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"Impact Of Heat Treatment on Mechanical and Corrosion Properties of Stainless Steels"

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ABSTRACT

Stainless Steel utilized in an extensive variety of packages which includes plane, mechanical device and railways. Stainless metal is most effective makes use of in primary enterprise however also can be utilized in non-primary enterprise which include watch production that includes micro length of elements. Stainless is an iron alloy containing 0.02 to 2.14% of C, Cr content material more than 12% and different alloying elements. Engineering materials, broadly speaking metal, are warmth handled below managed collection of heating and cooling to regulate their bodily and mechanical homes to satisfy favoured engineering application. In this study, the impact of Solutionization warmth remedy at the microstructures, a few decided on mechanical homes and corrosion homes of chrome steel have been studied. Solutionization is the method of heating to 1050^0C temperature and air cooled to get unmarried section homogeneous austenite section. the microstructure of the pattern changed into tested the use of metallographic microscope. The metal samples have been warmth handled in an electric powered tubular furnace at specific temperature stages and steady soaking instances after which cooled in air cooling. Rockwell and Brinell hardness values of warmth handled and untreated samples have been decided the use of popular methods. Corrosion research of warmth handled and untreated samples have been decided through the use of weight reduction size and potenitiostatic curves and corrosion price values are compared.

Keywords: *Stainless Steel, Corrosion, Heat Treatment, Alloy*

1. INTRODUCTION

In 1913, English metallurgist Harry Brearly, working on a project to improve rifle barrels, accidentally discovered that adding chromium to low carbon steel gives it stain resistance. In addition to iron, carbon, and chromium, modern stainless steel may also contain other elements, such as nickel, niobium, molybdenum, and titanium. Nickel, molybdenum, niobium, and chromium enhance the corrosion resistance of stainless steel. It is the addition of a minimum of 12% chromium to the steel that makes it resist rust, or stain 'less' than other types of steel. The chromium in the steel combines with oxygen in the atmosphere to form a thin, invisible layer of chrome-containing oxide, called the passive film. The sizes of chromium atoms and their oxides are similar, so they pack neatly together on the surface of the metal, forming a stable layer only a few atoms thick. If the metal is cut or scratched and the passive film is disrupted, more oxide will quickly form and recover the exposed surface, protecting it from oxidative corrosion. (Iron, on the other hand, rusts quickly because atomic iron is much smaller than its oxide, so the oxide forms a loose rather than tightly-packed layer and flakes away. The passive film requires oxygen to self-repair, so stainless steels have poor corrosion resistance in low-oxygen and poor circulation environments. In seawater, chlorides from the salt will attack and destroy the passive film more quickly than it can be repaired in a low oxygen environment. Stainless steel is an iron-containing alloy, a substance made up of two or more chemical elements. Stainless steel is characterized by having chromium content greater than 12 %. Generally stainless steel is an alloy that distributed into four different groups. The group is Austenitic, Ferritic, Duplex and Martensitic. In treatment of stainless steel, heat is used as an option to give better structure and strength of its physical properties. Usually, types of heat treatment process depend on the type of alloy and the application.

2. MATERIALS AND METHODS

2.1. Heat treatment, hardness tests, optical microscopy and corrosion studies of the stainless-steel sample were done step wise with illustrations is as follows.

- Heat treatment of the stainless-steel samples at 550^0C, 580^0C, 620^0C and 680^0C were done in muffle furnace.
- Rough polishing of the samples using belt grinder.
- Smooth polishing of the sample using emery papers.
- Obtaining the mirror image by polishing with diamond paste on a dual disc polisher.
- Etching of the samples
- Optical microscopy and image analysis of the samples.
- Brinell hardness testing of the samples.
- Potentiodynamic studies of the samples by using electrochemical system.

3. EXPERIMENTAL PROCEDURE

3.1.Heat Treatment Method

The six stainless steel samples are heat treated to Condition A (heated to 1050^0C and air cooling) in electrical tube furnace. Again, those samples are heat treated at different temperatures and different soaking times and air cooled. The temperatures and soaking time are as listed in table.

