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A Study of the Relationship between Tensile Properties and Microstructure of Austempered Medium Carbon Steel using Rubber Seed Oil as a Quenching Medium

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Abstract: - *The relationship between tensile properties and microstructure of medium carbon steel which had its matrix toughened by an austempering process in rubber seed oil as quenchant was studied. The austempered medium carbon steel exhibits good mechanical properties with a unique microstructure consisting of a matrix of bainitic ferrite and retained austenite. The austempering time had effect on tensile properties (tensile strength(UTS), yield strength, percentage elongation, impact energy and hardness value). These properties have correlation with the microstructure of the austempered medium carbon steel. The results revealed that the yield and tensile strength of the medium carbon steel austempered in rubber seed oil was found to increase with an increase in austempering time up to 4 hrs when it attained a fully bainitic structure, and then decreases. The variation in the properties with the bainitic level reveals the relationship between mechanical properties and bainite content.*

Key words: austempering, austenitized, bainite, Rubber seed oil, socked.

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I. Introduction

Heat treatment can be defined as "a process in which ferrous alloys are acted upon thermally so as to change their structures and properties in the desired direction [1]. 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.

Austempering heat treatment is the isothermal transformation of a ferrous alloy at a temperature below that of pearlite formation and above that of martensite formation. It is a high performance isothermal heat treatment alternative to conventional quenching and tempering, that imparts superior performance such as increased strength, toughness, wear resistance, hardness and fatigue strength to ferrous metals, [3]. 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. The metallurgical phase obtained is a combination of acicular ferrite and fine, complex carbides called bainite, [4]. Bainite is basically classified as upper and lower bainite based on the morphology of the structures that result by different transformation characteristics because of the different temperatures at which the structures form. The main microstructural difference between upper and lower bainite is the carbide precipitation. In upper bainite, since the transformation temperature is high, the process is fast, thus carbon atoms do not have sufficient time to precipitate inside ferrite plates (laths). On the other hand, lower bainite formation reaction is slow due to relatively lower temperature which allows carbon atoms to precipitate inside the ferrite laths. Lower bainitic components have better mechanical properties than the upper bainitic components.

Austempering of steel offers several advantages than the conventional quenching and tempering such as increased ductility or notch toughness at a given hardness level. The likely hood of distortion and cracking which occur in martensitic transformation is reduced. This lessens subsequent machining time, sorting, inspection and scrap. Austempering also offers shortest time cycle to through- harden within the hardness range of 35 to 55 HRC. This results to saving in energy and capital investment.

Austempering is mostly carried out in a nitrate/nitrite salt bath, due to the advantages they offer compared to other hot baths like lead, mineral oils and polymer solutions. However, in recent years attention is been given to vegetable oils by many researchers, [6] and [7]compared the cooling time-temperature and the cooling rate curves of soy bean oils reported that vegetable oils exhibited faster cooling rates than the mineral oil used. A study on quenching properties of sunflower, coconut, palm, and groundnut oils by Prabhu, [8] compared the quench severities obtained with a petroleum oil. They reported that vegetable oils performed better than mineral oils in a decreasing order: Sunflower oil > Coconut oil > Palm oil > Groundnut oil.

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. Rubber seed oil is non consumable vegetable oil which has little or no application in human nutrition. In this study the potential of rubber seed oil as austempering quenchant for medium carbon steel has been investigated .

II. Experimental Procedure

The raw materials used in this study include rubber seed oil and medium carbon steel. The medium carbon steel was procured from Total Steel Kaduna. It was analyzed at Geosciences Laboratory Kaduna for the experimental work. The chemical composition of the steel is shown in Table 1. The rubber seed oil used for the investigation was obtained off shelf from the Rubber Research Institute, Okomo, Edo state.

Table 1: Chemical Composition of the Medium Carbon Steel

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

Table 2: Chemical composition of the rubber seed oil

Acid Value	Free Fatty acid	Saponification value mgKOH	Iodine Value g/100g	Peroxide value Meg/kg	Viscocity at 380C Mm2/sec	Flash point
34.4	17.2	198.6	76.80	160.3	87.2	250

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 850 and 950^{0}C for 1hr and then austempered in rubber seed oil bath at 250 ^{0}C and 300^{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. A minimum of three samples were tested for each heat-treatment condition. Screw-type samples (ASTM.A370-68) with 10mm 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 10x10x50mm, (ASTM E 23-93a) 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. Samples for metallurgical microscopy were prepared by standard metallurgical techniques, and then etched in 2% Nital. A metallurgical microscope was used to observe the microstructural change of the austempered medium carbon steel for various austempering temperatures and times.

