CHEMICAL AND MECHANICAL PROPERTIES OF LOW CARBON STEEL: INSIGHT FROM PROCESS PARAMETERS

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ABSTRACT

The ability of steel bar to function well in structural applications is a function of its mechanical properties. Many factors account for the variations in the mechanical properties of low carbon steel. Therefore, understanding the influence of Physical and chemical compositions on their mechanical properties is essential for material development and applications. This study therefore, explored the effects of the section sizes ranging from 10mm - 16 mm in diameters. Chemical compositions of the steel samples were carried out using XRF. Tests samples were machined using lathe machine and their tensile, hardness and impact properties were determined. Results showed that their carbon contents ranged from 0.01% to 0.25% and the ultimate tensile strength and the yield strength properties decreased with increase in sample diameter. Hence, the diameters of the rods have great influence on the mechanical properties of the materials. The results of this study are relevant to steel industries that produce low carbon steel and structural engineers that make use of this steel in construction.

Keywords: Mechanical properties, Steel, Size, Chemical Composition

Introduction

Low-carbon steels (LCS) are alloys containing carbon (C) and iron (Fe) with other elements in trace amount. The concentration of carbon is very low (< ~0.1 wt%) in such a way that the maximum content of carbon lies close to or within the single-phase α-ferrite phase field at the eutectoid temperature (1, 2). Being the cheapest type of steel made them useful in many construction and manufacturing industries including; auto bodies, fence wire, galvanized sheets, large pipe, storage tanks, and various parts (3). The ability of steel bar to function well in structural applications is a function of its mechanical properties and are very imperative (4, 5). This implies that the ability of steel to function as expected in this area of application is dictated by the mechanical properties. The mechanical property of metals is all about the mechanical behaviour of materials which describes the response of materials to mechanical loads or deformation. It determined the range of usefulness of the metal and establish the service that can be projected. Understanding the influence of physics and chemistry on their mechanical properties is essential for material development and applications. Thus, researchers are occupied with the discovery and the development of novel materials that are readily available, non-toxic, sensitive and suitable for applications that have been projected to be investigated in research laboratory, especially in terms of their load response at different working conditions such as toughness, hardness, fatigue and strength [6]. LCS are widely available and possess many features suitable for a variety of applications. Their mechanical properties respond to forming and solidification process involved, composition, size, and thermal treatments. Scholars have reported mechanical properties of numerous types of materials. The prediction of mechanical properties of hot rolled steel products have been reported (7) and the development of models for the prediction of mechanical properties of rolled ribbed medium carbon steel are well documented (8). Therefore, in production of this steel in accordance with operational requirements, an assessment and estimation of the mechanical properties are very important. Hence, it becomes necessary as a matter of obligation for all manufacturers of steel products to give adequate and accurate data about the mechanical properties of their products. The purpose of this research is to investigate the influence of section sizes as a process variable on the mechanical properties of the typical low carbon steel commonly used in various structural engineering work from a particular steel company in Nigeria. This will assist government regulatory agencies such as Standards Organization of Nigeria and research institutes in their primary responsibilities as well as the design Engineers of building/structures to know the boundary of application of these products.

2.0 Experimental Procedures

The test samples used were sourced from Underground Foundry Steel Company Ltd, Lagos, Nigeria, in form of rolled carbon steel rods of different diameters ranging from 10 mm to 16 mm. The tensile test samples were prepared using ASTM E370 standard specification. The tensile strength at maximum load, tensile strength at break and yield strength tensile were determined from the test samples according to ASTM E8-09/E8M-09 standards using Universal Tensile machine (UTM) (Istrong 3367) Model. Tinus Oisen model and Rockwell hardness tester Scale B were used to determine the impact toughness and hardness of the test samples in agreement with ASTM E23 standard measures and ASTM E18-08 (for transverse hardness) and ASTM E140-07 (for longitudinal hardness) standards.

Results and Discussion

The chemical composition of different gauges of the test samples is shown in Table 1. the results show that the composition of elements in 10 mm, 12 mm and 16 mm samples are not significantly different. The results of mechanical properties tests carried out on low carbon steel of diameters 10 mm, 12 mm, and 16 mm are presented in Figures 1-5. These include the Ultimate Tensile Strength (UTS) at maximum load, the Yield Strength (YS), Impact Toughness, Longitudinal and Transverse Hardness tests on the scale of Rockwell and Vickers. Figure 1 show the results of ultimate tensile strength while figure 2 displayed the result for the yield strength. It is observed that these two properties decreased with increase in sample diameter.

Low carbon steel sample of 10 mm diameter has the highest UTS and YS values while the 12 mm diameter sample exhibited the least UTS and YS values. Overall decrease in UTS and YS of 4.6 % and 4.2 % were observed for 12 mm and 16 mm diameter test samples respectively in comparison with the 10 mm diameter sample.