Table 1.1: Solution Heat Treatment

Solution treated 1050^0c and air coolbelow (condition A)	Temperature(^{0}c)	Soaking time	Type of cooling
	550	4hr	Air
	580	4hr	Air
	620	4hr	Air
	680	4hr	Air

3.2.Brinell hardness Method

In the Brinell hardness test, a tough spherical indenter is pressed below a set traditional load onto the graceful surface of a material. once the equilibrium is reached, the load and therefore the indenter are withdrawn, and the diameter of the indentation shaped on the surface is measured employing a magnifier with a constitutional millimetre scale. The Brinell hardness is expressed because the quantitative relation of the indenter load W to the world of the acetabular (i.e., contact) surface of the spherical indentation that's assumed to support the load and is given as Brinell hardness variety (BHN).

Where, P – Applied Load in kg, D – Diameter of indenter in mm. d – Diameter of indentation in mm.

3.3.Metallography Testing

Metallography is that the bailiwick of examining and determining the constitution and also the underlying structure of (or spatial relationships between) the constituents in metals, alloys and materials (sometimes referred to as materialography). the foremost acquainted tool of metallography is the light-weight microscope. Optical (light) characterization of the microstructures of metals and alloys involves the identification and activity of phases, precipitates, and constituents, and the determination of the scale and form of the grains.

Corrosion Studies:

Corrosion resistance of Austenitic Stainless Steels were studied by two techniques.

- Weight loss method
- Electrochemical method

3.3.1. Weight Loss Method

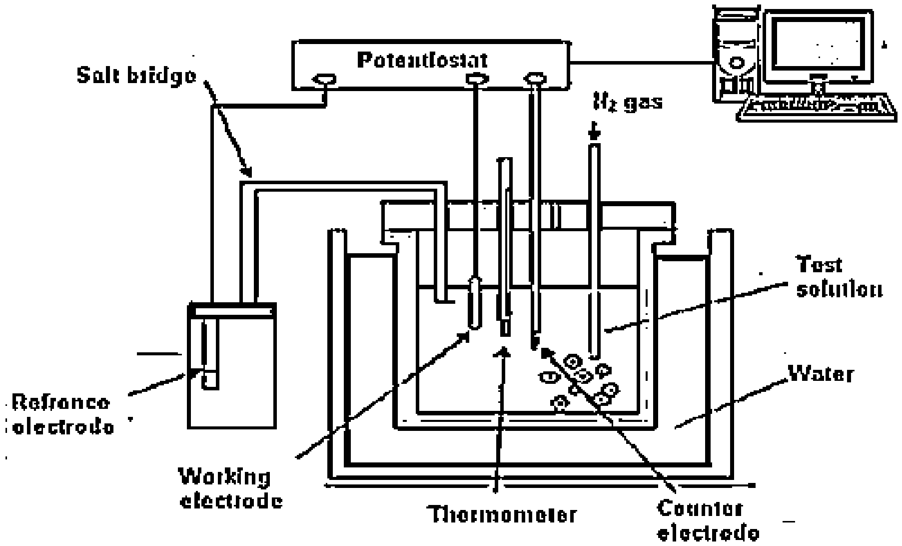
esults which are in the below table shown that weight loss and corrosion rate. is high for solution treated aged 580^{0}C sample followed by just solutionised sample at 1050^{0}C.weight loss and corrosion rate are very less for solution treated aged 520^{0}C sample. The results shows that we can get less weight loss and corrosion rate only at some optimum aged temperatures. The corrosion rate was calculated by using the below formula:

$Corrosion\ rate\ (mpy) = 534\ w/\ \rho AT$

Where, w is the weight loss of the sample (mg), ρ is the density (gcm-3), A is the surface area of the sample (in2) and T is the time (hour).

3.3.2. Electrochemical Method

To examine the consequence of heat treatment on the corrosion comportment. Electrochemical tests were conducted on the solutionised and aged samples in 1N HCl. confirmations a customary of budding, E vs I logarithm subversions of the utter charge of the contemporary density, Icorr, for solutionised and aged samples. In electrochemical method by using electro chemical workstation or potentiostat we measure the corrosion rate by potentiostat we do the potentiodynamic studies from



his we get Tafel plots which

Fig.1.1: Electrochemical Testing Setup

are drawn between log (E) VS log (I). from this we drawn tangents on this graph to known the Icorr Values from taking average of 3 I_{corr} Values.

