Journal of Applied Sciences Research, 3(12): 1719-1723, 2007

Effects of Tempering on the Microstructure and Mechanical Properties of Low Carbon, Low Alloy Martensitic Steel

Bello K.A., Hassan S.B. and Abdulwahab M.

Department of Metallurgical Engineering, Ahmadu Bello University Zaria, Nigeria.

Abstract: In this study, the effects of tempering thermal treatment on the microstructural and properties behaviour of 0.22wt pct C microalloyed steel were investigated. The microalloyed steel samples were austenitized and quenched to produce a lath martensite followed by annealing in intercritical region ($\alpha+\lambda$) and subsequently quenched to produce a dual phase of ferrite-martensite microstructure. The specimens were subsequently tempered at temperatures of 250, 350 and 450°C for 1 hour. The microstructures, tensile and impact toughness properties of these steels were analyzed and compared with the microalloyed steel that were conventionally quenched and tempered. The result showed that tempered dual phase microalloyed steel samples significantly exhibited superb mechanical properties including higher tensile strength, ductility and impact toughness as compared with that of conventionally quenched and tempered steel samples.

Keywords: Microalloyed Steel, Quenching, Tempering, Intercritical region, Ferrite-Martensite

INTRODUCTION

Steel is arguably world's most "advanced" material. It is very versatile material with a wide range of attractive properties which can be produced at a very competitive production cost[1,2]. The optimization of alloying contents in the iron-carbon alloy system combined with different mechanical and heat treatments lead to immense opportunities for parameter variations and these are continuously being developed[3].

Applications of steels for engineering components require a complete understanding of material properties and design requirement. Through the last few decades a category of steels known as high strength steels have undergone constant research[1]. As a result, quenched and tempered microalloyed steels are most likely candidate material for the next generation of high-strength steel sheets. For a given alloy content, quenched and tempered microalloyed steel exhibit good combination of strength and toughness[4,5].

Traditionally, quenched and tempered steels sheets are being employed in automotive industry in the areas of structural members, power transmission and impact resistance systems. With the advent of dual-phase (DP) heat treatment, the possibility of introducing dual phase treated sheets is becoming attractive proposition in those areas. Dual-phase microalloyed steel consists of martensitic islands in a ductile ferrite matrix[6,7]. Their potential as superior strength and formability substitutes for current automotive steels was recognized and has provided an incentive for their rapid development acceptance in this role[8]. This successful application has preceded the acquisition of a complete understanding of the detailed relationships between their process route, microstructure, and mechanical properties, although some research has been carried out in order to optimize the variables in the strength/formability balance [1,9,10]. However, the Microstructural evolution and mechanical properties of tempered dual phase steels is also of interest but has received little attention.

The objective of this work, therefore, was to study and compare the effect of variation of tempering temperatures on the microstructure and mechanical properties of quenched and conventionally tempered microalloyed steels with that of tempered dual phase microalloyed steels.

MATERIALS AND METHODS

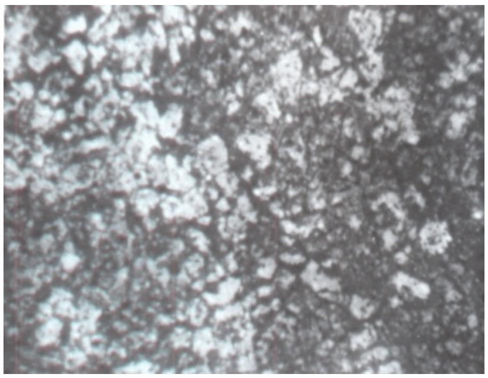
Materials: Commercial microalloyed steel used in the present investigation was supplied by SCC Nigeria Limited (Abuja, Nigeria) in the form of 15-mm-thick hot rolled plates. The steel was analyzed and the chemical compositions are given in Table 1.

Equipment: The equipment used for this research are; Muffle furnace with a maximum temperature of 1600°C, Brine (quechant), SAE 40 Engine Oil (quechant), Grinding and Polishing Machine, Optical Metallurgical Microscope with an in-built camera, Lathe turning machine, Monsanto type W-tensiometer, Izod impact testing machine.

