A Review on Comparison of Mechanical Properties of Dissimilar Steels Welded By TIG and MIG

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Abstract. In this review the study will be carried out on comparison of Mechanical Properties like Hardness and Strength of joints welded by TIG and MIG processes. Welding of dissimilar steels has became most common process now days in wide applications in industries. The Stainless Steel and Mild Steel joints have more applications in structural industries which provide good combination of Mechanical Properties like strength, Corrosion resistance etc. Selections of welding process for different material are difficult because of their physical and chemical properties. To obtain good quality of weld, it is necessary to select proper welding technique according to the materials selected for welding

1. Introduction

The Welding process is the joining two metals by alloying the base metal with the addition of filler material between the welded metal surface, creating strong bond between metals to be joined. This permanent metal bonding method is highly efficient and economical. Various types of welding techniques are used in fabrications which are applied in short time. Welding techniques are different from each other in their applications and type of equipment used. Welding of structural parts using unlike steels make the equipment simpler and cheaper [1].

Dissimilar steel welds has a big advantage due to its economic advantages in the oil and gas industry and the excellent performance of two different metals. These metals have combined strength and corrosion resistance. Much research is being done on properties of these differential joints, and more important work is being done on the consequences of welding joints and the changes in mechanical properties of joint[2]. It is usually more difficult to join different steels than identical steels, but this is usually due to a number of factors, including differences in chemical composition and coefficient of thermal expansion. In addition various steel joints for ferritic steels and austenitic steels are believed to cause cracking , weakness, and unexpected phase dispersion due to the properties of the joints welded to the welding interface[3-4]. Changes in the range of negative metals, such as ferrite in the delta phase, corrosion at grain boundaries, and sigma phase. Various uneven steel welds are extensively useful in nuclear,chemical,power generation, petrochemical, and more other industries[5−7].

Stainless steel is primarily used in industry and trade, as well as in the manfacture of autoparts, vechiles and freight cars.Stainless steels alloys form alloys with materials such as nickel, chromium and magnesium. They have excellent corrosion resistance and low manufacturing costs. Stainless steels is classified in to three types austenitic, ferritic and martensitic. The crystal structure of austenitic steel is FCC structure. The ferritic steel have better mechanical properties than austenitic steels, its corrosion resistance is low because the alloy content of nickel and chromium is low. It is a three-dimensional structure based on the body. Martensitic stainless steels is very hard and processed into all shapes and sizes, but it is not corrosion resistant as ferritic stainless steel[8].

Mild steel is having excellent welding nature. This are mainly used as tanks, bridge coloum, ships body, pipelines, building , train coaches and various vechiles. It is having great production compared to other steels due to its extensive usage in fabrications. Due to larger use of steel in structural, the production economy and high efficiency are important factors for development in future[9]. Traditional weld techniques should have high flexibility and agile for integration and more efficient. In this productive world, it is important to make industries globally competitive[10].

Tungsten Arc Gas Welding is the proces were the arc is appeared in between the non melted tungsten electrode and the weld part and between them this arc is maintained. The inert gas emitted by the welding torch protects the area affected by heat , weld metal and the electrodes of tungsten from environmental pollution. Helium and Argon are regularly used inert gases in this process because the reaction between gases and joining metals is zero. The gas sheild acts as protective layer for welding and also removes active properties in ambient air [11].

Metal Arc Gas welding the most commonly used welding technique in ferrous and non-ferrous manufacturing environment[12].MIG weld produce the electric arc by continuous monitor on metal of weld electrode wire. The parameters of welding also have a very important use in obtaining about quality of the welded joint in terms of geometry of weld bead and its mechanical properties[13].

2. Experimental Procedure

V. Anand Rao et al Investigated on SS 310 for welding aspects by TIG welding process. Samples of 50mm x 50mm x 3 mm are prepared and joined in a type of joint called single groove butt at an angle 45°. Root space for all samples kept uniform which is of 1mm. Welding is conducted manually in one pass with TIG technique using DCEN with an argon gas sheild. Total 9 samples were prepared and three different types of filler rods are used to weld three pair of plates. Three types of filler rods used were 316L, 347 and 309L. The parameter varied for each experiment was welding current. The quality of welding was assessed by ultrasonic flaw detector and microstructure was studied by optical microscope[14,15]. For this microstructure analysis the sample was cut to a width of 10mm and glinted and depicted with picric acid. Welded plates mechanical properties is determined by cutting the sample to a width of 10 mm , and sample was subjected to tensile test and the remaining is used in three point bending test with width 30mm [11, 16].