By using this Icorr values.

We calculate the corrosion rate by using below formula.

$Corrosion\ rate\ (mm/yr) = K(icorr)\ EW/\ p$

CR is given in mm/yr., Icorr in μ A/cm^2, K=0.00327mm g/ μ A cm yr

ρ= 7.97 density in g/cm3

EW= Equivalent Weight=25.50(for stainless steels)

4. RESULTS AND DISCUSSION

4.1.Microstructure Results

❖ **Microstructure of solution treated stainless steel at 1050^{0}C at 500X**

In general, the austenitic stainless steels are solution treated at 950^{0}C – 1250^{0}C to homogenize the microstructure and chemical composition. In addition to homogenization this treatment removes the residual stresses and to recrystallization. Some alloys due to their low carbon content do not need a solution treatment due to their carbide formation, but benefit from a solution treatment to achieve maximum corrosion resistance. The austenitic stainless steels samples in this study were solution treated at 1050^{0}C and soaking for an hour followed by air cooled to area temperature. The optical micrograph of resolution treated sample at 1050^{0}C reveals that the homogenized solid solution with fine grains containing some little amounts of carbides on the grain boundaries.

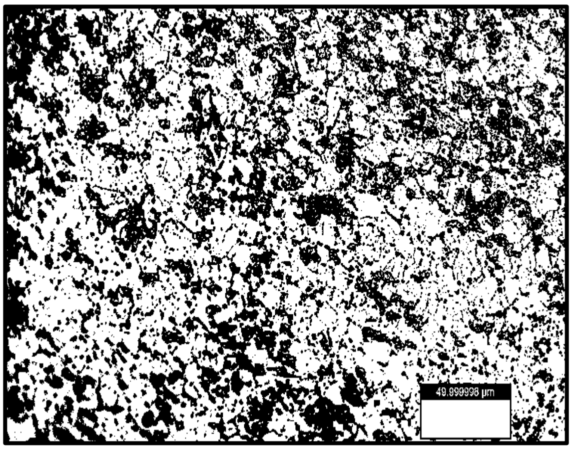


Fig.1.2: Optical micrograph of solution treated stainless steel at 1050^{0}C at 500X

❖ **Microstructure of solution treated + aged at 550^{0}C**

After answer remedy system a low temperature age hardening level is hired to attain the desired properties, as this remedy executed at low temperatures no distortion happens and for the duration of the hardening system a moderate lower in length takes place. The answer handled austenitic stainless steels have been subjected to an getting older remedy with an goal of figuring out the impact of getting older temperature on microstructure of homogenized austenitic stainless steels that might impart a nice stage of mechanical properties. In order to attain the above intention one of the homogenized austenitic chrome steel samples on this look at turned into elderly at 5500C and soaking for 4hours accompanied via way of means of air cooled to room temperature. And this elderly remedy pattern turned into tested in optical microscope. The optical micrograph of this pattern is provided in beneath Fig. The resultant optical micrograph well-known shows that the formation of carbides alongside the grain barriers without affecting the grain length.

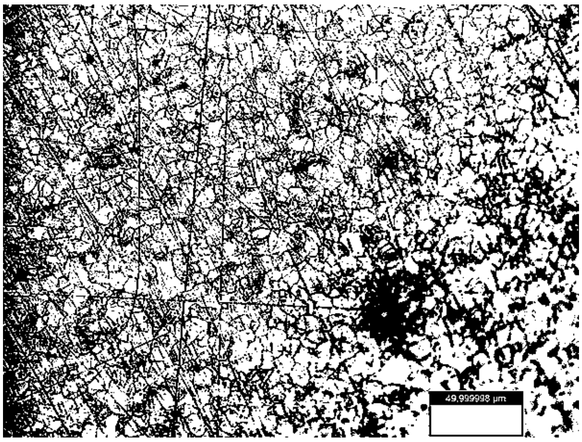


Fig.1.3: Optical Micrograph of solution treated + aged at 550^{0}C at 500X

❖ **Microstructure of solution treated + aged at 580^{0}C**

The microstructure of austenitic stainless steel which was solution treated + aged at 580^{0}C and soaking for 4 hours followed by air cooling to room temperature is shown in fig. It can be seen that the ageing treatment at 580^{0}C results in slightly coarsened the size of the carbides while grain size is remains unchanged. The volume fraction of carbides also increases.

