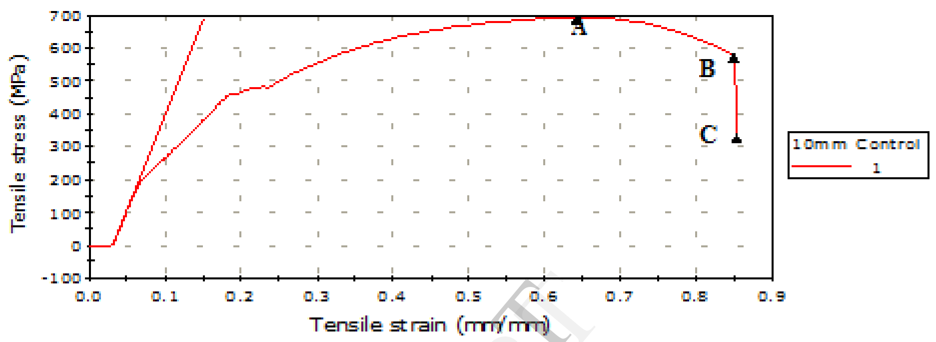

Figure 6: A graph of tensile stress against tensile strain for 10mm controlled specimen

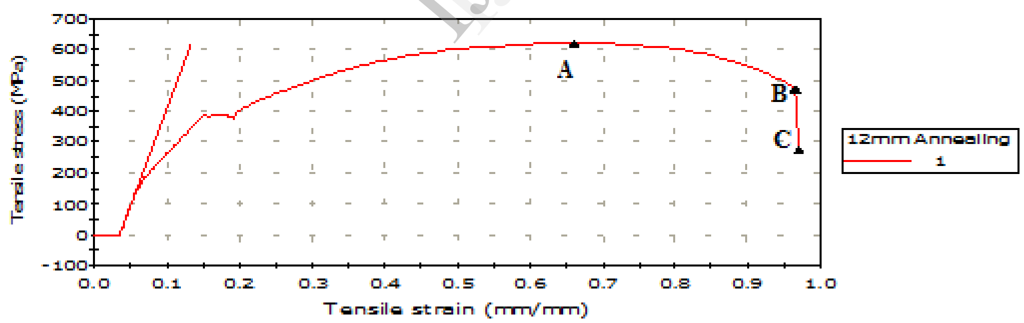

Figure 7: A graph of tensile stress against tensile strain for 12mm annealed specimen.

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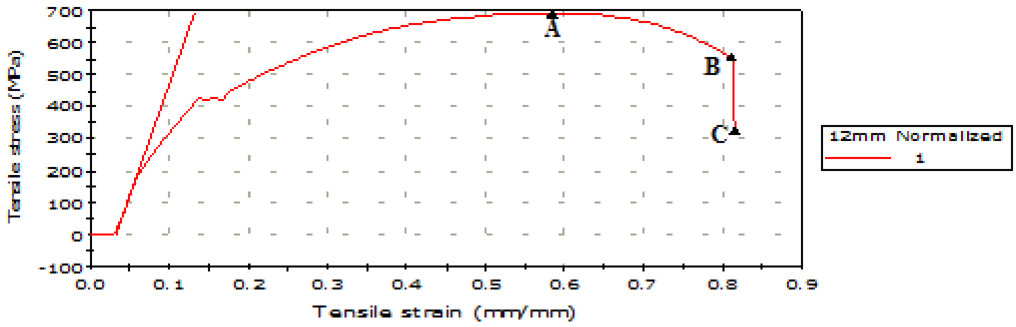

Figure 8: A graph of tensile stress against tensile strain for 12mm normalized specimen.

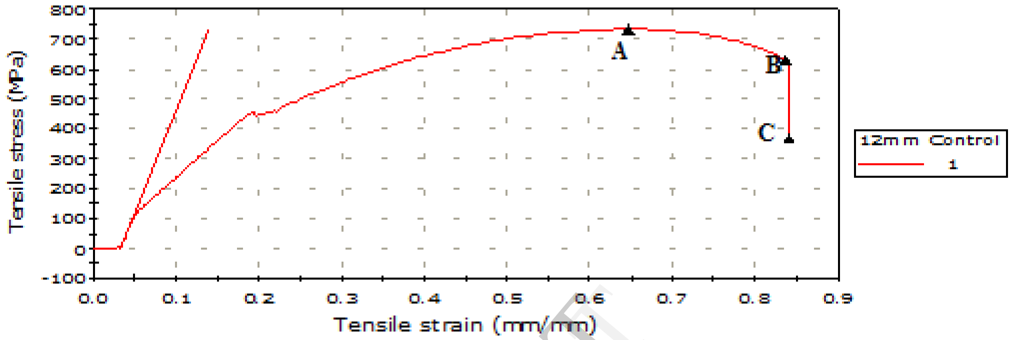

Figure 9: A graph of tensile stress against tensile strain for 12mm controlled specimen.

