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Strengthening of Alloy Steel by High Temperature Thermomechanical Treatment

[1]J.A. Omotoyinbo, [2]O.E. Olorunniwo, [2]O. Ogundare and [2]O.O. Oluwole

[1]Federal University of Technology, Akure. Nigeria.
[2]Obafemi Awolowo University, Ile-Ife. Nigeria.

Abstract: Micro-alloyed steels produced by controlled rolling are of the most attractive propositions in many engineering applications because of their relative low cost, moderate strength and very good toughness when compared with as-cast alloy steel.. This research work has shown the possible substitution of cheaper, low-alloy steel for the high alloy steel for the same application. The effect of HTMT on the mechanical properties of low alloy steel was investigated.

Key words: Strengthening. High Temperature Themomechanical Treatment (HTMT), micro alloyed, controlled rolling.

INTRODUCTION

Steels are weaker than they should be theoretically because of dislocations and the ease with which these dislocations move under applied shear stress[4]. Therefore, the primary aim of strengthening is to retard the dislocationmovements. However, complete barrier can be dangerous because pile-up of dislocations can lead to a catastrophic crack[2].

Strength in steels arises from several phenomenon including solid solution strengthening, dispersion strengthening and ferrite grain refinement which usually contribute collectively to the observed mechanical properties such as ductility, strength,etc. Alloying elements' presence provides greater control over microstructure and consequent benefit in mechanical properties.

Therefore, to produce steels with improved strength-to-ductility ratio, a combined use of mechanical working and heat treatment is employed as strengthening mechanism[8], resulting in structural steels with improved weldability, cleanness and inclusion shape control[9].

This paper seeks to investigate and establish the possible benefits derived from strengthening of alloy steels by HTMT. This includes improved mechanical properties, substantial energy savings (through elimination of subsequent normalizing treatment) and possible substitution of cheaper, low alloy steel for high alloyed steel for the same application under the same conditions.

Experimental procedure: The chemical composition of low alloy steel as-cast specimens (AISI-SAE 1037), presented in table 1, was obtained from the Universal Steels Limited, Lagos, Nigeria. All mechanical tests (tensile, hardness, impact) were carried out according to the A 296 ASTM requirement.

MATERIALS AND METHODS

Tensile test samples: To prepare the tensile test specimen, the hot-rolled samples which were initially of round shape were prepared as follows. The 10mm diameter rod was held tightly in position on the bench vice where it was cut into lengths of 5mm ach with he aid of hack saw. Each of the samples was then mounted and turned consecutively on the lathe machine into cylindrical shape. The vernier caliper was used to take the accurate measurement. For reproducibility of results, four samples were prepared for the 10mm diameter rod. This process was repeated for the 12mm and 16mm diameter rod, one after the other.

The impact test samples: They were prepared by notching to 4mm depth at 45^0 with the aid of the lathe machine. Four samples were prepared each for 10mm, 12mm and 16mm diameter rod as well as for the as-cast sample to be used in izod impact test.

The hardness test sample-This sample is obtained by grinding the surface with emery paper. Then, with the aid of hacksaw and lathe machine, cut into 25mm x 25mm x 25mm square cube for Rockwell test. Four samples were prepared for 12mm and 16m diameter samples.

Microstructural test: The specimens were ground in succession with 220,320, 400, 600 frit emery paper. Then, they were polished until mirror-like surfaces was obtained. The surface was etched with Nital solution and examined under the microscope. For reproducibility of results, four samples were prepared for 10mm, 12mm and 16mm samples.

RESULTS AND DISCUSSIONS

From the result, it has been shown that the rolled (HTMT) samples possess both the yield strength and the

Corresponding Author: [2]O.E. Olorunniwo, Department of Material Sciences and Engineering, Obafemi Awolowo University, Ile-ife. Osun state, nigeria

Sample	% Elongation	`% red. in area	Fracture strength N/mm^2	UTS N/mm^2	Yield strength N/mm^2	Hardness HRC	Impact (J)
10mm diam as- rolled	1.80	51.41	668.11	688.78	255.10	47.58	48.15
12mm diam. As –rolled	4.63	56.55	367.36	377.55	239.8	41.4	45.57
16mm diam as-rolled	7.81	61.26	213.64	221.94	147.96	37.45	41.40
As-cast	0.80	3.60	171.94	-	-	55.78	11.25

Table 1: The low alloy steel specimens used have the following composition in weight percent as below.

C	0.368	Sn	0.014
Si	0.226	Al	0.003
S	0.33	Zn	0.003
P	0.039	Mo	0.021
Mn	0/688	Cu	0.227
Ni	0.177	As	0.014
Cr	0.119	Co	0.013
V	0.002	Pb	0.001
W	0.003	Fe	98.055

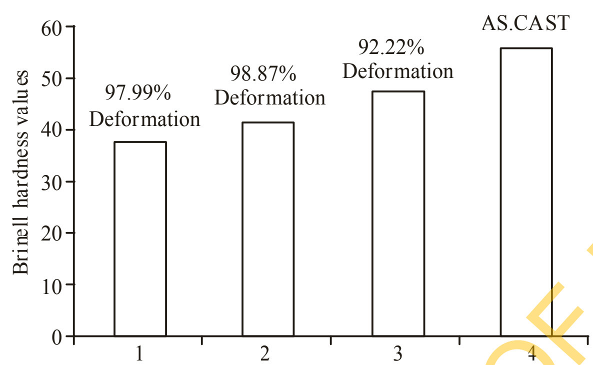

Fig. 1: Average hardness values.

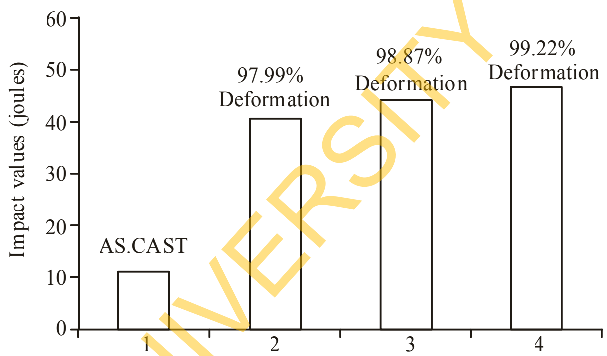

Fig. 2: Impact values

Ultimate Tensile Strength while the as-cast samples do not. Reasons that could be adduced to these are that, during the HTMT, the as-cast sample has its defective structure homogenized, blowholes and gas pores welded shut and atomic segregation reduced and internal stresses relieved[3]. These, coupled with hot plastic deformation as well as the presence of alloying elements (carbide formers such as nickel, titanium, etc), inhibiting dislocation movement, to effect strengthening with respect to Ultimate Tensile Strength (UTS) and yield stress[2,9].

Also, the as rolled (HTMT) samples are much more ductile than the as cast samples for the same reason cited above[6]. Conversely, the as-cast samples are harder than the as rolled due to the presence of inclusions, residual internal stress, residual coring and non-uniformity during solidification, which are virtually elimination by HTMT[1,8].

Conclusion: The application of HTMT on low alloy steel has led to the reduction in hardness while the strength and toughness increase considerably, compared to the as-cast samples. Hence, for applications that require adequate mechanical properties, high temperature themomechanically treated low alloy steel should be employed

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