Investigation of the use of micro-alloy and As-Cast Microalloy steel in Automotive application

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Abstract. Vehicle industry assume unequivocal role in the financial development of the nation. The significant test before car industry is to deliver light weight parts without diminishing strength parts, for example, connecting rod and driveline segment, this can be accomplished by utilizing high strength low alloy steel. In all metal forming process forged parts posses high yield strength due to the favored direction of grains. Accordingly present exploration work zeroed in on Micro basic and Mechanical Behavior of As-Cast and Hot Forged Microalloy Steel. Impact of thermo-mechanical handling and cooling rate is additionally considered. Characteristic evaluation investigation of As-projected steel and hot fashioned steel is contemplated utilizing optical and SEM technique. Tensile testing performed on Instron testing machine. It is observed that due to the thermomechanical handling of steel there is development of strain instigated precipitate that advantage as far as effect strength and toughness of steel.

Keywords:- Micro-alloy, precipitate, forging, thermo-mechanical.

Introduction:- The major requirement of today’s automotive industry is to utilise high strength low alloy(HSLA) steel. This concept reduces the weight of the steel without reducing the strength. Automotive components continuously developed in such a manner that the strength to weight ratio of component can be improved [1]. This will further enhance the fuel economy of the vehicle. To meet these requirements forged microalloyed steel are gaining the popularity in automotive components such as crankshaft, crank, suspension system and piston. There are many alloying element that used in steel to improved strength to weight ratio, such as vanadium, niobium and titanium these comes under the category of microalloying elements. Aluminium is also mixed to improve the strength of the alloy in comparison to its weight but at the same time it is detrimental for the machinability of steel [2]. The major advantage to use microalloy steel over conventional steel is that it can be use as direct cool without any subsequent heat treatment. Conventional plain carbon steel requires post cooling heat-treatment to remove the phases rich in carbon. Microalloying element not only used to transform carbon rich phases but also act as inhibitor for the austenite grain growth. Vanadium produce stable
carbide, nitride and carbonitrides at low temperature whereas niobium is used to restrict the austenitic grain growth, niobium also posses the strong affinity towards the carbonitrides[3-4]. It is not sufficient to add the microalloying element in steel in addition a careful selection of thermo-mechanical processing also equally important. Precipitation behaviour and precipitation dissolution of microalloy steel are carefully studied in present paper. Vanadium are soluble in austenite phase at relatively lower temperature as compared to niobium and titanium. Therefore vanadium require lower thermo-mechanical processing temperature, the literature suggest that vanadium carbonitrides are stable in temperature range 750°C to 900°C, the thermo mechanical processing under these temperature limits enhance the chance to the formation of strain induced precipitates. Unlike niobium and titanium vanadium does not prevent the coarsening of austenitic grain growth because it goes into the solution above 900°C[5-6]. The microstructure of air cooled microalloyed steel consist ferrite and pearlite due to the fact that nucleation of ferrite occurs due to the diffusion means[7]. To alter this microstructure various cooling techniques are used that refine the grain growth and also promotes diffusion less cooling. The vanadium precipitation increases the strength of steel upt0 100 MPa. This strength can be further improved by refining the size of precipitates. Study suggests that average size of 5 to 7 nm precipitate increase the strength by 200MPa [8-10]. Many literatures suggest that only 50 to 60% amount of vanadium precipitates out from the solid solution to further promote the vanadium precipitation by using the nitrogen in the steel [11].

The carbon and microalloying elements in HSLA are the two crucial element that decide the properties and microstructure of steel. Niobium and titanium are the strong carbide former at relatively higher temperature. But the precipitation behaviour of these alloying is complex in nature hence in current studies vanadium based microalloy steel study is under consideration with the suitable thermo-mechanical processing [12-13]. Vanadium, as a micro alloying element can be included into the accompanying sorts of steel like high-quality hot moved ribbed rebars for development, high-quality low-alloyed steel plate of medium thickness, pipeline steel, sheet steel, microalloyed fashioning prepares, spring steel, jolts steel; Vanadium, as an alloying component can be included into the bite the dust steel, fast steel, ultra-high quality steel, bearing steel [14-15].

That is why present research work is a comparative study of As cast microalloy steel and hot forged steel, hot forged steel temperature is select in such a manner that it facilitates the strain induced precipitations.

2. Experimental Procedure and Alloy preparation:- Experiments are performed to understand the mirostructural difference between the as cast and forged steel of vanadium based high strength and low alloy steel. Both the cast alloy and forged alloy are under characterized in optical and SEM. The strength comparison of standard specimen was completed on Instron Testing Machine.
Alloy of prechosen composition was cast in induction furnace. The chemical composition of alloy is given in Table-01. The size of casting is 25kg.

| C   | Mn | Si | V (ppm) | N (ppm) |
|-----|----|----|---------|---------|
| 0.20| 1.48| 0.40| 0.065   | 100     |

A part of this alloy was first heated to a temperature of 1000°C and soaked for a period of 10 min and than hot forged in forging shop at temperature of 800°C. Subsequently cooled in water at an average cooling rate of 80°C/s. The schedule of thermomechanical processing is given in Fig.01

![Fig.01. Thermo-mechanical processing of Alloy](image)

3. Results and Discussion:- In this section the results are consist of Optical, SEM and tensile test comparison of As-cast and forged alloy. The results obtained from optical microscopy and scanning electron microscopy discussed here in details.

