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The Effects of Pre-strain on the Tensile Mechanical Properties of a 0.35%C Steel

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Abstract

A study has been made on the effect of pre-strain on the tensile mechanical properties of a 0.35%C steel. The samples were spheroidized and machined to tensile specimens and then pre-strained to 0.1, 0.15 and 0.2 respectively while some were left unpre-strained (control). The pre-strained samples and control were then tested to fracture. Pre-straining increased the Yield, Ultimate and Fracture Strengths of the samples but reduced the ductility. The 0.2 pre-strain showed the highest incremental values of Yield, Ultimate and Fracture Strength; 17.39%, 10.48% and 7.14% respectively with 16% reduction in ductility.

Keywords: Heat Treatment, Pre-strain, 0.35%C Steel

1.0 Introduction

Steels contain many types of particles of various shapes and sizes arising from impurities or deliberate alloying additions [1, 2]. When such heterogeneous material is subjected to strain, the particles act as sources of strain concentration which lead to formation of cavities. Such cavities are the first stage of ductile fracture [3, 4, 5]. If this is so, then pre-strained steels may have an increased susceptibility to ductile failure. The consequences of this on accepted methods of engineering practice are of great importance. Cavities are often nucleated as soon as a material experiences plastic straining. [6, 7, 8]. During these processes, they are subjected to plastic strain. For example, the vast technology of metal working depends mainly on plastic deformation, which has been exploited on a commercial scale in wire, sheet, tube and extrusion manufacture. Although an increase in strength is normally associated with such deformation, microscopical damage (cavities) have been found to develop due to cold work [1, 9]. In this case the applied stresses are creating work hardening in the material, and a traditional view is that this improves the strength without any other serious consequences [10, 11, 12]. Moreover, in some instances fabrication practices call for deliberate overstressing (proof stressing or hydro testing of pressure vessels) and although it is the intention of the procedure to preserve the integrity of the structure, microscopical damage can develop in a cumulative fashion during these procedures. The aim of this study is to investigate the effect of plastic pre-straining on the mechanical behavior of a 0.35%C steel used for pressure vessels.

2.0 Materials and Methods

The material used for this study was a 0.35%C steel obtained from Universal Steels, Lagos in cylindrical rod form of diameter 14mm and length 3m. The chemical composition as supplied by the manufacturer is shown in Table 1.

Table 1: Chemical Composition of Steel

Element	C	Si	Mn	S	P	Cr	Ni	Cu	Nb	Al	B	W	Mo	V	Ti	Fe
Content (wt%)	0.35	0.16	0.61	0.06	0.06	0.19	0.14	0.32	0.0001	0.04	0.0001	0.0001	0.0001	0.0001	0.0001	98.09

The as received steel material was turned (using a lathe machine) to remove the ribs and then cut with a hack saw into lengths of 100mm.

The samples were heated in the furnace at 870^{o}C, held at that temperature for 20 minutes and quenched in water. They were then spheroidized at 700^{o}C for another 20minutes.

Fifteen tensile specimens were produced having gauge length diameter of 5mm and gauge length 40mm respectively. Tensile tests were carried out at room temperature at a cross head speed of 10^{-5} m/s until a predetermined load was reached on the load-displacement curve. Two control samples were initially tested to fracture to identify three levels of pretrain between the yield point and the Ultimate Tensile Strength. Two samples were then pre-strained to strain level 0.1, another two were pre-

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strained to strain level 0.15 and another two were pre-strained to strain level 0.2. Three samples were left unpre-strained to serve as control.

One sample from each level of pre-strain was later strained to fracture at the same cross head speed of 10^{-5} m/s for the evaluation of its tensile properties. One unpre-strained sample was also strained to fracture for the same purpose.

3.0 Results

The stress – strain graph of the unpre-strained is shown in Fig 1. Figs 2-4 show the graphs for the varied pre-strain levels and Figs 5-7 show the graphs of the pre-strained specimens strained to final fracture.

The effect of Prestrain on the Mechanical properties evaluated from the stress-strain data obtained are shown in Figs 8 and 9.