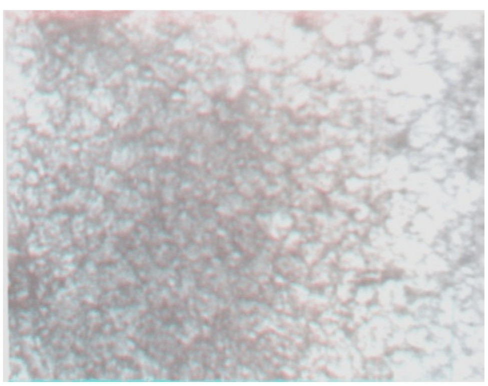
Corresponding Author: Bello K.A., Department of Metallurgical Engineering, Ahmadu Bello University Zaria, Nigeria.
Tel.: +234806-036-0240. E-mail address: bellkam@yahoo.com

Table 1: Chemical Compositions of the Steel Used.

%C	%Mn	%Si	%P	%S	%Mo	%V	%Ti	%Al
0.22	1.20	0.25	0.025	0.025	0.001	0.004	0.002	0.051

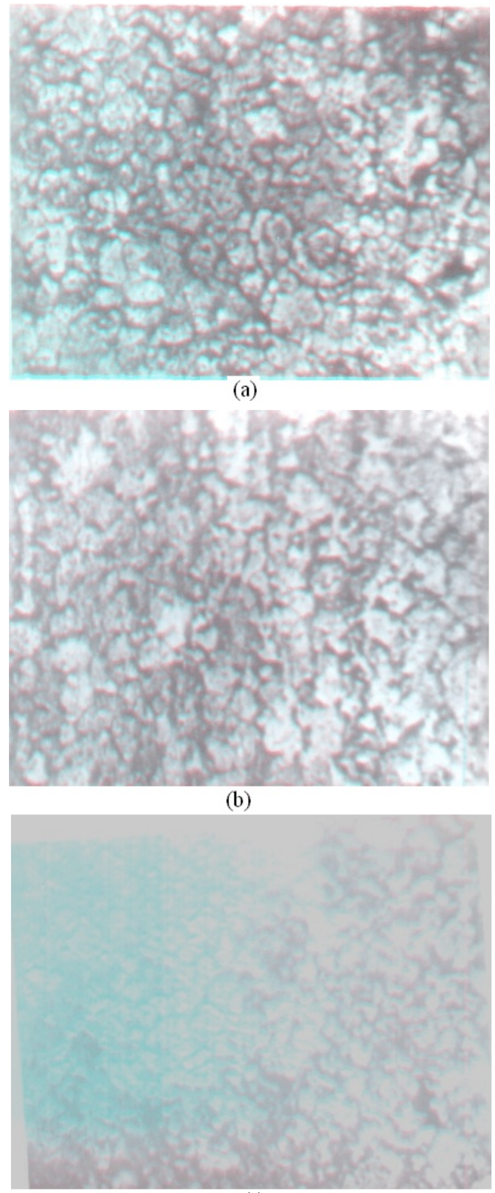


Micrograph 1: Microstructure of microalloyed steel sample austenitized at 920°C and quenched in iced brine (-8°C) solution. The structure consist only lath martensite.



Micrograph 2: Microstructure of martensitic microalloyed steel sample intercritically annealed (DP-treated) at 770°C for 60minutes and quenched in oil. The structure consists of martensite (dark) in a ferrite matrix (white).