III. Result And Discussion

The microstructure of the as-received medium carbon steel consists of ferrite (white) and pearlite as shown in Plate 1. The austempered medium carbon steel samples gave bainitic ferrite and retained austenite microstructures as expected. Features of the microstructure that promote strength are the fine structure of the bainitic ferrite needles, dispersed carbide, and low levels of retained austenite. This structure contributes to the low ductility, but higher levels of tensile strength and hardness value at low austempering temperature of 250^{0}C. The microstructures obtained for 1hr, 2hrs, 3hrs, 4hrs and 5hrs of austempering time are shown in plates 2 to 6. The medium carbon steel austempered for 1hr consists of bainite and boundry ferrite with retained austenite (see plate 2). At 2hrs austempering time the microstructure consists of more bainite and ferrite when compared to 1hr of austempering, and no martensite is seen in the microstructure.(plate 3).

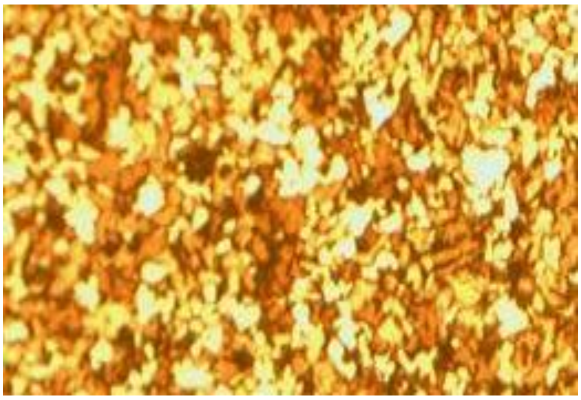

Plate 1: The as-received structure of medium carbon steel showing ferrite (white) and pearlite (dark); (x400)

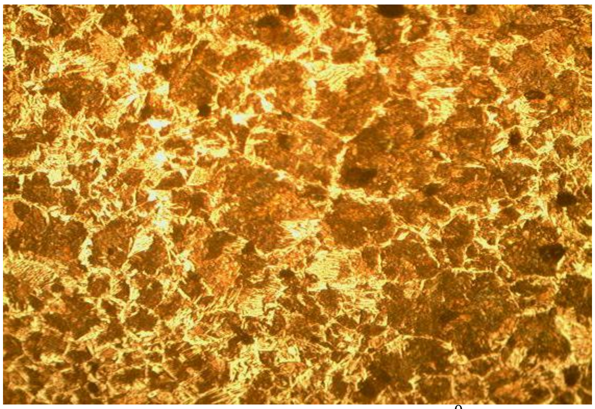

Plate 2: Structure of 0.62 % carbon steel austenitised at 950 ^{0}C, austempered in rubber seed oil at 250 ^{0}C for 1 hr, showing boundry ferrite (white) in matrix of bainite; (x400)

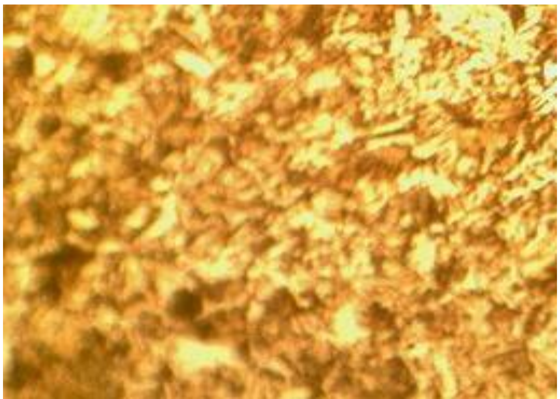

Plate 3: Structure of 0.62 % carbon steel austenitised at 950^{0}C, austempered in rubber seed oil at 250 ^{0}C for 2 hrs, showing mixture of ferrite in bainite; (x400)