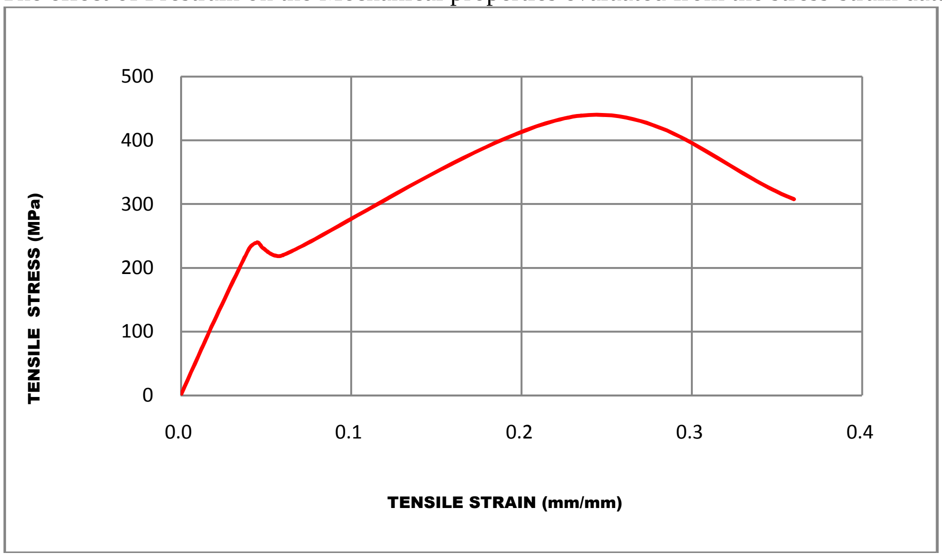

Fig 1: Graph of Unprestrained Steel Sample

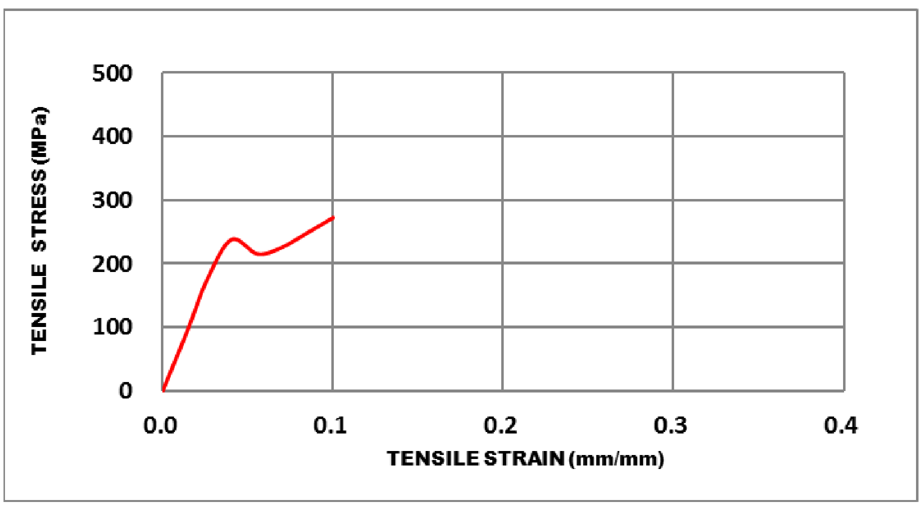

Fig 2: Graph of 0.1 Prestrain Steel Sample

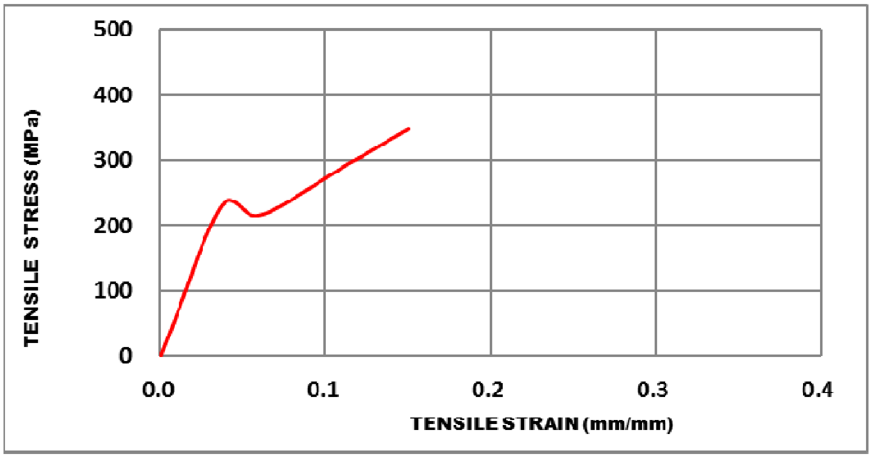

Fig 3: Graph of 0.15 Prestrain Steel Sample

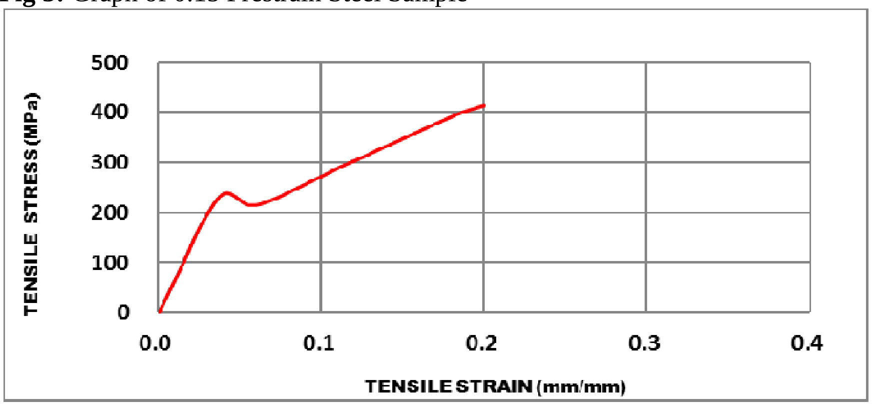