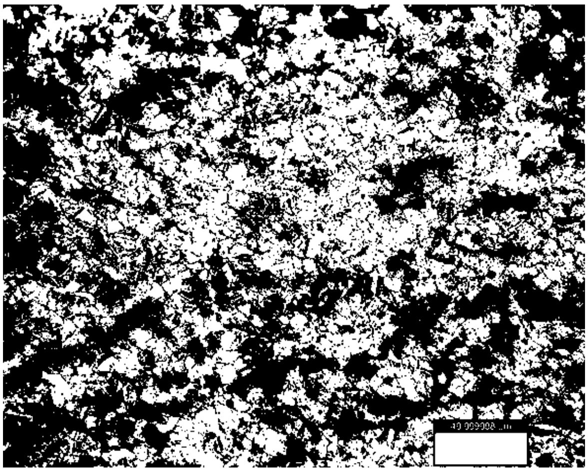


Fig.1.4: Optical micrograph of solution treated + aged stainless-steel at 580^{0}C at 500X

❖ **Microstructure of solution treated + aged at 620^{0}C**

The microstructure of austenitic stainless steel which was solution treated + aged at 620^{0}C and soaking for 4 hours followed by air cooling to room temperature is shown in fig. It can be seen that the ageing treatment at 620^{0}C results in significant change in volume fraction and size of the carbides. It reveals that the volume fraction of carbides decreases by dissolving the fine carbides and also it is observed that the increasing the grain size of the austenite takes place.

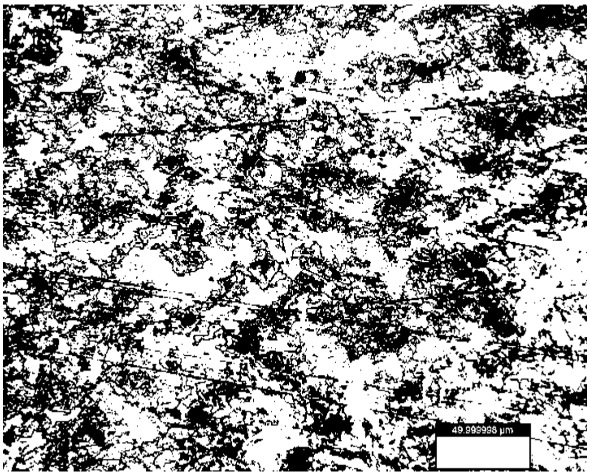


Fig.1.5: Optical micrograph of solution treated + aged stainless steel at 620^{0}C at 500X

❖ **Microstructure of solution treated + aged at 680^{0}C**

The microstructure of austenitic stainless steel which was solution treated + aged at 680^{0}C and soaking for 4 hours followed by air cooling to room temperature is shown in fig. It can be seen that the ageing treatment at 680^{0}C results in optimum grain size of austenite and it is also observed that the increasing of volume fraction of carbides with optimum size of carbides along the grain boundaries takes place.

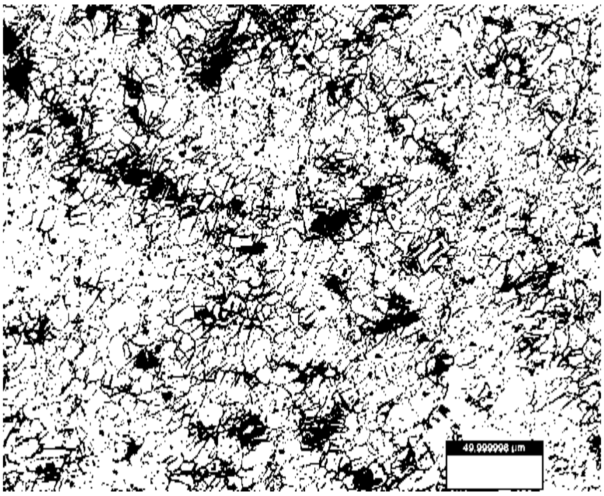


Fig.1.6: Optical micrograph of solution treated + aged stainless steel at 680^{0}C at 500X

