Microstructure and Mechanical behaviour of Stainless Steel

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Abstract: The progression of pipeline industry require good standard for corrosion resistivity in steel. It will lead a huge concern for endless steel manufacturers. The mechanical properties of stainless steel can be astoundingly improved through sensible alloying component, for example, V, Nb and Cr and legitimate planning of thermo-mechanical handling with boundaries that refine and homogenize the microstructure. After complete the way toward moving, control of cooling rate is basic to shape the vital stages in the last microstructu

1. Introduction:- The onsite performance of stainless steel mainly depends on the degradation behavior in term of corrosion rate. The corrosion of steel can be controlled by altering the microstructure, surface coating, and alloying. The stainless steel is very popular due to its excellent corrosion resistance [1]. The available SS are mainly categorize as austeniteic, martensitic, and ferritic; among these the Cr-Ni-austenitic and Cr-ferritic SS having a superior corrosion resistance. The Cr & Ni provide a excellent anti oxidation property but due to the exhaustion of Ni the cost of Ni becomes a obstacle for its use. So now the global scenario is to switch towards the Ni-less ferritic SS. The metallurgist developed a ferritic SS with high percentage of Cr (18-22%) for high corrosion resistance like SUS400 series (SUS 430, SUS 445). The result reveled that5 the SUS 445 (22%Cr + 1-2%Mo) having a high corrosion resistance in acidic solution compare to SUS316 (Ni- containing austenite) SS. In the similar manner, another study revealed the high corrosion resistance with 24% Cr - SS when compare with SUS 410, SUS 445 & SUS430 . The duplex stainless steel ( ferittic + austenitic) is also very popular in pump, valves and pipe fitting applications. The Cr, Mo, Ni, Mn, W, and Cu are the significant alloying elements for producing
super duplex stainless steel [2]. The addition of Cu by 1.0wt.% in duplex stainless steel reduce the corrosion rate by enhance the corrosion resistance. The heat treatment is very effective tool for improving the performance of stainless steel. The austenitic temperature affect the corrosion resistance, by increasing temperature to 1100°C, the dispersion of carbide by simultaneously increasing Cr in alloy matrix were increases, and improve the general corrosion. The study on AISI304 SS were revealed the similar concept. The many researcher explore the effect of temperature on the corrosion behavior, the outcomes of these study established a relation that by increasing temperature the localized corrosion may occurs very easily and spread at faster rate. The surfacing by friction stir processing for improving hardness and corrosion resistance is also a very efficient technique [3]. The one study on AISI420 martesitic SS were processed by FSP, found that pitting corrosion resistance was improved and hardness improved to 634 to 698 HV1. The 2507 super duplex stainless steel was processed by FSP observed that by increasing number of FSP passes, mechanical properties, microstructure and corrosion resistance was noticeably improved. The another study; a ingot of AISI420 were refined by electro-slag refining and then forged at 900°C & 1000°C. The hot forged specimen was annealed at 700°C and exposed by air cooling. The annealed block were austenitized for 30, 60 and 120min at 980°C, 1015°C and 1050°C. After secondary treatment the significant improvement in mechanical and corrosion resistance was obtained at 1050°C austenitized temperature. The 316L stainless steel was processed by gas metal arc additive manufacturing and then heat treated at 1000°C to 1200°C significantly improve the strength and corrosion resistance[4-6].

2. Sample Preparation and Experiment Setup:- The chemical constituents of alloy is given in table-01. The alloy is cast using induction furnace. The chemical composition is given here.

Table 1: Chemical constituents of the alloy

| C    | Si | Mn  | Cr | N (ppm) |
|------|----|-----|----|---------|
| 0.24 | 0.55 | 1.53 | 13 | 110     |
Alloy prepared in induction furnace. When hardening is done, the standard example was handled in Gleeble 3800®. Compound was warmed inside the test system at the rate of heating 40°C/s until temperature of 1100°C/s is reached, the holding time of the solution is 10 minutes then the thermomechanical recreation was begun at 800°C in which 60% thickness decrease was finished utilizing plain strain pressure on Gleeble 3800®. From that point V Alloy was cool to ambient temperature at a cooling rate of 800°C/s. The thermo mechanical handling calendar of the amalgam is given in figure 1. All thermo precisely prepared examples were additionally exposed to microstructure portrayal utilizing optical and examining electron microscopy (SEM) [7-8].

![Thermo-mechanical simulation Schedule of Alloy.](image)

**Fig.1 Thermo-mechanical simulation Schedule of Alloy.**

### 2.1 Optical Microscopy Characterization:

The alloy of prechosen composition characterized in optical microscopy. The optical micrographs are shown in fig. 2. It consist acicular types of product. It is also reveals from the images that the micrograph also consist of polygonal ferrite, this is due to the non-equilibrium cooling [9-10]. Under non equilibrium cooling the austenite converts into pearlite and ferrite but due to its increased cooling rate the formation of bainite reveals in Optical micrograph images. Higher magnification images of alloy confirm the presence of lathe like structure that is martensite. It is presents due to higher cooling rate. The structure depicts like acicular ferrite microstructure, few dendrites like structure likewise appears martensitic matrix. Optical images uncovered that the grains of the example is increasingly refined contrasted, due to the higher peening impact at lower temperature. Microstructure uncovers that alloy deformed at 800°C is not quite the same as the lamellar structure. This microstructure comprises of acicular ferrite and high
volume part of fine ferrite [11-12]. Some pearlite is likewise present. This plainly shows the nearness of V(C,N) based accelerate. As nitrogen uncover the vanadium from the strong arrangement.

2.2 SEM Characterization:-

SEM images confirm the presence of martensite, polygonal ferrite and retained austenite, the SEM micrographs are shown in Fig.02. the increased cooling rate promotes the formation of martensitic grains. Some retained austenite is also present in micro structure that is due to the fact that there non equilibrium cooling of the sample. These retained austenite are the softer phase contain inside the hard martensitic structure. Comparable perception can be produced using the SEM images of the relating alloy (Fig.3).
Checking electron micrograph obviously uncovers the stage present is acicular ferrite, it implies that the cooling rate is adequately higher that it can evade the development of pearlite and it is adequately more slow to keep away from the arrangement of martensite. The needle shape structure is the away from of essence of acicular banite and martensite [13-14]. Cautious investigation of electron micrograph uncovers a bimodal structure of polygonal ferrite and acicular bainite has been created by control condition preparing at 800°C. Some held austenite is additionally present in the amalgams that changed into pearlite and bainite[15-17].

![Fig. 03 Scanning Electron Micrograph of alloy.](image)

2.3 Transmission Electron Microscopy Results:-
Selected area Diffraction pattern (SADP) and dark field images of alloy are shown in fig.04. TEM images reveals the presence of carbide at the location 1 and 2 [18-20]. The dark field images shows the size of precipitates, the size of precipitate lies in the range of 5nm to 10nm. There are two type of precipitate present one is spherical and other is elliptical [21-23]. The elliptical shape precipitate occurs due to strain induced precipitate [29-35]. The possible cause of getting precipitate may be the insufficient ageing or lack of artificial ageing [24-26]. Higher amount of pearlite reduce the tensile strength significantly because pearlitic structure have notches & the stress concentration over these notches is very high. It is main disadvantage of pearlitic structure [27-28].

3. Conclusion:- Microstructure and Mechanical behavior of Stainless Steel is studied in present study and following conclusion are derived.

- The microstructure consist polygonal ferrite and acicular type of product.
- Retained austenite also present due to non equilibrium cooling.
- TEM images shows the uniform distribution of carbide precipitates
- Precipitation density increases with percentage deformation.

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