Sanjay Kumar conducted experiment to optimize welding parameters on TIG welded SS AISI 304 plate. The plate sizes used for the experiment were 200×50×3 mm. The filler rod used in the welding was the E 308 L. Tungsten gas arc welding (GTAW) is often used for welding difficult metals which are magnesium, titanium aluminum, and stainless steels [17]. Taguchi technique is used as optimization [18] method which used a set of 27 experiments. Minitab 17 is used to design experiment. To obtain the particular result on each factor, signal to noise ratio has been used. The signal is used for displaying the response on each factor, and sound is used to measure effect on the deviation from the average response[19-20]. Further hardness test was conducted by Brineel hardness machine with 1000-kg load . The hardness is obtained in all other areas of weld. Bending test is also conducted till 180^0.

A.R. Khalifeh carried out the experiment on joining dissimilar steels by TIG welding process. The dissimilar steels used are 304L AISI austenitic steel and ferritic low carbon steel St37. ER310L, ER316L, ER308L and ER309 are used as filler rods. Welded was performed using current grade 120-150A with the help of TIG welding machine. The welding is completed in four passes. The magne-gage ferrit-ometer unit metallographic examination and ferrit-ometry test are carried out on each side of the welded joints. The unit is calibrated per AWS A4.2-91. Microhardness of the welded structure is conducted. Tensile and impact tests are performed to go through mechanical properties of the weld joints[21].

Shanti Lal Meena analyzed about the welding parameters like Welding speed, Plate thickness Welding current and Rate of gas flow on bead geometry which are height and width of bead reinforcement, and synergic weld penetration by voltage expatriate for SS 304L . It is welded by synergic welding machine which is having a 550 A cycle at 40°C and speed of wire is 25 m/min. The filler rod used was 308L with diameter of 1.2 mm. Bead plate technique is used to weld stainless steel plate (304L) using semi-motorized welder. Samples microstructure studies are done in the WZ, HAZ and BM. Using an Omnitech MVH Auto Micro Hardness checker with a pyramid shaped diamond dot, the microhardness is measured at different levels[22].

Nabendu Ghosh implemented optimization technique know as PCA-based Taguchi Method . To weld the butt joint of dimension 100 x 65 x 3 mm units of AISI 316L austenitic steel, MIG process is employed and AISI 316 L is used as filler wire. Rate of gas flow, welding current and distance between nozzle and plate are treated as of different parameters. Using the method principal component analyses (PCA) yield strength, percentage of elongation and ultimate strength of the welded samples are arranged, examined and determined[23].

Xiao-yong WANG investigated about welding of stainless steel with Mg alloy by metal inert gas welding technique. Plates of 200×50×3 mm dimensions which are Mg alloy of AZ31B and low carbon steel Q235 were taken as metals and AZ61 and AZ31 Mg alloy welding wires selected for filler rods having 1.6mm of diameter. Sample piece of Mg steel joint for test is cut from weld joints. By the help of scanning electron microscope and optical microscope the microstructure and composition of Mg steel joints examination had done. The scanning electron microscope and optical microscope are additional included with energy dispersive X-ray spectroscope X-ray diffraction and transmission electron microscope. The Vickers micro hardness is measured with of 50 g force and time 10 seconds. At room temperature tensile testing of Mg steel joint was conducted using Universal test system[24].

Ramesh Rudrapati experimented to analyze the influence of parameters of welding such as the rate of gas flow, the distance between nozzle and plate, and welding current on percentage elongation (PE) and ultimate tensile strength (UTS) of AISI409 ferritic steel size of 100x65x3 mm welded with MIG process and wire of 1.2mm in diameter is used as filler wire which is of AISI 316 L. Butt welds are made with different input parameters. Welded samples have undergone X-ray radiographic and visual examination. This control methods are used more often because they are easy to use, fast, inexpensive related to other , and provide high essential report about the joints. After visual inspections, the samples are cut into small pieces, then this small pieces were polished and etched to study microstructures[26].

