International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1482-1489 www.ijaem.net ISSN: 2395-5252

Effect of Martempering on Hardness and Fatigue Behaviour of Rst37-2 Steel

Agbadua Segun Afokhainu
National Engineering Design Development Institute, Nnewi, Nigeria,

Submitted: 15-07-2022 Revised: 27-07-2022 Accepted: 29-07-2022

ABSTRACT
One of the problems of design Engineers is how to increase service life of products and to achieve this feat the need to improve the strength of materials and this leads to this research. Fatigue has bedevilled service life of machines over time and efforts to improve on fatigue life of material leads to the study of martempering of Rst37-2 steel to improve on the service performance.
Rst37-2 steel was heated to austenite temperature and cooled drastically in a salt bath and the martensite obtained was further heated to 250^{0}C and soaked in it for two hours to reduce the hardness and brittleness and cooled in air for 24hours. The martempered steel was subjected to brinell hardness and fatigue test and results obtained were analysed.
The heat treatment process called martempering instilled ductility and toughness on Rst37-2 steel. The thermal gradient that exists between the surface and the center was reduced and the results show that martempered steel is tougher with a better wear resistance and fatigue resistance improves with time, while hardness strength reduces with time and becomes tougher and more ductile with age.
Keywords; Martempering, Rst37-2 steel, Martensite start time(Ms),Austenite

I. INTRODUCTION

Rst37-2 steel belongs to high strength steel and has many applications among which is riveting, bolting and welding purposes and is used in applications combining good welding properties with its guaranteed strength. Rst37-2 can offer super heavy steel plate of about 600mm thickness and it is used for making moulds, measuring tools, building ships, bridges and vehicles structure and all kinds of tools.

Hardness is the resistance to scratch and directly related to tensile strength is one of the properties of materials that is vital in selection of materials for machine construction. A material surface may be very hard and the interior soft and as such fails in a cyclic service environment before the predicted life and fails in a brittle fashion when subjected to stress and to increase the material performance heat treatment is done. Service environment is paramount in equipment design and as most equipment fail as a result of stresses. However, effort to improve on the service life of integral parts of machines leads to good materials selection and heat treatment method to be used on the candidate material to be used in the construction of the machine not undermining the service environment. Steel has been used for engineering designs and construction for some decades and in service do experience several challenges amongst which is fatigue(agbadua etal 2011).

Fatigue is the failure experienced by a machine in service as a result of dynamic loading of the machine and the material fails at a stress lower than the ultimate stress. Fatigue failure that was known long ago has developed to a major source of worry in modern technology as it accounts for most of the failures due to mechanical causes and it occurs without warning with dire consequences(Orumwense etal, 2016) and other areas where fatigue poses a great threats are; automobiles, compressors, aircrafts, pumps and turbines. A martempered Rst37-2 steel exhibits a good combination of ductility and toughness. Though fatigue life can be addressed by care in design, fabrication and maintenance and proper selection of materials, it could be enhanced further by the use of phase transformation mechanisms that could lead to the development of other steel products like bainite steels with better fatigue resistance.

Heat treatment is the treatment of engineering materials to improve on the properties of the material for its suitability as the choice for the service. Martempering is a type of heat treatment that involves two processes; Quenching and Tempering. The steel is heated to austenitic temperature 910^{0}C and cooled drastically without allowing complete alignment of crystals to form ferrite and pearlite leads to the formation of martensite and the material formed is hard and brittle. The martensite is further heat treated by tempering at temperature range of 180-250^{0}C and holding it for a sufficient time for the temperature to become uniform and air cooled and it leads to improve ductility and toughness and crystals alignment.

Martempering is a process employed to minimise the distortion without trading off the hardness and the austenitized metal part is immersed in a bath at a temperature just above the martensite start temperature (Ms). The use of interrupted quenching leads to the stoppage of cooling at a point above the martensite transformation region to ensure sufficient time for the center to cool to the same temperature like the surface. The metal is removed from the bath and cooled in air to room temperature to allow the austenite transform to martensite. Martempering is a method by which the stresses and strains generated during the quenching of a steel component can be controlled. Abbasi, F. etal(1987), Yazıcı, A (2012).Tempering relieves stresses produced due to quenching and converts any retained austenite to pearlite, thus reducing the possibility of spontaneous transformations that can lead to cracking (e-funda engineering fundamentals, 2006).

