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Investigation of the Potential of Jatropha Seed Oil as Austempering Quenchant for Medium Carbon Steel

Akor, T.[1] Ashwe, A.[2]

[1] Department of Mechanical Engineering, Nigerian Defence Academey Kaduna
[2] Department of Mechanical Engineering, University of Agriculture, Makurdi.

ABSTRACT: *This study investigates the suitability of jatropha seed oil as quenching medium for austempering medium carbon steel. Test samples were austenitized at 950^{0}C; socked for 1hr; austempered for varying periods of 1, 2, 3, 4 and 5hrs. The result showed significant increase in tensile strength and impact energy apart from achieving an appreciable increase in hardness. It also tally with recommended values of medium carbon steel austempered in salt bath, implying that jatropha oil can be used as hot bath for the austempering of medium carbon steel.*

KEY WORDS: *austempering, austenitized, bainite , socked, matrix.*

I. INTRODUCTION

Heat treatment can be defined as a process in which steels or alloys are acted upon thermally so as to change their structures and properties in the desired direction. Austempering heat treatment is a high performance isothermal heat treatment alternative to conventional quenching and tempering, that imparts superior performance to ferrous metals. It is a multi-step process that includes austenitizing, followed by cooling rapidly enough to avoid the formation of pearlite to a temperature above the martensite start (Ms) and then holding until the desired microstructure is formed, [1]. The metallurgical phase obtained is called bainite. In conventional heat treatment, parts are quenched to room temperature, and martensite reaction begins immediately which is actually a "non-uniform phase transformation" due to inside and outside temperature differences in the quenched part, [2]. This non-uniformity causes distortion and tiny micro-cracks to appear which reduce the strength of the part. However, during the austempering cycle, occurrence of bainite takes place over a longer period of time (many minutes or hours). This results in uniform growth, and a much stronger (less disturbed) microstructure.

Austempering is usually a preferred heat treatment especially to conventional quenching and tempering. This is mainly because this type of heat treatment offers:

- improved mechanical properties (particularly higher ductility or notch toughness at a given high hardness);
- a reduction in the likely hood of distortion and cracking which can occur in martensitic transformations;
- lower cost than that of conventional quenching and tempering. ;
- conventional quenching and tempering comprise a three step operation – that is, austenitizing, quenching and tempering, whereas austempering requires only two processing steps, [3].

Salt bath has been the conventional quenching medium for austempering heat treatment of steels. However, oils are among the quenching media of industrial significance. Oils of mineral and vegetable origins have been used as quenchants. The use of oils of mineral origin is however compromised by the film or nucleate boiling heat transfer they exhibit, resulting to lower-temperature cooling rates. This characteristic is absent in vegetable oils, where heat transfer is dominated by convective cooling, [4]. The cooling rate for vegetable oils is faster than that of comparable quenchants, making them suitable for austempering heat treatment. The cooling time-temperature and cooling-rate curves obtained show that the cooling properties of series of vegetable oils appear to be comparable to each other. The development of a quenchant from locally available vegetable oils as feed stock, especially the non consumable oils is expected to be a significant contribution to the foundry industry. Jatropha seed oil is non consumable vegetable oil which has little or no application in human nutrition.

In this study the potential of jatropha seed oil as austempering quenchant for medium carbon steel has been investigated .

II. METHODOLOGY

The raw materials used in this study include jatropha seed oil and medium carbon steel. The medium carbon steel was procured from Total Steel Kaduna. It was analyzed at the National Geosciences Research Laboratory Kaduna for the experimental work. The chemical composition of the steel is shown in Table 1. Jatropha seeds were harvested from Rafin Sewa Gora; Zango LGA of Kaduna State and processed for oil at National Research Institute for Chemical Technology, (NARICT), Zaria, Kaduna State.

Table 1**:** Chemical Composition of the Material

C	Mn	Si	S	P	Mg	Cu	Al	Balance
0.62	0.7	0.31	0.004	0.046	0.001	0.119	0.002	Fe

Due to the fact that the chemical composition of AISI 1080 steel is similar to that of medium carbon steel; TTT diagram of 1080 steel was used as a reference during this study. Samples for tensile tests and charpy impact tests were machined from the medium carbon steel procured from Total Steel. Prior to testing, the samples were austenitised at 950^0C for 1hr and then austempered in hot jatropha oil bath at 250 ^{0}C for varying periods of 1hr, 2hrs, 3hrs, 4hrs and 5hrs. After austempering samples were air cooled, after which they were washed with kerosene. Samples were tested in the as recieved and austempered condition. A minimum of three samples were tested for each heat-treatment condition. Screw-type samples (ASTM.A370-68) with 5mm diameter and 75mm gauge length were used for tensile tests. All tensile tests were performed at room temperature. Each sample was subjected to tension till fracture, at a strain rate 1.3x10-3s-1. The dimensions of the notched charpy samples were 5x5x50mm. Standard ASTM procedure defined with designation number E 23-93a (Standard test methods for notched bar impact testing of metallic materials) was employed in this study. The test consists of measuring the energy absorbed in breaking, by one blow from a pendulum. At least three samples were tested for each austempering period and an average value taken. Hardness test was done according to standard ASTM procedure defined with designation number E18–1989.