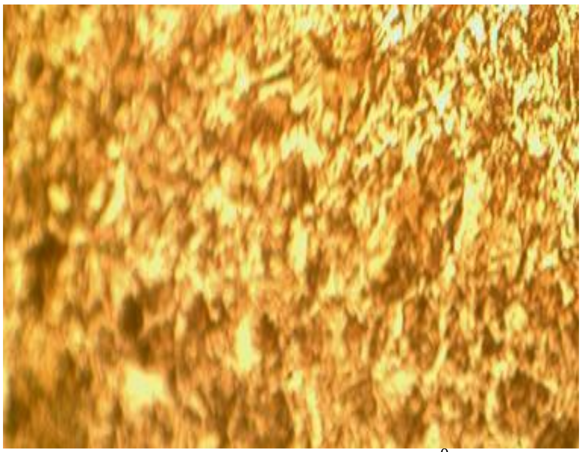

Plate 4: Structure of 0.62 % carbon steel austenitised at 950 ^{0}C, austempered in rubber seed `
oil at 250 ^{0}C for 3 hrs, showing dominance of bainitic phase; (x400)

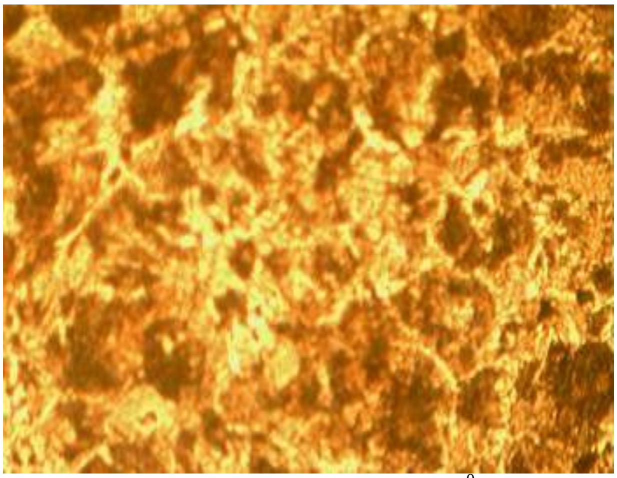

Plate 5: Structure of 0.62 % carbon steel austenitised at 950^{0}C, austempered in rubber seed
oil at 250 ^{0}C for 4hrs, showing bainite in retained austenite (x400)

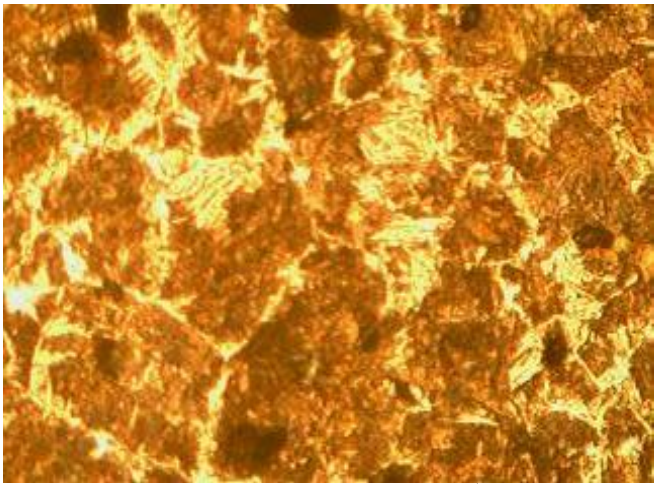

Plate 6: Structure of 0.62% carbon steel austenitised at 950^{0}C, austempered in rubber seed
oil at 250 ^{0}C for 5hrs, showing bainite in retained austenite; (x400)

At the longer austempering time of 3hrs, 4hrs and 5hrs; there was a substantial amount of bainitic ferrite and less retained austenite was observed. At the longer periods of austempering time, there was slight change in the tensile strength and hardness values but elongation and impact energy values decreased. Tensile strength of 876 N/mm^2, yield strength of 523 N/mm^2, impact energy value of 46J and hardness value of 265 BHN were obtained. The variation in the properties with the bainitic level reveals the relationships between mechanical properties and bainitic ferrite and retained austenite contents. Plates 7 to 11 shows the structure of medium carbon steel austenitized at 950^0C and austemperer in rubber seed oil at 300^0C. The structure consist mostly of bainite in retained austenite