To determine the effect of martempering on hardness and fatigue behaviour of Rst37-2 steel and the steel was heated above the upper critical point and then quenched in a salt bath kept at a temperature of 180-250° C and finally held at a temperature above martensite(Ms) until the temperature becomes uniform throughout the cross-section of the workpiece and cooled in air to room temperature.

II. MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 Rst 37-2 STEEL

Rst37-2 steel was used in the study with Fe-0.15C. The Chemical composition of the steel was done at Material Science and Engineering laboratory in Obafemi Awolowo University (OAU) Ife and the result is shown in table1 below.

Table 1: Chemical Composition of Rst37-2 Steel

Element	C	Mn	Si	N	P	S	Na	K	Cr	Cu	Fe
Avg	0.15	0.5	0.23	0.01	0.04	0.07	0.04	0.04	0.10	0.25	98.4

2.1.2 Fatigue Testing Machine (Avery Dennison7305 Model)

The load is imposed at one end of the specimen by an oscillating spindle driven by means of a connecting rod, crank and double eccentric. The load is measured at opposite end of the specimen by means of a torsion dynamometer and the angle of twist is registered on dial gauges. Three dynamometers are supplied and calibration curves are provided giving the relationship between dial gauge reading and imposed torque.

2.1.3 Furnace

The furnace is a carbon muffle type with an attached thermocouple that operates at a temperature range of 0^{0}C-1200^{0}C.

2.1.4 Acuscope Camera

The camera has a magnification of X 400. It was used to snap the specimen in order to reveal the microstructure.

2.1.5 Universal motion Inc

Hardness test was done using Universal motion Inc. The machine has different indenter that is impressed on the material to be tested and the indentation measured with the aid of a microscope. The readings were taken and the average obtained for precision.

2.2 METHODS

Rst 37-2 steel was acquired from a local market in lagos and the compositional analysis was done to ascertain the chemical composition and was heated in the muffle furnace to austenitic temperature of 928^{0}C and soaked for 25 minutes and fast quenched in a salt bath to get martensite and the martensite obtained was tempered at a temperature of 250^{0}C and soaked for two(2) hours and then air cooled.

Hardness test was done on the bought Rst 37-2 steel and the heat treated one to see the effect of martempering on the hardness properties of the material using Brinell hardness testing machine. The test was performed every three days for a period of seven times and the results used to plot a graph of Hardness against time. The following equation was used for the readings.

$$BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2}} \quad 1$$

BHN=Brinell Hardness Number, P=applied Force(Kg), D= Diameter of the ball(mm), d=diameter of indentation depth(mm)

The stair case method was used in applying the moment and the applied bending moment was increased by a fixed increment and the next specimen was tested with the new bending moment. The material was subjected to 40, 80, 120,160, 200Kgfcm and when the material failed the applied moment was increased. Five samples of the exposed materials were subjected to fatigue test every other three days respectively; 3, 6, 9, 12, 15, 18 and 21days with Avery Dennison fatigue(Avery model 7305) testing machine. The numbers of days chosen for this experiment was to observe the martempered Rst 37-2 steel behaviour and be able to predict its performance with time.

III. RESULTS AND DISCUSSION

The Rst37-2 steels used in this research were isothermally transformed into martensitic steel from the austenitic temperature and finally tempered at the temperature of 250^0C and soaked for two(2) hours and quenched in the air for 24hours.