Fig 4: Graph of 0.2 Prestrain Steel Sample

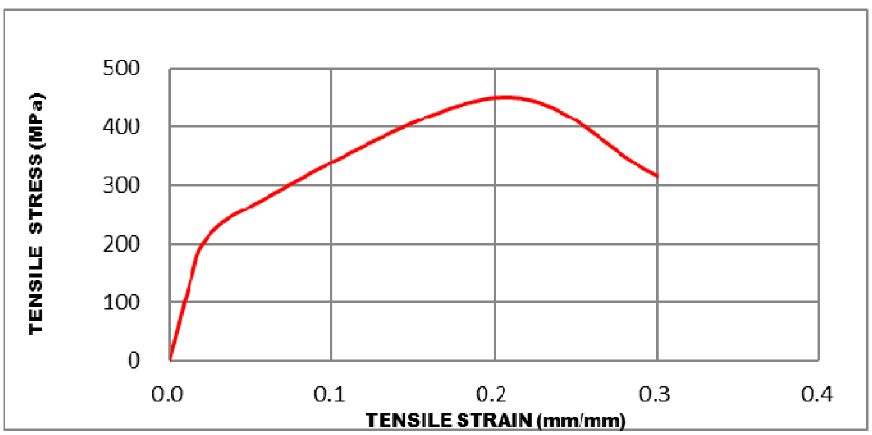

Fig 5: Graph of 0.1 Prestrain Steel Sample (Fracture)

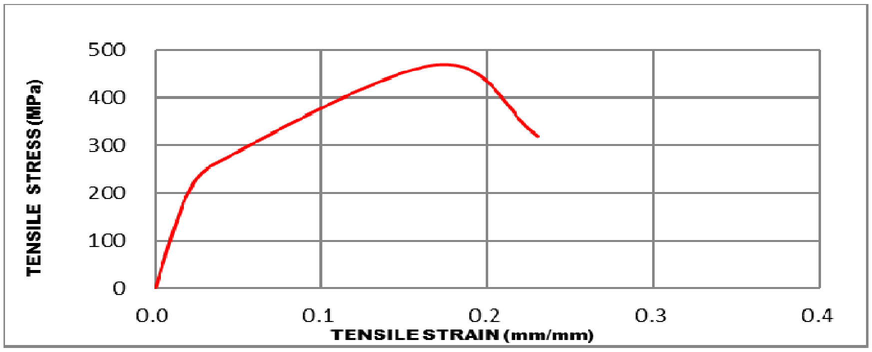

Fig 6: Graph of 0.15 Prestrain Steel Sample (Fracture)

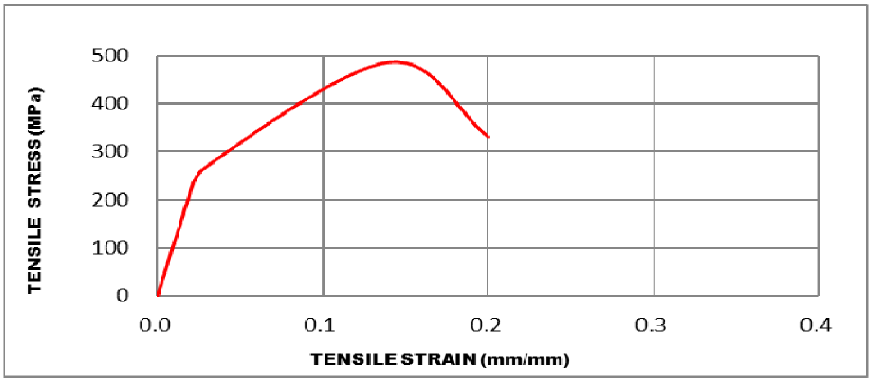

Fig 7: Graph of 0.2 Prestrain Steel Sample (Fracture)