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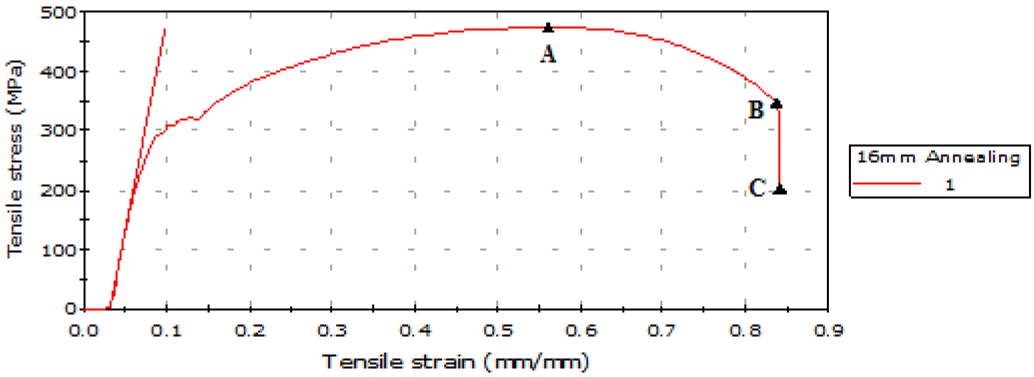

Figure 10: A graph of tensile stress against tensile strain for 16mm annealed specimen.

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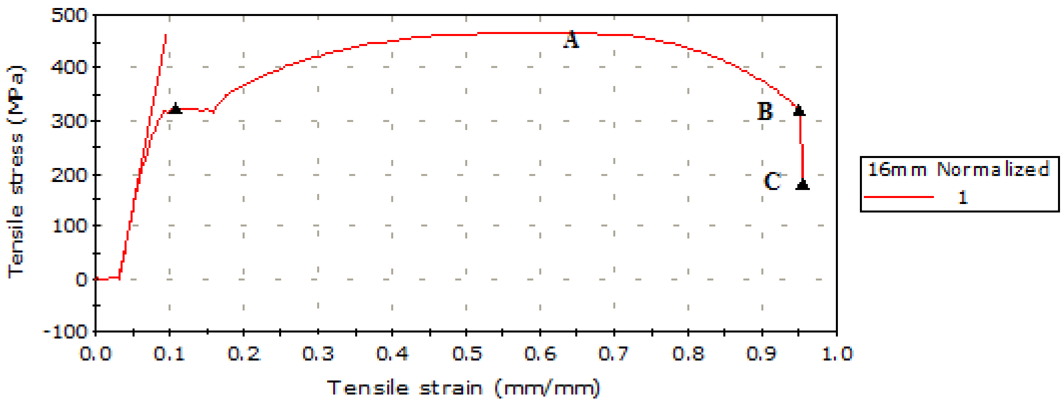

Figure 11: A graph of tensile stress against tensile strain for 16mm normalized specimen.

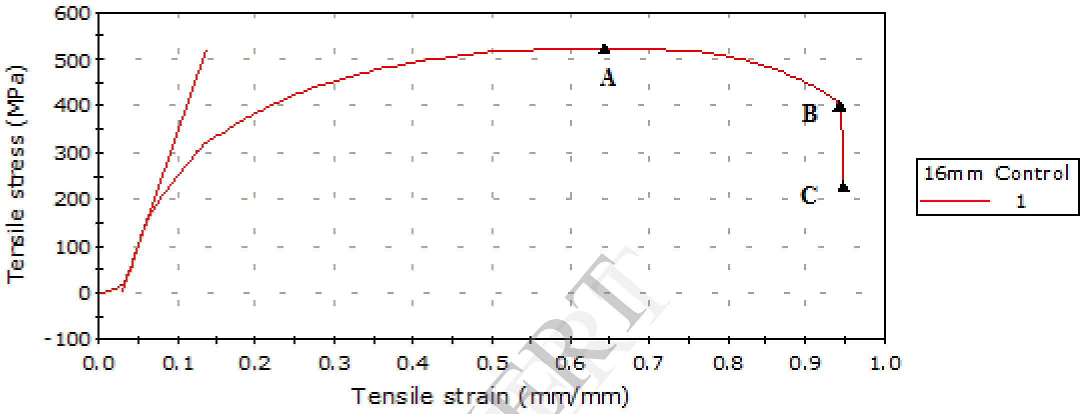

Figure 12: A graph of tensile stress against tensile strain for 16mm controlled specimen.

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