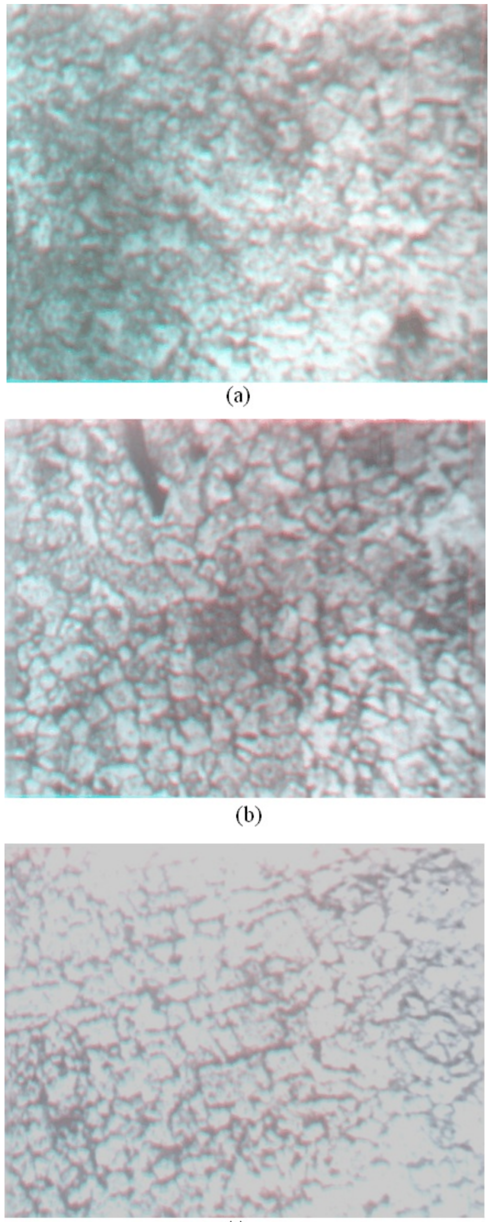
Methods: The steel samples were austenitized at 920°C in an electric muffle furnace for 1hr and quenched in 9% iced brine (-8°C) to produce 100% lath martensitic microstructure. Part of these samples was then intercritically annealed at the intercritical temperature of 770°C, held for 60min and then quenched in oil (28°C) to room temperature to produce a composite dual microstructure of ferrite and martensite. The initial quenched and the intercritically annealed samples were subsequently tempered at a temperature of 250-450°C for 60minutes followed by air-cooling.



(c)

Micrograph 3: Microstructure of dual phase microalloyed steel samples and tempered at (a) 250°C (b) 350°C (c) 450°C.

The microstructures of all the heat treated conditions were examined by means of optical metallurgical microscope. The samples for optical microscopy were cut along the rolled direction, ground, polished, etched in a 2% Nital solution and analyzed using optical microscopy. Tensile tests were carried out



Micrograph 4: Microstructure of the as-quenched steel samples tempered at (a) 250ºC (b) 350ºC (c) 450ºC.

on round samples with a diameter of 12.5mm and a gauge length of 50mm following. Impact tests were carried out using standard Izod V-notch-type samples. A minimum of three samples was tested for each heat-treated microstructure.

RESULTS AND DISCUSSIONS

Microstructure: Micrograph1 shows martensite structure in a sample austenitized at 920ºC and quenched in iced brine solution. Micrograph 2 shows the microstructure of quenched sample subjected to intercritical thermal treatment and quenched in oil. The structure consists of fine distribution of lath martensite in a ferrite matrix. Micrograph 3(a-c) reveal the microstructure of sample quenched from the intercritical temperature of 770ºC (1hr) and tempered at 250 to 450ºC. The structures of these tempered samples consist of ferrite and tempered martensite, the proportions of which depend on tempering temperature. The tempered martensite with associated ferrite is responsible for the unique combination of strength, ductility, and toughness that were obtained in tempered dual phase steels. Micrograph 4(a-c) show microstructure of samples quenched and tempered at 250-450ºC range. As expected, this reveals tempered martensite only.

Mechanical Properties: Evaluation of mechanical properties of the tempered dual phase steel samples indicates that the dual phase (DP) sample has undergone microstructural changes on tempering that are akin to those of fully martensite low carbon steel. The yield strength and tensile strength are plotted against the tempering temperature as shown in fig.1 and fig.2 respectively. The tensile strength of the tempered DP steels decreases with an increase in tempering temperature range of 250-450ºC. Similarly the yield strength decreases but does not show significant variation as tempering temperature increases. The results of variations of percentage elongation and impact toughness with the tempering temperature are represented in fig.3 and fig.4 respectively. The percentage elongation increases with an increase in the tempering temperature. The percentage elongation of the tempered dual phase specimen is slightly greater than that of the dual phase samples.

The yield strength, tensile strength, elongation and impact toughness of the conventional quenched and tempered steel are plotted against the tempering temperature (250-450ºC). These results are also indicated in fig.1-4. The yield and tensile strength of conventional quenched and tempered steel significantly decreased with increase in the tempering temperature. An increase in the elongation and impact toughness is observed with tempering temperature but comparatively low to that of tempered dual phase steel samples.