3.1 Hardness

Figure 1 is the plot for hardness against time. It was observed that hardness of the sample without treatment is the lowest with 103BHN while the hardness for the three days exposure in the environment is the highest and the hardness start to decrease on day 12 and 15 it shows constant hardness. The hardness decreases further from day18 and 21

3.2 Fatigue

Figure 2 shows the plot of stress against No of cycles after the heat treatment process and it shows appreciable fatigue resistance to applied stress. Figure 3, is a plot for the material exposed to the environment for three days. A weak resistance to the applied stress was observed. Figure 4, shows the fatigue behavior of Rst 37-2 steel exposed to the environment for 6days and it shows appreciable fatigue resistance. Figure 5 shows the fatigue behavior of the material exposed to the environment for 9days to the applied stress and the fatigue behavior is like non ferrous material. Figure 6 shows the fatigue behavior of the specimen that was exposed to air for 12 days. The fatigue resistance was bad.Figure 7 shows the fatigue resistance of the specimen in air for 15days. The fatigue resistance is bad compared to other days. Figure 8 shows the plot of fatigue behavior of material in the environment for 18days and the result shows that the resistance to applied stress is bad.figure9 shows the fatigue behavior of the material in the environment for 21days. The fatigue resistance was better compared to other days the material was tested. The fatigue resistance on day 21 is better than the specimen that was not martempered. From the plots 2-9 the fatigue resistance fatigue resistance increases with Age.

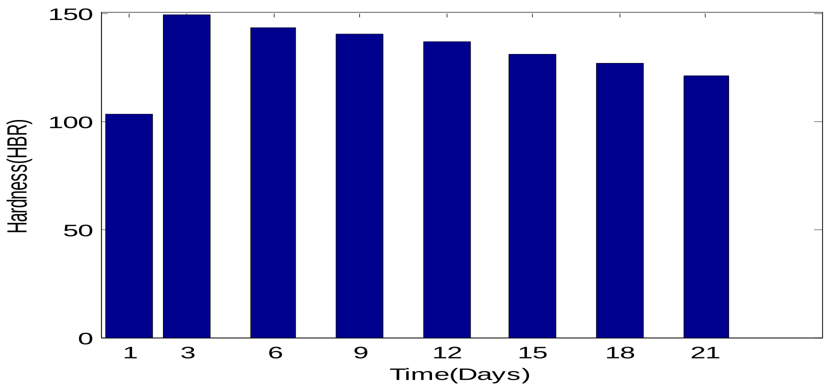

Figure 1:The graph of hardness(HBR) against Time(Days)

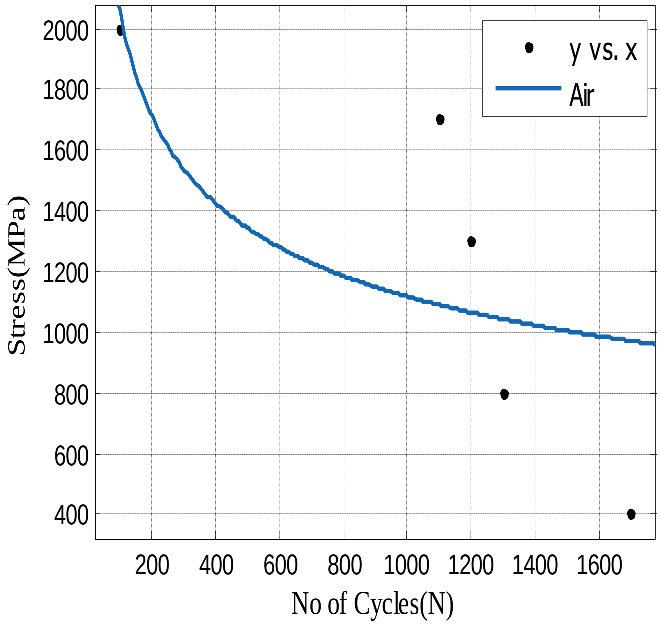

Figure 2: Fatigue Resistance (MPa) against Number of Cycles to Failure (N) of Rst-37-2 steel in As-received