Pradeep Khanna examined about the response of hotness on the size and dissipating of high stress created on stainless steel 409M during the MIG welding. Five welds are completed with utilizing bead on plate method, for Stainless steel 409M plates with size of 250mm length 150mm breadth and 6mm height. Various mixtures of welding parameters are utilised while welding viz. speed of welding and rate of wire feed were fluctuated between 30-50 cm/min and 2.8-10.8 m/min respectively and various other parameters which are arc voltage (V), electrode to work angle (θ) and distance between nozzle and plate (N) are kept same at 26v, 90°, and 15mm respectively. Fig.1 shows the rosette settings of strain gauge and strain gauge element. Each plate has 5 strain gauge rosttes attached according to dimensions as shown in figure.2. The strain gauge uses, Gauge diameter (D) of 10mm, Gauge width (GW) of 3mm, Gauge length (GL) of 3mm, Resistance of 120Ω, Gauge factor of 2. A Recording Wheatstone bridge and Precision milling guide are tools used for measure the residual stress. Before drilling a hole in the rosette, the basic reading is settled to zero. According to ASTM rules diameter of drill is chosen as 3.17mm[27].

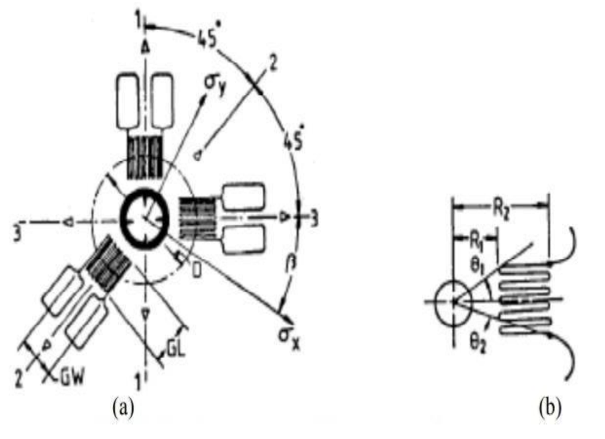

Fig.1. (a) Rosette setting of Strain gauge (b) Element on strain gauge[27]

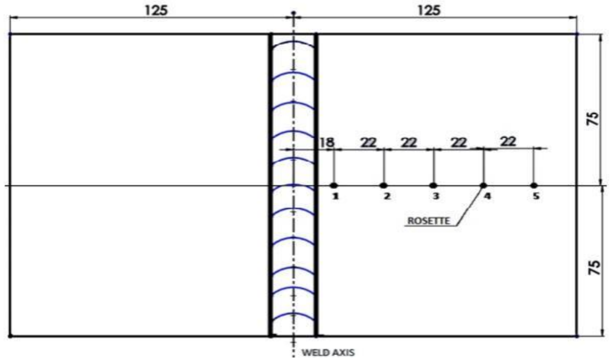

Fig.2. Strain gauges arrangement on weld plate[27]

3. Results and Discussion

V. Anand Rao et al exhibited the results of tensile test, bending test and microstructure of the welded joints. The UTS of sample weld with filler rod 316L has less compared with joint made with 309L or 347 fillers and when 347 and 316L filler rods are used strength of weld increases proportionally . The 309L and 316L filler welds had better bend strength more than 370 MPa, and the 347L filler rods reduce the bend strength and is accomplice by surface cracks. The ultrasonic test penetration errors, even if 309L had dissolved Sulphur which could lead to penetration defects. Microstructure images showded that the 309L is having a significant second phase formation due to changes in chromium transformation rate and uncontrolled heat supply. The Microstructure of samples C,F,I at HAZ, WZ, and base metal are shown in figure.3.

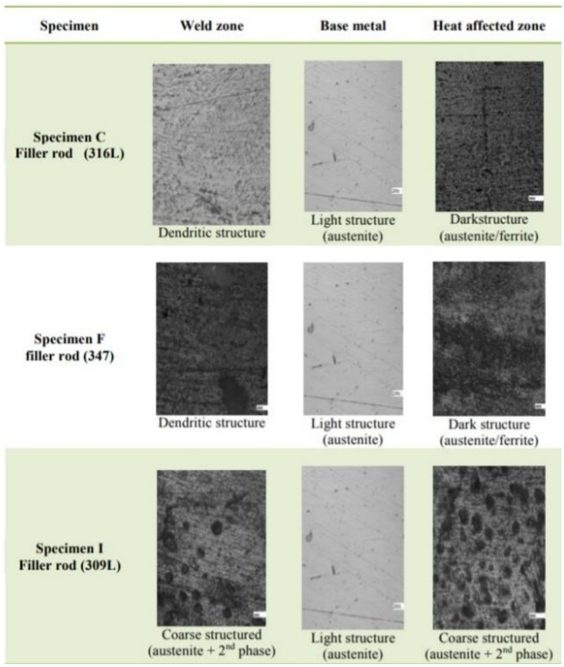

Fig.3. SS310 weldment Microstructure at three regions at 200X[11]