Table 1: Chemical Composition of Low Carbon Steel

Element	10mm	12mm	16mm
Carbon (C)	0.2091	0.2110	0.2111
Chromium (Cr)	0.0179	0.0181	0.0186
Cobalt (Co)	0.0029	0.0020	0.0025
Phosphorus (P)	0.0109	0.0121	0.0118
Lead (Pb)	0.0070	0.0070	0.0061
Sulphur (S)	0.0191	0.0179	0.0178
Vanadium (V)	0.0010	0.0021	0.0025
Cupper (Cu)	0.0412	0.0421	0.0411
Manganese (Mn)	0.0281	0.0296	0.0301
Aluminium (Al)	0.0169	0.0172	0.0199
Silicon (Si)	0.0081	0.0080	0.0065
Iron (Fe)	99.531	99.452	99.537

The decrease in UTS and YS of the samples could be attributed to size effect. This effect can influence mechanical properties of a material because strength of a bulk material is in random. Therefore, the strength of the weakest structural material decreases as the size of the structure increases, thereby influencing the overall strength of the material. This is in agreement with fact that large beam and a small beam with the same stress will fail if they are made of the same material (9). This result is also in agreement with previous investigation carried out (10) where it was reported that ultimate tensile strength of copper alloy decreased with increase in specimen diameter.

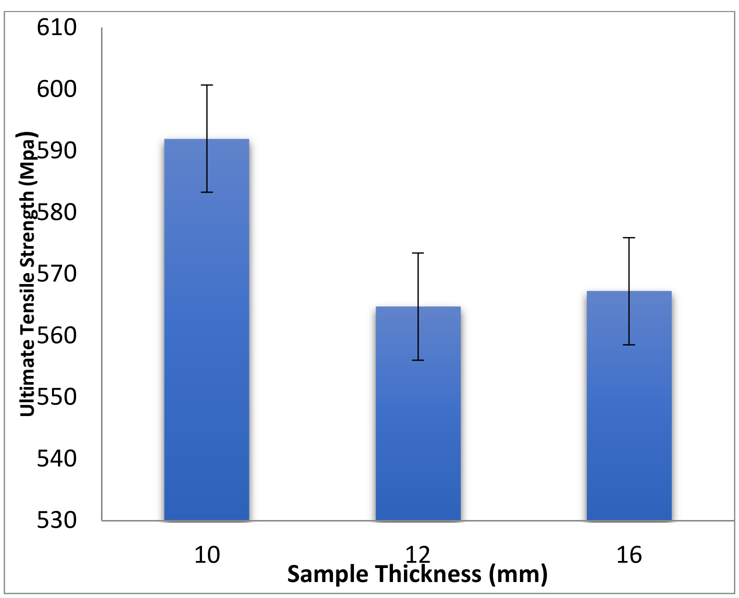

Figure 1: Variation of Ultimate Tensile Strength with Different Diameters of Low Carbon Steel

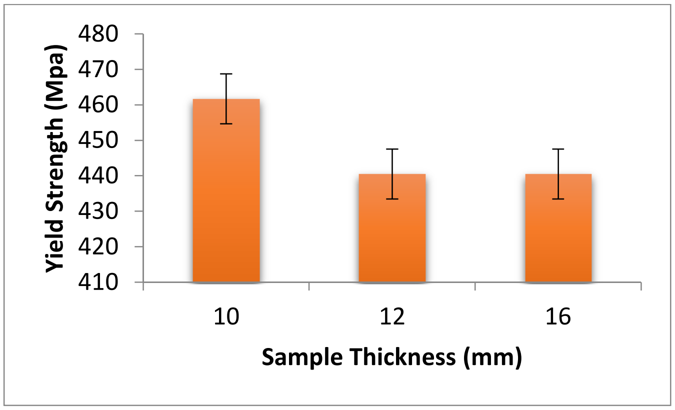

Figure 2: Variation of Yield Strength with Different Diameters of Low Carbon Steel

Figure 3 shows the results of Impact Toughness tests carried out on the samples. The results show that impact toughness of the samples increases progressively with increase in diameter of the samples. Increase in impact strength of 1.3 % and 2.5 % are observed for 12 mm and 16 mm rod samples respectively in comparison with 10 mm diameter rod. The results obtained from impact strength test are in agreement with previous work reported (11).

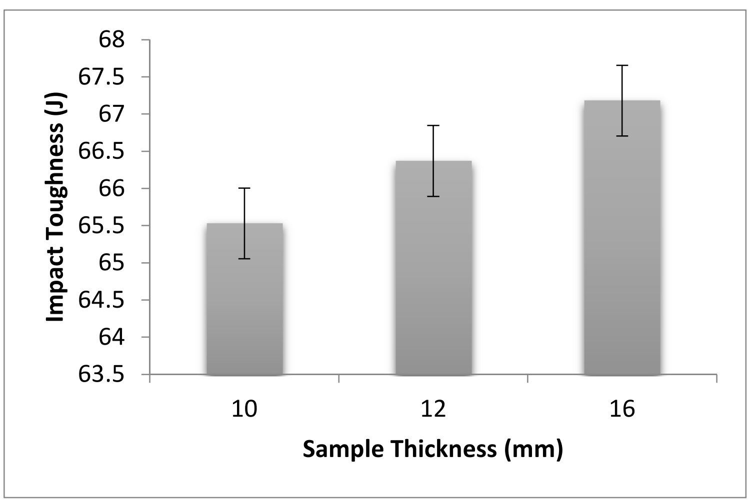

Figure 3: Variation of Impact Toughness with Different Diameters of Low Carbon Steel