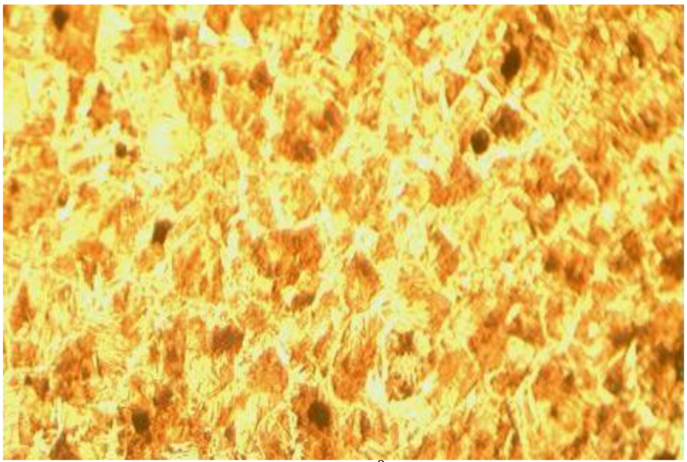

Plate 7: Structure of 0.62% carbon steel austenitised at 950^0C, austempered in rubber seed oil at 300 ^{0}C for 1hr, showing of ferrite in bainite; (x400)

Plate 8: Structure of 0.62% carbon steel austenitised at 950^0C, austempered in rubber seed oil at 300 ^{0}C for 2hrs, showing bainite in retained austenite; (x400)

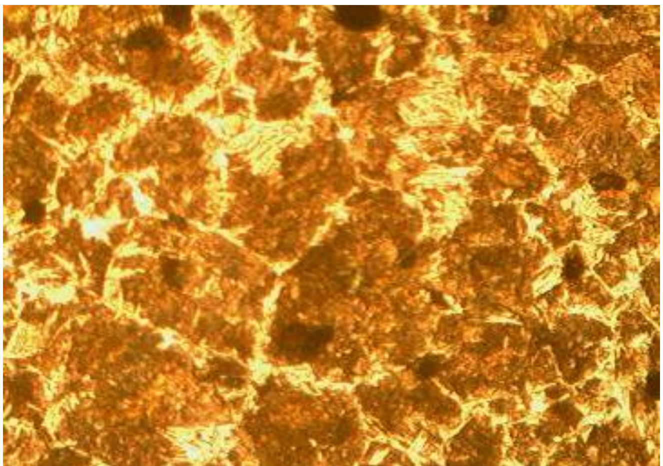

Plate 9: Structure of 0.62% carbon steel austenitised at 950^0C, austempered in rubber seed oil at 300 ^{0}C for 3hrs, showing bainite in retained austenite; (x400)

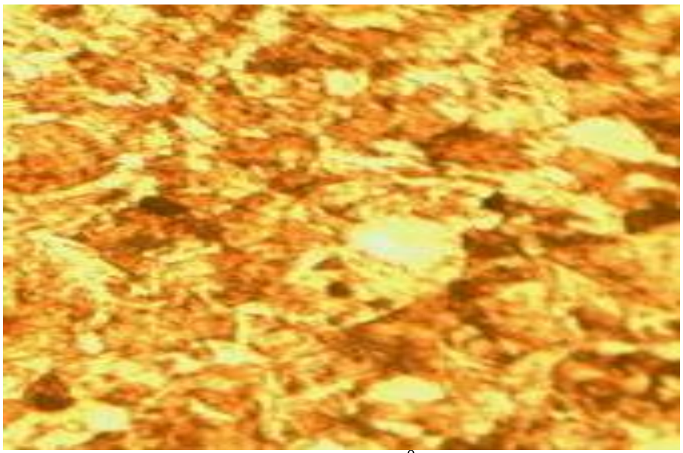

Plate 10: Structure of 0.62% carbon steel austenitised at 950^{0}C, austempered in rubber seed oil at 300 ^{0}C for 4hrs, showing bainite in retained austenite; (x400)

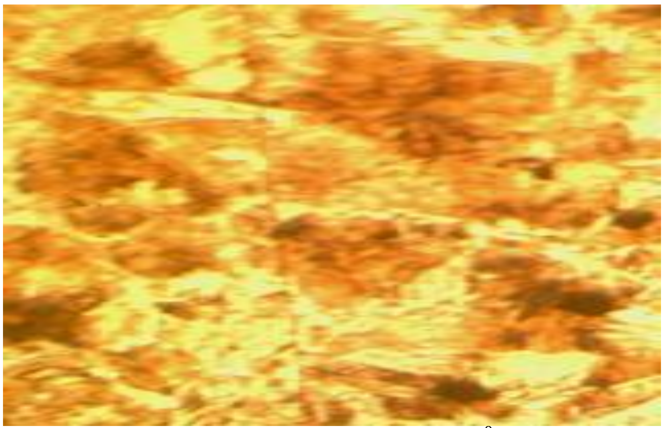

Plate 11: Structure of 0.62% carbon steel austenitised at 950^{0}C, austempered in rubber seed oil at 300 ^{0}C for 5hrs, showing bainite in retained austenite; (x400)