3.1 Optical Microscopy:- optical sample of size 20x15x12 mm³ was prepared through polishing in 2% nital solution. The optical micrograph of cast alloy are shown in Fig-02, micrograph is taken from the centre of the alloy. the cast alloy it predominantly consist ferrite and pearlite [16-17]. This is due to diffusion of austenite into ferrite and cementite. The pearlite phase consists of layer structure the layer structure is caused due to the nucleation of cementite in ferrite network [18]. Low magnification optical images show the presence of polygonal ferrite and pearlite matrix but higher magnification images reveals that there exist large elongated grains of ferrite. These coarse grains of ferrite weaken the alloy [19-20]. The black phase present in microstructure is the network of pearlite. Due to air cooling the structure is ferrite-pearlitic structure, higher amount of pearlite reduce the tensile strength significantly because pearlitic structure have notches, the stress concentration over these notches is
very high so crack will initiate easily into the pearlitic structure. It is the main demerit of pearlitic structure [21].

The optical microstructure of hot forged alloy is shown in Fig.03, it shows that there is significant reduction in the pearlite phase [22-23]. Lower magnification image confirm the presence of polygonal ferrite whereas higher magnification images confirm the presence of acicular ferrite and some lathlike structure. It is also evident from the higher magnification image that there is a considerable grain refinement occur in ferrite grains. The difference between the As-Cast alloy and hot forged alloy reflect due to two reason, first it is due to the thermo-mechanical processing and the second reason is the post deformation cooling [24-25]. This change benefit the alloy in impact strength toughness and other mechanical properties. The grain refinement of ferrite grains also improves the strength and ductility together.
3.2 Scanning Electron Microscopy:

The SEM images of As-Cast sample confirm the presence of pearlite as shown in Fig.04, the notches present in pearlite structure are the nucleation sites for the cracks. The spacing between the layer is of the order of 0.1 micron[26]. Theoretically all the three sample contains 0.2% of carbon hence under equilibrium condition the % volume fraction of pearlite can be calculated by using lever law. % volume fraction of pearlite in 0.2% carbon steel = (0.8-0.2)/.8 = 75%, %volume fraction of ferrite in 0.2% carbon steel = 25%. In actual condition the measure of pearlite under air cooling is around 92% this is because of the better nucleation of cementite in the pearlite organize. This sort of nucleation impact the quality and pliability essentially because of essence of milder stage ferrite encompassed by cementite.

On the other hand Fig.05 shows the SEM images of hot forged alloy. Here image is clearly reveals the presence of lathlike microstructure that is martensite and acicular ferrite, this happen due to the water quenching of alloy. Due thermomechanical processing vanadium forms strain induced precipitation these strain induced precipitate stop the migration of grain boundaries and add strength to the alloy. The function of microalloy accelerate relies upon the temperature at which it structures corresponding to the change temperature of the steel. By and by, the rate at which steel cools will anyway decide the genuine temperature at which precipitates and transformation happen. The higher the cooling rate the lower the temperature at which the precipitates structure. Pace of cooling can, indeed, decide if a precipitate structures in austenite or ferrite [27].

Fig.04. Optical Micrograph of Cast Alloy[18]
3.3. Tensile Testing:-

The tensile test were done for both prechosen alloy on instron testing machine. Three test sample of each alloy is prepared as per the ASTM standard the gauge length flat sample is 20mm. the strain rate for all the sample is kept constant. A plot of stress against strain was draw from each test as shown in Fig.06. From these plots the yield pressure and elastic of the alloys were determined, results shows that there is an increase of 104 MPa in yield strength[28-29]. The yield strength of As Cast alloy is 398 MPa whereas the yield strength of Forged Alloy is 502 MPa. This is due to the fact that there is formation of strain induced precipitate in hot forged alloy. This precipitate of vanadium carbonitrides prevent the migration of grain boundary[30]. The total percentage elongation of cast alloy is higher than the forged alloy.

Fig.06. Stress- Strain Curve of the As- Cast and Hot Forged Alloy.
4. Conclusion: Comparison of microstructural and mechanical properties of microalloy steel was studied and following conclusion is drawn.

- Forged steel consist higher grain refinement compared to As-cast steel
- Thermo-mechanical processing of alloy reduced the pearlite phase significantly.
- There is an increment of 104 MPa in strength of Hot-Forged Steel compared to As-Cast.
- The mechanical property of V-N steel is satisfactory compared to the V steel. The yield strength of V-N steel is noticed up to 502MPa, for the controlled rolled steel.
- The average size of the grain formed in Hot-Forged steel is up to 6 to 7 microne with increase in percentage of vanadium.

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