4.2.HARDNESS VALUES

The mechanical properties of stainless steels mainly depend on the microstructure and heat treatment. Therefore, the hardness values are mainly dependent on the heat treatment. Both Hardness values Rockwell hardness and Brinell hardness values taken at various aged temperatures are mentioned in the below table. From these values we conclude that hardness values increasing when increasing the aging temperatures except at 620^{0}C because of the dissolution of chromium. But at again increasing the temperatures re appearance of carbides takes place so that at again when aging at 680^{0}C.

Table 1.2: Hardness Values at various processing temperatures

Processing conditions	Rockwell hardness	Brinell hardness
Solution treated at 1050^0 C	76.9	477.7
ST + aged at 550^0 C	80.6	477.7
ST + aged at 580^0 C	82	555.6
ST + aged at 620^0 C	79.1	363.4
ST + aged at 680^0 C	95.9	653.8

4.3.Corrosion studies values and Graph

Corrosion research on decided on chrome steel have proven that indeed, due to their uncommon alloy compositions and precise single-section nature primarily based totally on a short-variety ordered amorphous structure, decrease corrosion costs and a stepped forward passivation capacity particularly in near-impartial media are attained. On the alternative hand, their excessive susceptibility to chloride-caused corrosion procedures and their sturdy tendency for hydrogen absorption beneathneath cathodic polarization situations and the associated feasible de-stabilization of the amorphous structural nation are crucial aspects. More unique research could be essential to attain a deeper know-how of those degradation phenomena and to make clear the position of every constituent detail and of the precise microstructural nation.

Table 1.3: Solutionised Heat Treatment of Stainless-Steel Corrosion rate Values (Weight loss Method)

Sample	Initial weight(gms)	Final weight(gms)	Weight loss	Corrosion rate(mpy)
Condition A	34.9671	34.9641	0.0030	165.56
ST+ aged 550^{0}C	37.1328	37.1309	0.0019	99.43
ST+ aged 580^{0}C	37.3055	37.3020	0.0035	183.5
ST+ aged 620^{0}C	36.4397	36.4378	0.0019	100.69
ST+ aged 680^{0}C	37.3975	37.3954	0.0021	110.41

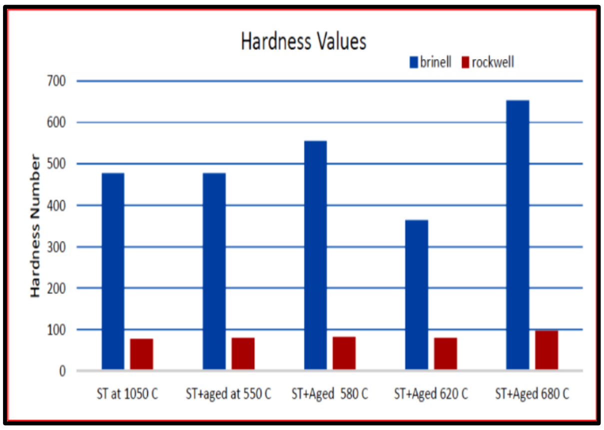


Fig.1.7: Hardness vs temperature

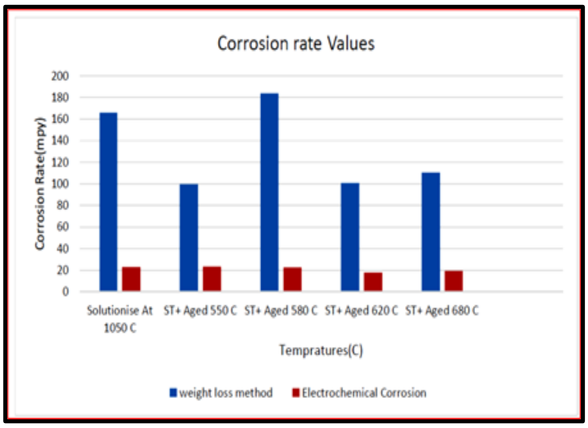


Fig.1.8: Corrosion rate vs temperature

The corrosion rate values from the electro chemical studies are in this below table. From these values we observed that corrosion rate is high for solution treated and aged at 550^{0}C and low for solution treated +