Sanjay Kumar presented the link between welding parameters and the values of response at a assured level of 95%. Highest hardness is occurred at 70 A which is the second current level, 50 V the third voltage level, 0.5mm which is intial root gap and initial rate of gas flow of 16 L/min and at first voltage level, second current level, third gas flow rate level and first level of root gap the highest Bending strength was obtained. ANOVA result has shown that stress is very sensitive to changes in mechanical properties of welded joints.

A.R. Khalifeh concluded that the in ferritic carbon steel St 37 aspect HAZ consists the fine recrystallized and Widmanstatten ferrite coarse grains and in AISI 304L HAZ does not show any variation in microstructure. Figure.4 shows the tensil strength SEM micrograph. The fine and dimple structures at factured area on samples are due to failure in ductile manner while tensile test. The yield strength of AISI 304L and St37 unlike joints was below base metals and at the aspect of the St37 dissimilar joints the failures was occurred. The welded joints made by electrode ER310 has shown the highest impact energy of 160 J and it was low with joints welded by ER309L electrode of 120 J. Sensible combination of the resistance of hot cracks and mechanical properties for the unlike welds can be obtained by using electrodes ER309L and ER316L which end up in NF=9.5 and NF=8.

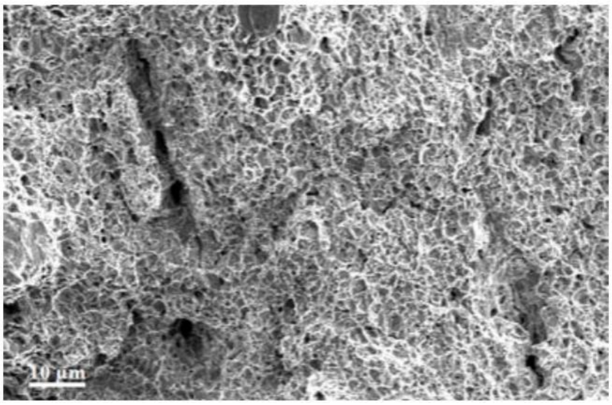

Fig.4. Tensile testing SEM micrograph image of St37 and AISI 304L factured at welded zone.[21]

Shanti Lal Meena halted by carrying out the microstructural analysis, microhardness tests for the SS 304L welded joints. From microstructural analysis observations the stability and differences are caused by carbon dioxide in the formation of protective gases. With increase in current, the pore area and inclusion are reduced . For base metal and the weld zone, the size distribution range and pearlite content is almost identical. Pearlite content is higher in HAZ and grain content is found in the lower range, showing better microstructure than BM and WZ. In Heat Affected Zone the size of grain decreased compared to base metal and micro hardness value is increased. Variations of microhardness at different levels are shown in figure.5. Higher hardness is occurred at point A, C and E which are in HAZ.

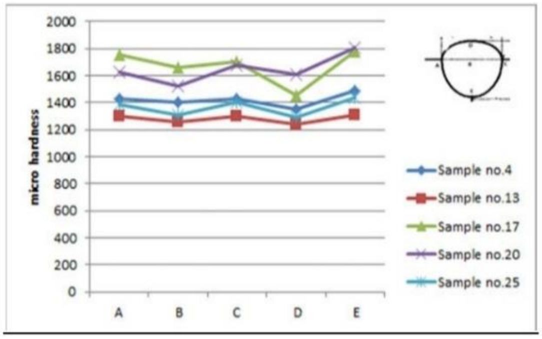

Fig.5. Variation of microhardness at different levels.[22]

Nabendu Ghosh obtained the results of AISI 316L welded joint by Taguchi method. And the tensile test of joint made with current of 100A, 20 l/min of flow rate and distance between nozzle and plate is of 15 mm was obtained as ultimate tensile strength of 591.1774 Mpa the best yield strength which is 322.7427 Mpa elongation percentage is 54.539. The worst result has been obtained for joint made with the 124 A of current , rate of gas flow is 10L/min and, distance between nozzle and plate of 15 mm which gave the ultimate tensile strength which is 426.23343 Mpa, yield strength of 242.42773 and percentage of elongation is of 19.524. Main effect graphs and signal noise ratio graphs, has helped in determining the optimum parametric combination. The minimum factor setting changes when weld current is of 100 A, rate of Gas inflow is 20L/min and distance between nozzle and plate is 9mm. Figure.6 shows the signal noise ratio plot of multi-response performance index.