The results of hardness test on Rockwell scale and Vickers scale are presented in Figure 4 and Figure 5 respectively. From Figure 4, it is observed that longitudinal hardness decreased with increase in specimen diameter. Decrease in longitudinal Rockwell hardness value of 1.84 % and 9.22 % are observed for 12 mm and 16 mm samples respectively in comparison with the 10 mm diameter sample. The results obtained from transverse Rockwell hardness test also show that 10 mm diameter sample had the highest value while decrease in transverse Rockwell hardness value of 27 % and 4.78 % are observed for 12 mm and 16 mm samples respectively in comparison with the 10 mm diameter sample. The results show that samples Rockwell hardness value decreased with increasing sample diameters.

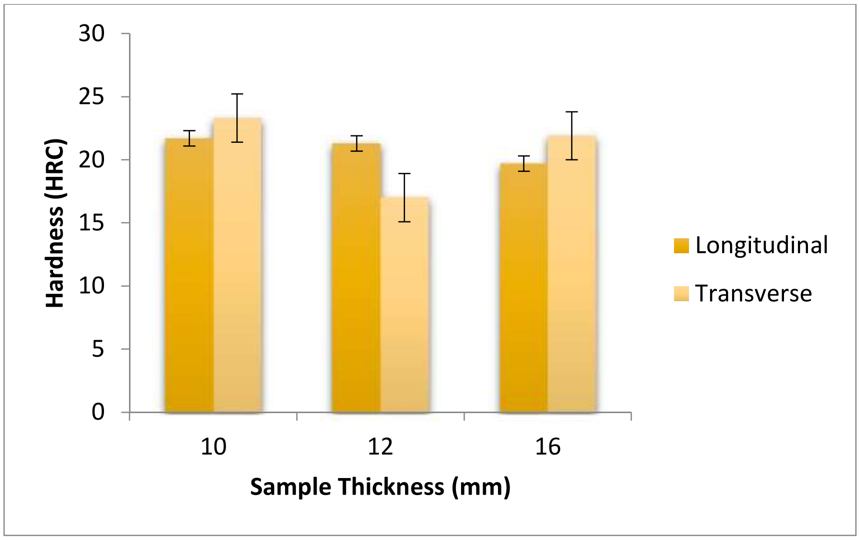

Figure 4: Variation of Rockwell Hardness with Different Diameters of Low Carbon Steel

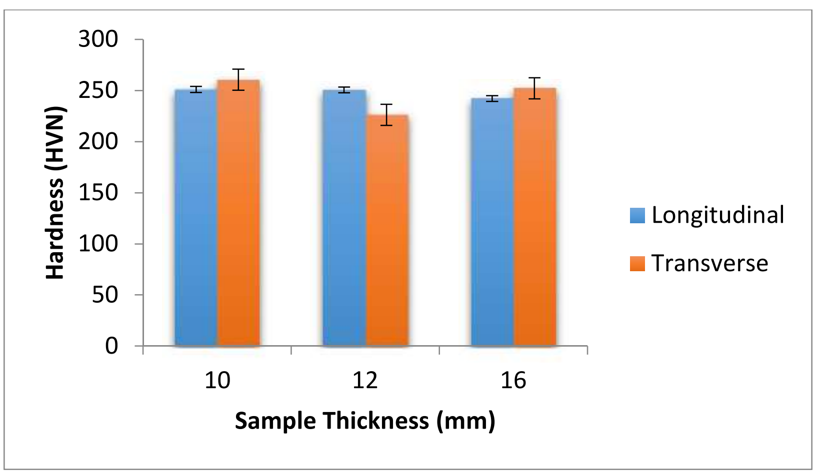

Figure 5: Variation of Vickers Hardness with Different Diameters of Low Carbon Steel

Figure 5 shows Vickers hardness test results for the samples. The results show that 10 mm diameter sample had the highest hardness value for both transverse and longitudinal Vickers hardness. Decrease in longitudinal hardness value 0.4 % and 3.55 % are observed for 12 mm and 16 mm samples, while decrease in transverse hardness value of 13.17 % and 3.26 % are observed for 12 mm 16 mm diameter samples respectively. The trend obtained for hardness test is similar to the results obtained from UTS and YS.

The variation of hardness with sample diameter could also be attributed to structural effect. According to (12). The results obtained from instigation carried out on the samples are in agreement with previous investigations reported by other author (9).

Conclusions

The low carbon Steels have virtuous prospective to be inexpensive and effective raw material for construction and for making whole body shell and the various parts of automobiles. From the results, it was concluded that the size of the rods is directly proportional to the carbon contents of the rods while the size of the rods greatly influences their mechanical properties. This will help structural engineers that madk use of this steel in construction.

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