aged 620^{0}C. From table it is clearly indicating that from aged temperatures 550^{0}C to 620^{0}C the corrosion rate values are decreasing. The results show that at some optimum aged temperature we got less corrosion rate values are not comparable.

The corrosion rate calculations at various aged temperatures are below

Table 1.4: Solutionised Heat Treatment of Stainless-Steel Corrosion rate Values (Potentiodynamic studies)

SL.NO	Sample(^{0}c)	Icorr in A	CR=Corrosion Rate in 10^{-3} mm/yr.
1	Without Heat treatment	1.728868	18.0880
2	Condition A	2.187732	22.8888
3	550	2.23146	23.3463
4	580	2.16380	22.6384
5	620	1.69279	17.7105
6	680	1.841740	19.2689

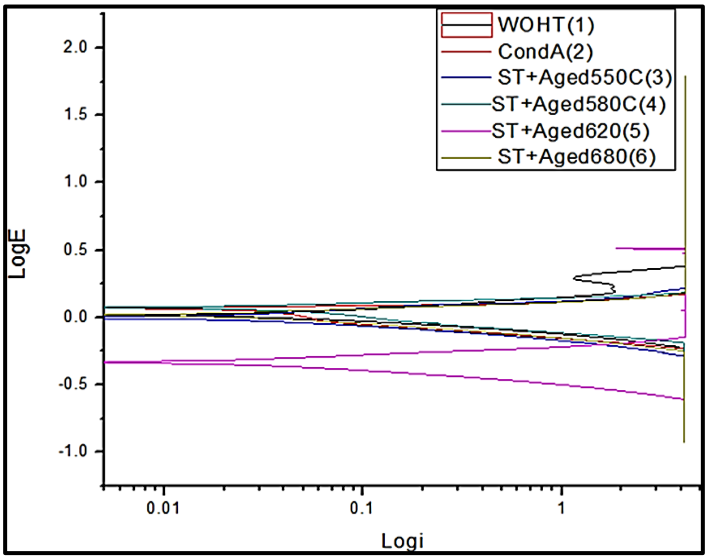


Fig.1.9: Potentiodynamic polarization curves of Solutionised samples and without heat treatment samples a) Without Heat treatment b) Solutionised (Cond A) c) ST+Aged 550^{0}C d) ST+Aged 580^{0}C e) ST+Aged 620^{0}C f) ST+Aged 680^{0}C

At Temperature 550^{0}C chromium carbides are formed because of this chromium content decreases hence corrosion rate is increased whereas at 620^{0}C all chromium carbides are dissolved. This will give us high chromium content which will form passive layers. By Comparing these weight loss method and electrochemical method. Both these values.

CONCLUSION

From the above results and graphs. We Can conclude that the mechanical properties and corrosion rate values are mainly depends on the heat treatment and at solutionised temperatures. But in order to get the optimum mechanical properties and corrosion resistance properties have to choose the optimum temperatures.

- Temperature of ageing treatment affects the volume fraction, grain size of carbides as well as grain size of austenite.
- Ageing treatment at 680^{0}C gives the best microstructure with optimum grain size and volume fraction of carbides along the grain boundaries.
- At this temperature uniform distribution of carbides takes place and gives the maximum Rockwell hardness value as 95.9 and maximum Brinell hardness value as 653.8.
- In weight loss method at ageing temperatures 550^{0}C gives the less corrosion rate. This temperature is optimum for corrosion rate.
- In potentiodynamic studies at ageing temperature 620^{0}C gives the less corrosion rate. This temperature is optimum for corrosion rate because at that temperature the chromium carbides get dissolved in the matrix so that it forms a passive layer on the surface hence corrosion rate is decreased.

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