The variations of mechanical properties obtained for the medium carbon steel is shown in Figures 1–5. It is seen that the tensile and yield strengths are increased with increasing bainitic level in the matrix structure. The results show that the impact of energy increases to optimum values of 46 and 13J at at 4 hours of austempering at 250 and 300^{0}C and then decrease to 32 and 10J respectively as the austempering time increased beyound 4 hours (see Figure 1and 2). It is obvious from the result obtained, that the austempering temperature plays a role as it increases from 250 to 300^{0}C the morphology of the structure changes and consequently leads to increased impact toughness value. The low values of impact energy of some specimens could be connected to a decrease in the amount of retained austenite at longer austempering times. There was slight change in hardness values at higher austempering time. These hardness values clearly reflect the change in the mechanical properties. From the result of the study, the highest hardness value of 282 BHN was obtained at 250^{0}c for 2hours. Features of the microstructure that promote the hardness are the fine structure of the bainitic ferrite needles and low levels of the retained austenite. This structure contributes greatly to the high hardness values obtained at this low austempering temperature.

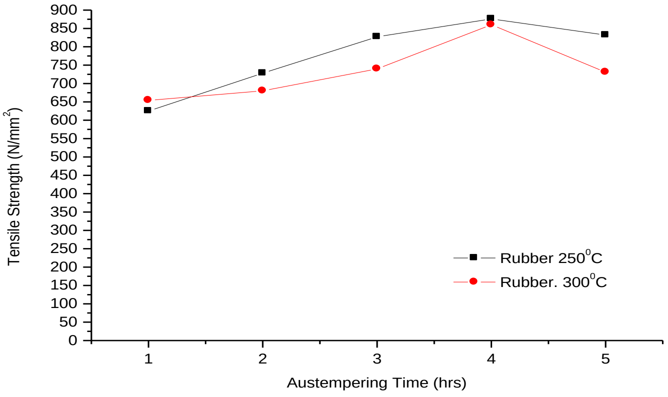

Figure 1: Tensile strength of medium carbon steel austentitized at 950 ^{0}C austempered in jatropha and rubber seed oils at 250 and 300 ^{0}C

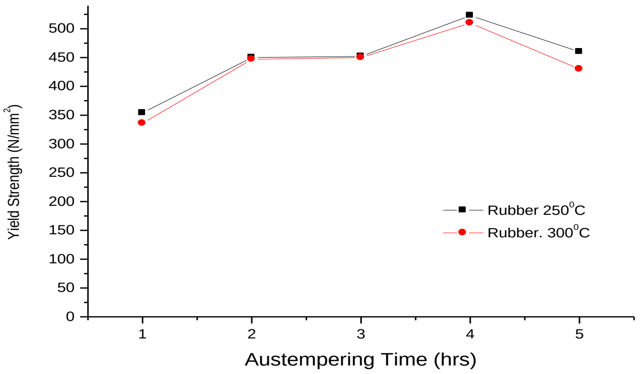

Figure 2: Yield strength of medium carbon steel austenitized at 950 ^{0}C austempered in jatropha and rubber seed oils at 250 and 300^{0}C.

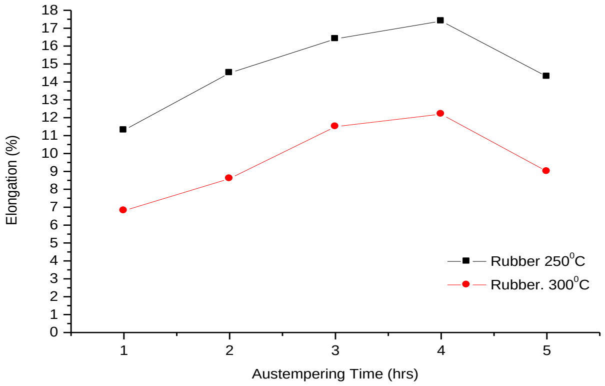

Figure 3:Percentage elongation of medium carbon steel austenitized at 950 ^{0}C austempered in jatropha and rubber seed oils at 250 and 300 ^{0}C