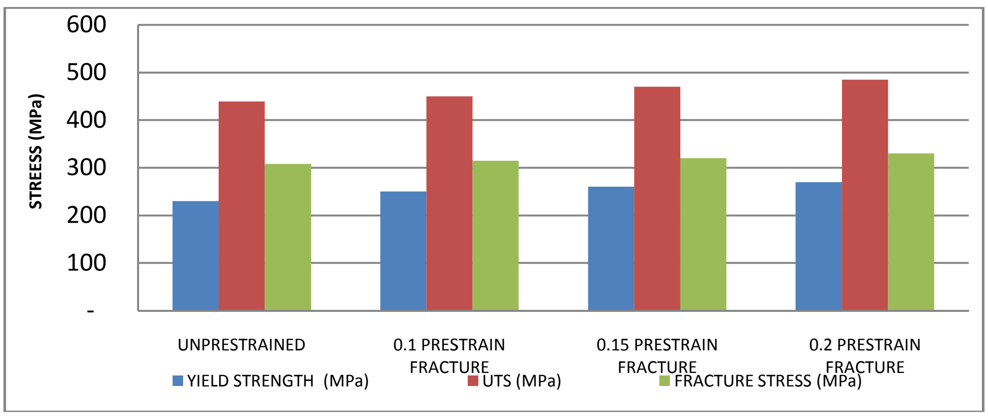

Fig 8: Effects of Prestrain on Yield Strength, UTS& Fracture Stress (Histogram)

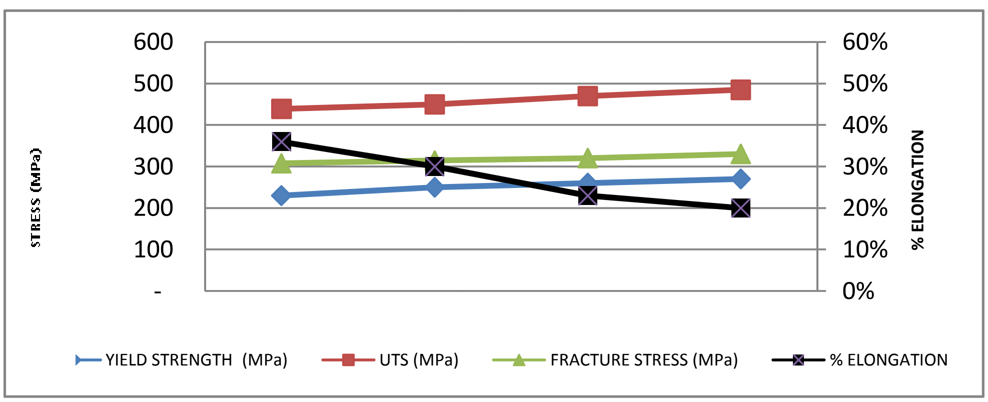

Fig 9: Effects of Prestrain on Yield Strength, UTS, Fracture Stress& %Elongation (Line Diagram)

4.0 Discussion

Figs 5 – 7 show an absence of observed yield point in the stress-strain graphs of the fractured pre-strained specimens. The probable explanation of this absence is that yield point is eliminated by localized plastic deformation.

From Figs 8 and 9, the Yield strength, UTS and Fracture Strength of the pre-strained samples increased progressively with increasing level of pre-strain but with a gradual decrease in ductility. This is in agreement with [11, 12] who observed higher strength and inferior ductility in prestrained steels. [11] observed this while considering prestrain in combination with aging treatment. This paper however treats prestrain in isolation so as to fully investigate its influence on the mechanical properties of steel. The observed higher strength can be attributed to the fact that the density of dislocations increases with increasing strain [10]. This was observed in his paper where he focuses on using compressive form of prestrain on stainless steel while this paper uses the tensile form of prestrain to investigate same. [12] also worked majorly on compressive prestrain while using just one value of tensile prestrain, this paper went further by using incremental values of prestrain to establish a proportional trend in its influence on both strength and ductility of the steel used.

5.0 Conclusion

Figs 8 and 9 show that pre-straining increased the Yield, Ultimate and Fracture Strengths of the samples but reduced the ductility. The 0.2 pre-strain showed the highest incremental values of Yield, Ultimate and Fracture Strength; 17.39%, 10.48% and 7.14% respectively with 16% reduction in ductility.

6.0 References

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