Conclusion: From the result of the investigation carried out in this research, it can be concluded that:

- The tempered dual phase steel samples are characterized by a comparatively high strength, ductility and toughness than the quenched and tempered samples.

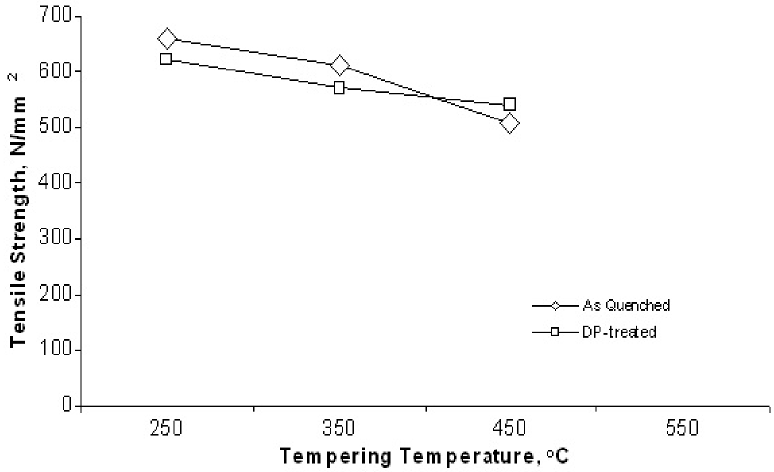


Fig. 1: Effect of tempering temperature on the tensile strength of as-quenched and DP-treated steels.

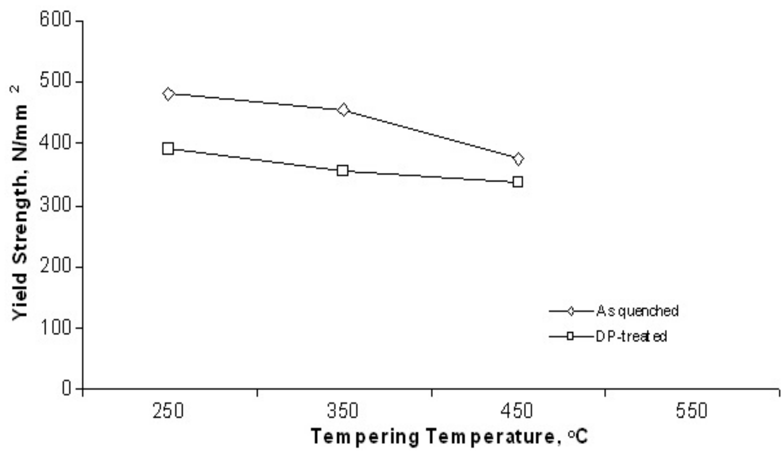


Fig. 2: Effect of tempering temperature on the yield strength of as-quenched and DP-treated steels.

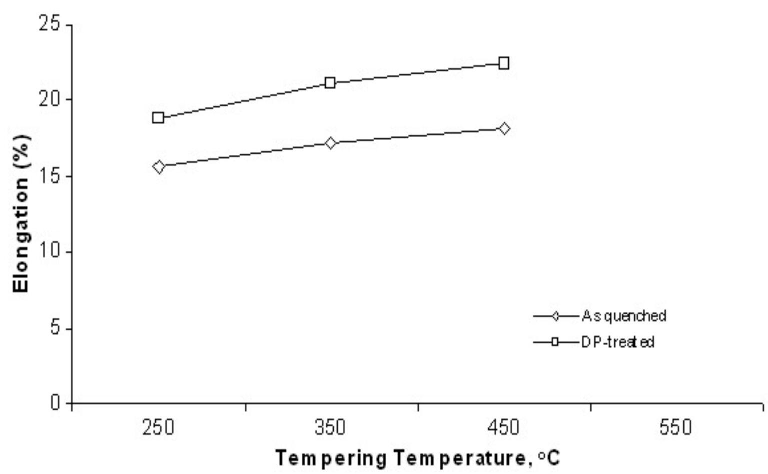


Fig. 3: Effect of tempering temperature on the % Elongation of as-quenched and DP-treated steels.