III. RESULT AND DISCUSSION

Fig. 1 displays the effect of austempering time on the tensile strength of medium carbon steel specimens austenised at 950 ^{0}C and austempered in hot jatropha oil bath maintained at 250 ^{0}C. It can be observed from the figure that the tensile strength of the medium carbon steel increased with increase in austempering time up to the optimum values at 5hrs. This increase in tensile strength is attributed to the formation of bainite in the matrix of the medium carbon steel, [5]. The figure indicates that the reaction is within stage one (Stage I reaction $\Upsilon_H \rightarrow \alpha + \Upsilon_{HC}$ -toughening); since there is no downward movement of the plot to indicate embrittlement as a result of the formation of cementite. Fig. 2 shows percentage elongation of the austempered medium carbon steel decreasing with austempering time. This is also in agreement with the stage I austempering reaction shown above. Fig. 3 shows the effect of austempering time on the hardness of medium carbon steel specimens austempered in hot jatropha oil bath. It is evident that as the austempering time increased the hardness values of the austempered specimens decreased to minimum value of 239BHN. Fig. 3 shows the effect of austempering time on the impact energy and hardness of medium carbon steel specimens austempered at 250 ^{0}C in hot jatropha oil baths. The impact energy values increase progressively with austempering time, whereas the hardness is observed to decrease with austempering time. This indicates a progression in the stage 1 reaction, increasing the amount of bainite in the matrix of the medium carbon steel. This is in agreement with [6].

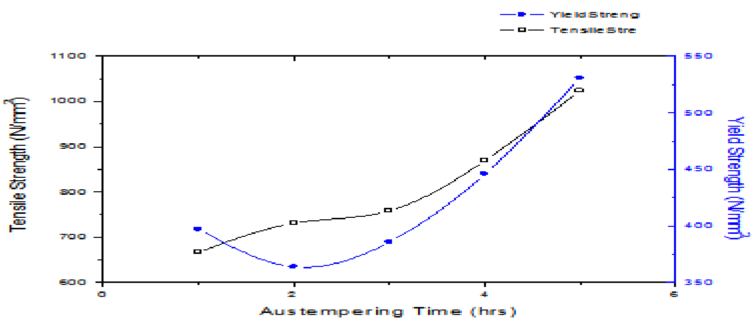

Figure 1: Effect of austempering time on the tensile strength and yield strength of medium carbon steel austenitized at 950^0C and austempered in hot jatropha oil at 250^0C for varying periods.

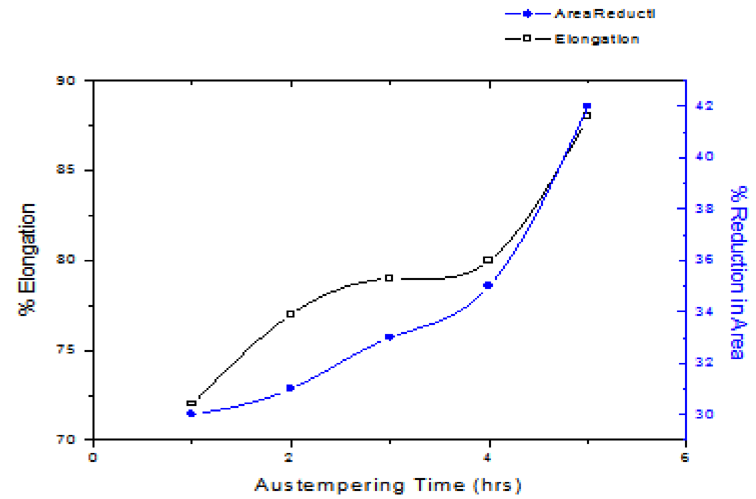

Figure 2: Effect of austempering time on percentage elongation and reduction in area of medium carbon steel austenitized at 950^0C and austempered in hot jatropha oil at 250^0C for varying periods

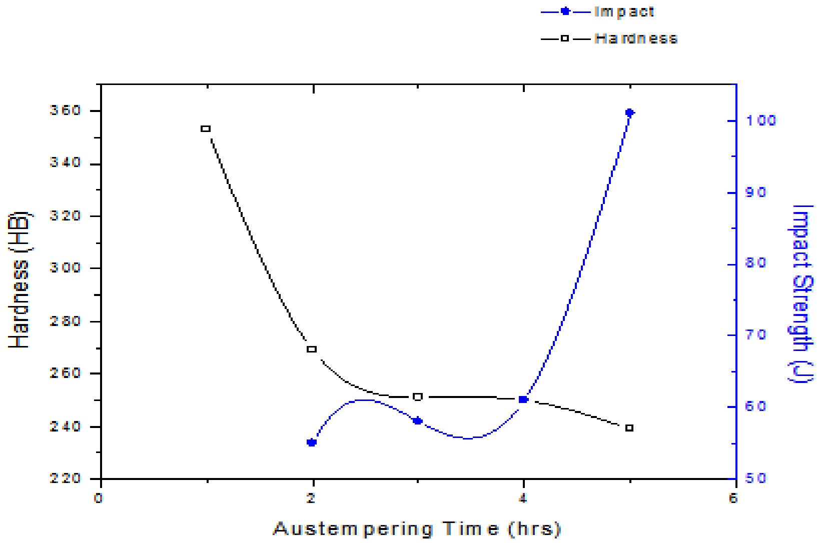

Figure 3: Effect of austempering time on Hardness superimposed on Impact strength values of medium carbon steel austenitized at 950^0C and austempered in hot jatropha oil at 250^0C for varying periods

IV. CONCLUSION

This research work investigated the potential of Jatropha, seed oils as austempering quenchants for medium carbon steel. From the observations and analysis of the results obtained, it can be deduced that; Jatropha was able to cause the formation of 'bainite' structure at 250 ^{0}C in the medium carbon steel. There is appreciable improvement in mechanical properties of the medium carbon steel when austempered in jatropha seed oil. The as-cast tensile, hardness and impact energy values of 570 N/mm^2; 196 BHN and 31J increased to 962 N/mm^2; 349 BHN and 47 J. The results indicate improvement in the mechanical properties of the ductile cast iron.

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