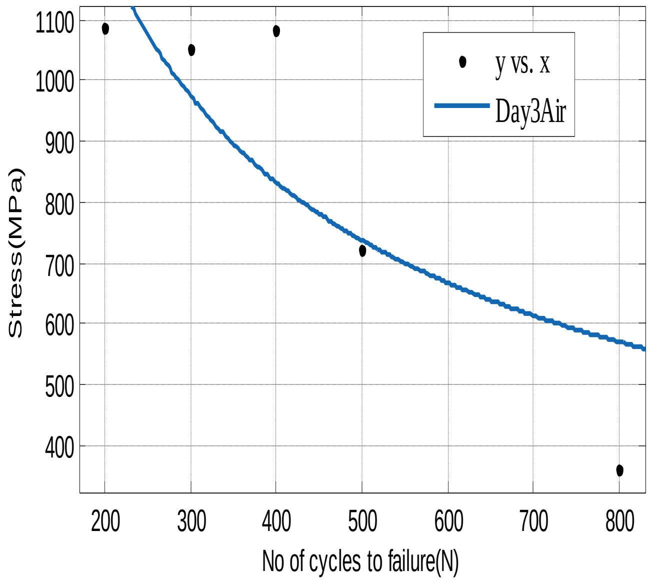

Figure3: Fatigue Resistance(MPa)against Number of cycles to failure(N) for a martempered Rst37-2 steel for three days exposure to air.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1482-1489 www.ijaem.net ISSN: 2395-5252

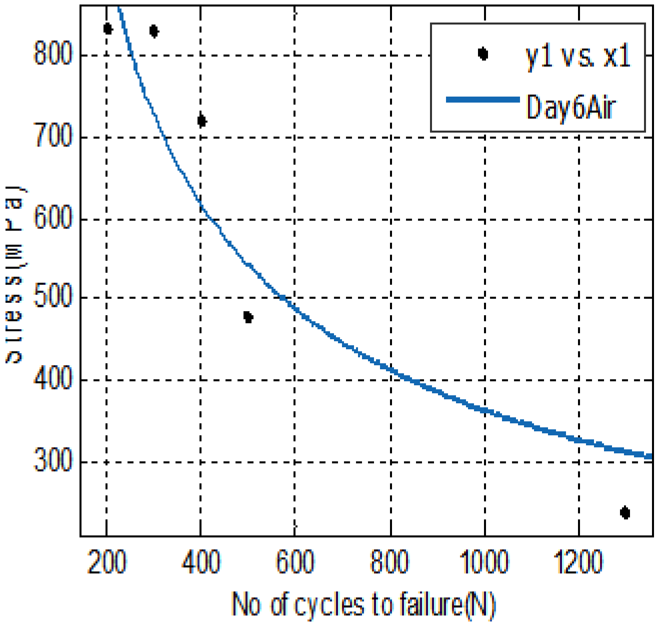

Figure4: Fatigue Resistance(MPa)against Number of cycles to failure(N) for a martempered Rst37-2 steel for Six days exposure to air.

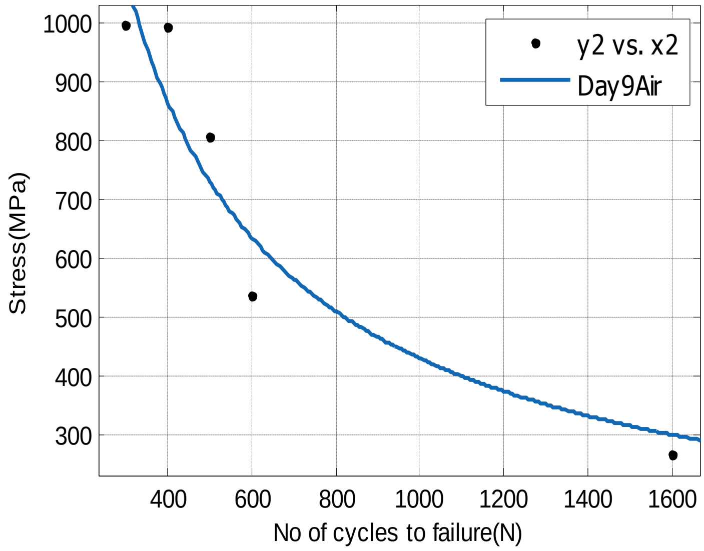

Figure5: Fatigue Resistance(MPa)against Number of cycles to failure(N) for a martempered Rst37-2 steel for Nine days exposure to air.