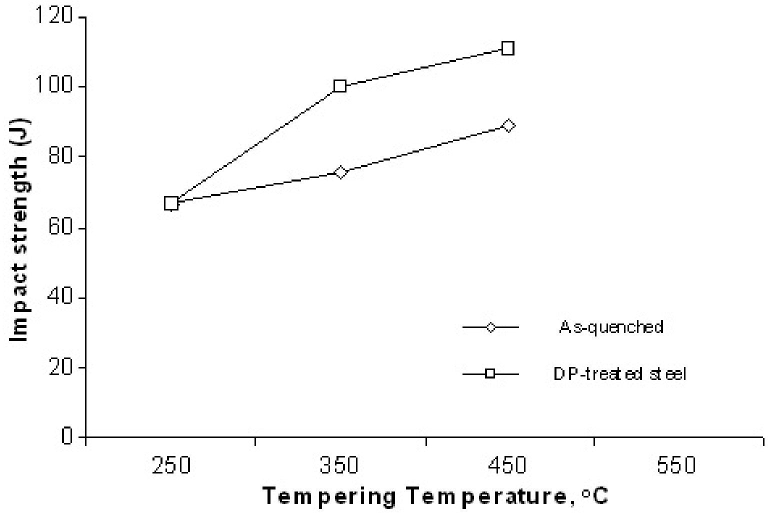


Fig. 4: Effect of tempering temperature on the Impact toughness of as-quenched and DP-treated steels.

- The elongation and impact toughness of the tempered dual phase steel samples are superior to those of quenched and tempered samples.
- The increase in tempering temperature in the range of 250-450°C shows no significant variation on the yield strength of the tempered dual phase steel.

ACKNOLEDGEMENTS

This work was carried out in co-operation with Ahmadu Bello University Zaria and Obafemi Awolowo University Metallurgical workshops as part of K.A Bello's M.Sc Thesis. The authors acknowledge the financial contribution made by the management of Islamic Education Trust (Minna, Nigeria) and Nigeria-Sao to me and Precipe JDA (Andarko Ltd. Nigeria)

REFERENCES

1. Sinha, A.K., 1989. Ferrous Physical Metallurgy. Butterworth, London, pp: 56.
2. Bello, K.A., 2007. Effect of Intercritical and Tempering Heat Treatment on the Microstructure and Mechanical Properties of a High Martensite Dual Phase Steel. M.Sc Thesis, Metallurgical Engineering Department, Ahmadu Bello University Zaria, Nigeria.
3. Keenha, E., 2004. Effect of Microstructure on Mechanical Properties of High Strength Steel Weld Metals. PhD Thesis, Chalmers University of Technology, pp: 1.
4. Barros, A.C., 2003. Microstructure and Mechanical of a Microalloyed Steel. Materials Research Journal, 6(2): 118.
5. Padmanabhan, K.A., S.V. Sarma and S. Sakaran, 2005. Low Cycle Fatigue Behaviour of a Multiphase Microalloyed Medium Carbon Steel: comparison between Ferrite-Pearlite and Quenched and Tempered Micostructure. Materials Science and Engineering Journal, 345: 328.
6. Saikaly, W., X. Bano, C. Issartel, G. Rigaut, L. Charrin and A. Charai, 2001. The Effects of Thermomechanical Processing on the Precipitation in an Industrial Dual Phase Steel Microalloyed with Titanium. Metallurgical and Transactions Journal, 32: 1939.
7. Sang, Y.K., W.P. Jin and D.L. Jung, 2006. Application of High Strength microalloyed Steel in a New Automotive Crankshaft. New Developments Products Proceedings, pp: 3.
8. Bhadeshia, H.K.D.H. and D.V. Edmonds, 1980. Analysis of Mechanical Properties and Microstructure of High-Silicon Dual- phase Steel. Journal of Metal Science, 10: 41-42.
9. Hulka, K., 2002. Dual Phase and Trip Steels. ASM, Metal park Ohio, pp: 1-4.
10. Bag, A., K.K. Ray and E.S. Dwarakadasa, 1999. Influence of Martensite Content and Morphology on the Tensile and Impact Properties of High Martensite Dual-Phase Steels. Journal of Metallurgical and Material Transaction A, 30: 1193-1202.