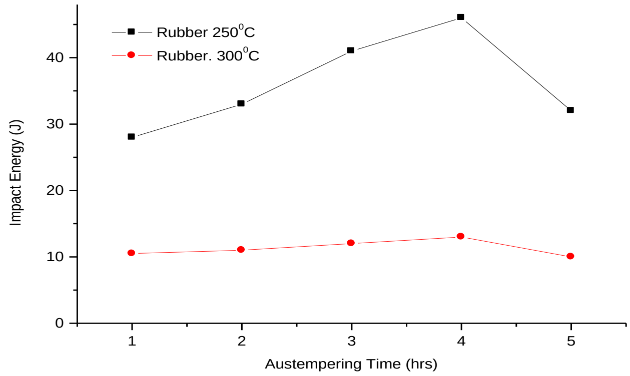

Figure 4: Impact energy of medium carbon steel austenitized at 950 ^{0}C austempered in jatropha and rubber seed oils at 250 and 300 ^{0}C .

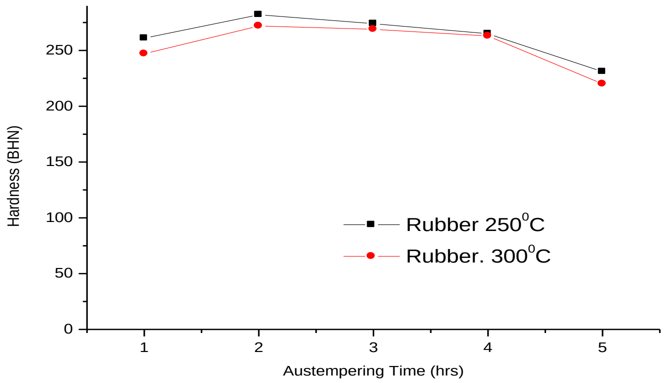

Figure 5: Hardness of medium carbon steel austenitized at 950 ^{0}C austempered in jatropha and rubber seed oils at 250 and 300 ^{0}C .

IV. Conclusion

The following conclusions are drawn from the results of the investigation carried out on the medium carbon steel austempered at two temperature levels and selected periods using rubber seed oil quenchant,

1. The microstructures consists of bainite and retained austenite. The variations in the properties with the bainitic level reveal the relationship between mechanical properties and bainitic and retained austenite contents. Sustainable amount of retained austenite was observed at 4 hrs austempering period where optimum combinations of mechanical properties were obtained and decreased as the time increased to 5 hrs austempering period. The tensile properties showed that the yield and ultimate tensile strength values are increased with increasing bainitic levels in the matrix structure. The impact strength and hardness values are also influenced significantly by the matrix microstructure

2. Good mechanical properties such as tensile strength as high as 876 N/mn^2, yield strength value of 531 N/mn^2 impact energy of 46 J and hardness value of 265 BHN were obtained.

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References

[1]. R. Maddin, Some thoughts on the Early Hardening of Iron. In: Olson, G.B and Owen, W.S. (eds) A History of Martensite. *Proceedings of American Society of Metals*. 2(1) 1992 480-482

[2]. O. P. Khanna, (A Textbook of Materials Science and Metallurgy 1st Edition, New Delhi, Dhampat Ra Public O. P. ations Ltd. 2002).

[3]. R. A. Harding Austempered Ductile Irons-Gears, *Materials and Design*. 6 (4). 1991 177 - 184.

[4]. P. Blackmore, 1st International Conference on Austempered Ductile Iron, *Materials and Design*.15: 117- 135

[5]. Metals Handbook, Heat Treating of Ductile Irons. 10th Edition, Ohio, American Society for Metals. Metals Park, USA (1981). pp300

[6]. O. Larry Proper Quenching Option yields. Retrieved from Modern Applications News. (2004). Pp 1- 5

[7]. K. N. Prabhu, and P. Fernandes, (Determination of Wetting Behavior, Spread Activation Energy, and Quench Severity of Bioquenchants. *Metallurgical and Materials Transactions B*.**38**(4):2007, 631-640

[8]. E. T. Daniel, K.. Elki, C. Souzal, E. Carvalho, de Souzal. Lauralice, F. C. and George, Effect of Antioxidants and Corrosion Inhibitor Additives on the Quenching Performance of Soybean Oil M.Sc thesis. Department of Materials, Aeronautic and Automotive Engineering; Engineering School of São Carlos- University of São Paulo CEP:13566-590, São Carlos, !SP, Brazil. (1999). PP 682