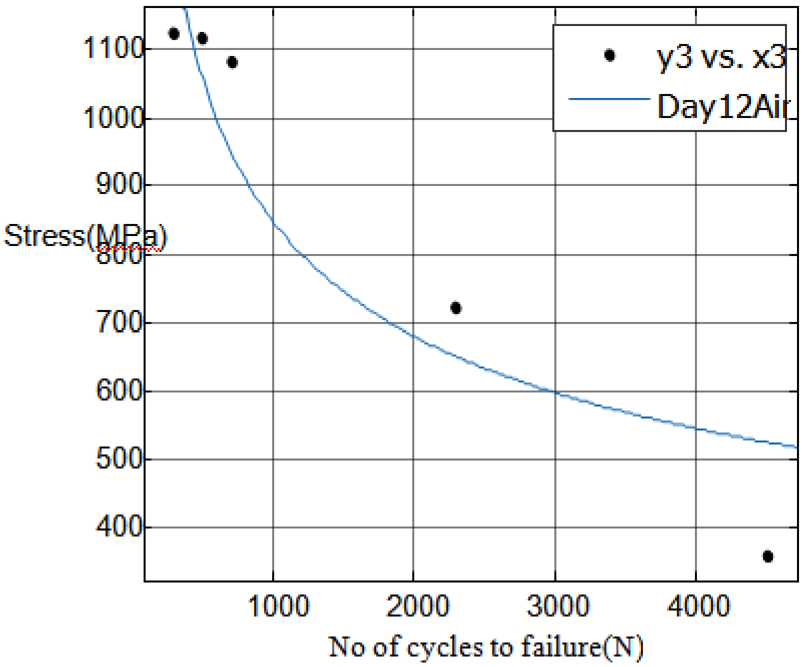

Figure 6: Fatigue Resistance(MPa)against Number of cycles to failure(N) for a martempered Rst37-2 steel for Twelve days exposure to air.

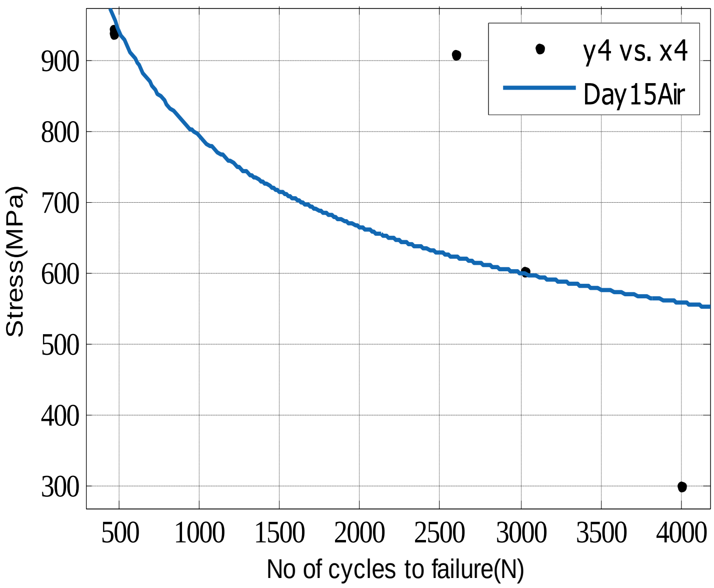

Figure 7: Fatigue Resistance(MPa)against Number of cycles to failure(N) for a martempered Rst37-2 steel for fifteen days exposure to air.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1482-1489 www.ijaem.net ISSN: 2395-5252