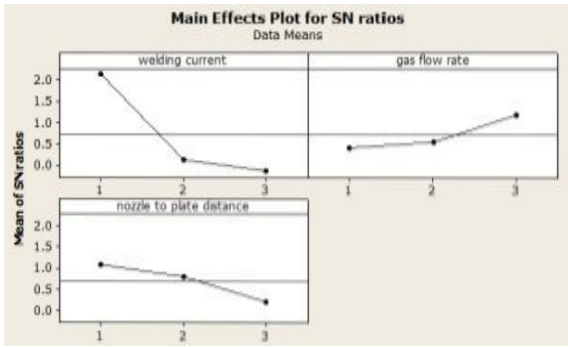

Fig.6. Representation of signal noise ratio plot of MPI[23]

Xiao-yong WANG found the mechanical properties and Microstructures of Mg steel dissimilar welded joints by metal inert-gas arc. The obtained results showed the temperature division at the joints is differing and Mg weldings are having the uniform and fine grains structure. The detailed Microstructure of MG-steel joint welded by different filler rods can be seen in figure-7. The strength of the joint improves the interface reaction between mg and steel and increases the input heat between 1680-2093 j/cm.The strength of the joint reaches to 192 MPa, which is 80% of Mg alloy base, but 6.20% of Al content increases. When welding heat is low, the joint strength is very low, apparently it improves when heat is 1919 J/cm - 2254 J/cm. The weld joints strength of 184.2 MPa is obtained with the input heat at 2093 j/cm which is maximum. Weld destruction occurs mostly at the Mg and steel interfaces, determining a weak link in the MG-steel joint.

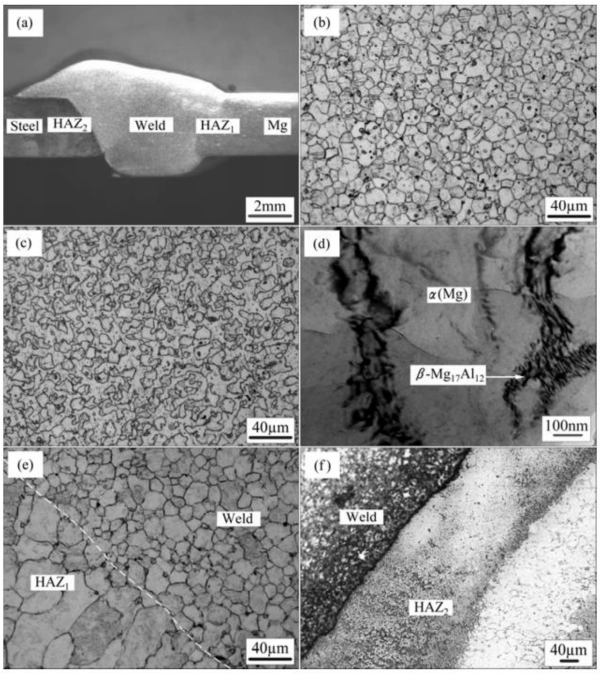

Fig.7. Mg steel joints Microstructures: (a) weld made by AZ31 as filler rod; (b) welded by AZ31 as filler rod; (c) welded by AZ61 as filler rod; (d) TEM Image of joint welded by AZ61 as filler rod ; (e) HAZ1 weld with AZ31 as filler rod; (f) HAZ2 weld with AZ31 as filler rod[24]

Ramesh Rudrapati concluded that drafts, blow holes, illegal deposits, and excessive intrusion were found in some samples. The radiograhy test results showed the differential reports that is linked to some of the sample and not sufficient of fusion, the other type of defect appears in samples is porosity. Porosity and blow holes are resulted by getting entrapped in solidifying metal. Statistical techniques which are signal to noise ratios analysis and graphical plot of main effects are used for finding the significant reactions of weld parameters on mechanical properties of weld samples which are UTS & PE. The simplification technique, Taguchi method is used as an largest parametric alloy, that can be producing welds of desired quality [25]. ANOVA results have given that the welding parameters are not significantly affect both reactions. In figure-8 the UTS graphs and in figure-9 PE graph plot can be seen. Maximum parametric welding condition are taken from distance between nozzle and plate (S) of 9 mm, rate of flow of gas (G) is 10 L/min and current supply (C) of 124 A, and shown by Taguchi technique to improving the two reactions which are UTS & PE. Taguchi's design method of experiments is regularly used for the analysing the weld joints ferritic steels.