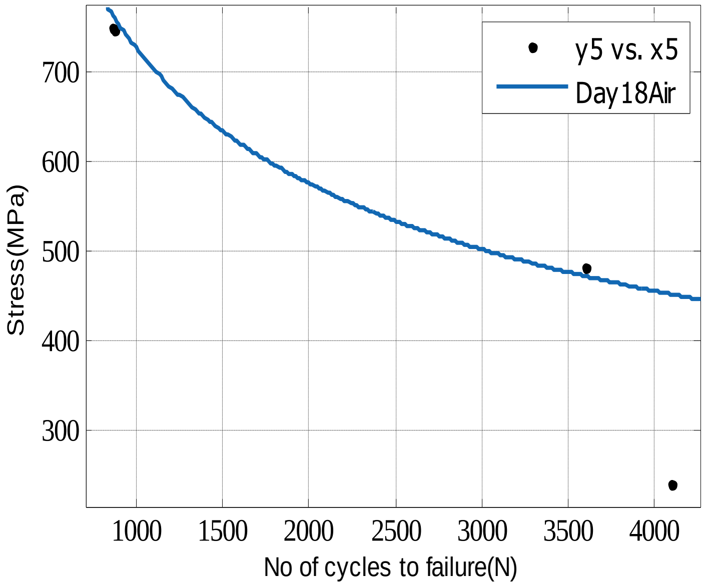

Figure 8: Fatigue Resistance(MPa)against Number of cycles to failure(N) for a martempered Rst37-2 steel for Eighteen days exposure to air.

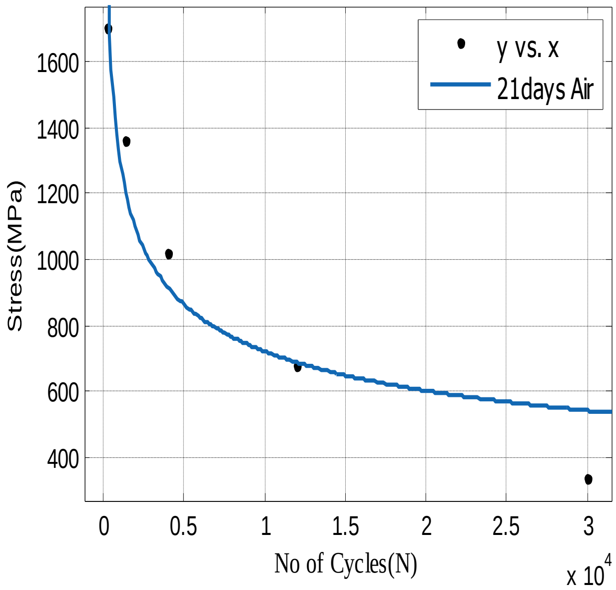

Figure 9: Fatigue Resistance(MPa)against Number of cycles to failure(N) for a martempered Rst37-2 steel for twenty days exposure to air.

IV. CONCLUSION

It can be deduced that hardness strength of martempered Rst37-2 steel is inversely proportional to the fatigue strength. Reason, hardness strength decreases with time while the fatigue strength increases with time and hardness a function of fatigue strength.

The effect of martempering on Rst37- 2 steel is that it impacts toughness and ductility and it equally reduces distortion that could cause micro-cracks as a result of even distribution of hardness strength in the thickness and the tempering of martensite relieves stresses and converts the retained austenite to pearlite and reduces the transformation that could lead to cracking.

The fatigue behavior of the martempered Rst37-2 steel improves with time while the hardness decreases with time and the martempering instill hardness on the entire thickness of Rst37-2 steel.

Since hardness is directly related to wear resistance, conclusion could be drawn that martempering increases the wear resistance of Rst37-2 steel.

REFERENCES

[1]. Segun Afokhainu Agbadua, etal (2011) Thermal Cycling Effects on the Fatigue Behaviour of Low Carbon Steel Journal of Minerals and Materials Characterization and Engineering 10(14)

[2]. Agbadua S.A. (2017), Comparative analysis of the effect of thermal cycling in fatigue behaviour of low and medium carbon steel American Journal of Mechanical and Industrial Engineering Science Publishing Group

[3]. Orumwense F.F.O. Emonena O.H. Agbadua S.A.(2016) Influence of Bainitic Transformation on Fatigue Behaviour of Medium Carbon Steel American Journal of Mechanical and Industrial Engineering Science Publishing Group

[4]. Abbasi, F. Fletcher, A.J. Soomro, A.B. (1987). "A critical assessment of the hardening of steel by martempering". International Journal of Production Research. 25 (7): 1069. doi:10.1080/00207548708919896.

[5]. Yazıcı, A (2012). "Investigation of the Wear Behavior of Martempered 30MnB5 Steel for Soil Tillage". Transaction of the ASABE. 55 (1): 15–20. doi:10.13031/2013.41243.

[6]. e-funda engineering fundamentals, 2006