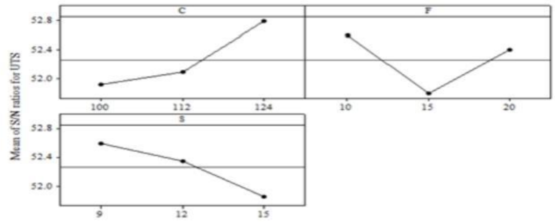

Fig.8. Ultimate tensile stress (UTS) Main effect graphs [25]

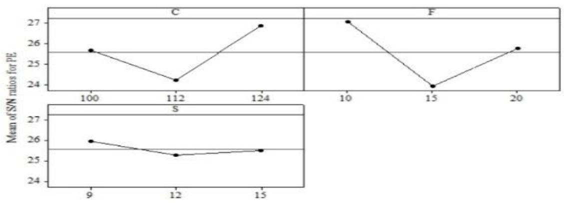

Fig.9. Percentage elongation (PE) Main effect graphs[25]

Pradeep Khanna analysed that the utmost surplus tensile stress shown is 150.23N/mm² at a 18mm of distance towards the welding line and therefore the most remaining compressive strength is shown as -50.61N/mm² at a about 65mm of distance from the centerline of weld in plate-5. The lowest surplus tensile stress obtained is 120.28 N/mm² from the centerline weld in plate-1 at a distance of 18mm. The tensile stresses magnitude is also increased with the heat increase. In tensile residual stress area the half widths are increased due to the increase in heat input. At welding bead the maximum tensile strength is below yeild stress due to the results of no crack formation in weld bead zone.

4. Conclusion

- Two welding techniques TIG and MIG are used to weld the different materials like stainless steel and mild steels.
- The welding was done by with varying the different parameters and the welded joints were gone through different tests. The tests conducted were tensile test, bend test, Ultasonic test, micro hardness test.
- The micro structural analysis has been done for the Base materials and Welded joints. Optimization technique, Taguchi method is used to find the joint which is having high mechanical properties obtained by using different parameters of welding.
- Dissimal joint of AISI 304L and St37 steels welded with TIG is having yeild strength of 352 MPa which is greather than joint Mg alloy AZ31B and low carbon steel Q235 welded by MIG
- The stainless steel welded by MIG is having better Tensile strength than joint of TIG.
- The change in miscrostructures of welded joints & base metals in MIG process is having major changes than TIG process. Grain size is improved in MIG process.

- ANOVA results have concluded that the welding parameters are not significantly affected.

References

1. C.H. Lee and K.H. Chang, J. Mater. Sci. 42 6607 (2007).
2. A.R. Khalifeh, A. Dehghan and E. Hajjari, AMS 26 6 721—727 (2013).
3. D.Y. Lin and C.C. Hsieh, Met. Mater. Int. 15 507 (2009).
4. N. Arivazhagan, S. Singh, S. Prakash and G.M. Reddy,Mater. Des. 32 3036 (2011).
5. P. Sedeka, J. Brozda, L. Wang and P.J. Withers, Int. J. Pressure Vessels Pip. 80 705 (2003).
6. S.M. Shushan, E.A. Charles and J. Congleton, Corros.Sci. 38 673 (1996).
7. K. Laha, K.S. Chandravathi, P. Parameswaran, S.Goyal and M.D. Mathew, Metall. Mater. Trans. A **43**1174 (2012).
8. Balaram Naik, A. Chennakeshava Reddy, TSEP (2018).
9. Suresh Kumar Tummala, Dhasharatha G, *E3S Web of Conferences* 87, 01030 (2019)
10. Sudhir Kumar, Rajender Singh, M**148** (2019) .
11. V.Anand Rao, Dr.R. Deivanathan, PE**97** 902 – 908 (2014).
12. A. G. Kamble and R. V. Rao, AM, **1**362–377(2013).
13. Bhagwan F. Jogia, A. S. Awaleb, S. R. Nirantarc , H. S. Bhusared,MTP**095**7086–7095(2018).
14. Suresh Kumar T, Sankar V, *2011 IEEE India Conference, INDICON,* 2011.
15. H.T.Zhang and JQ Song, ML**65** 3292-3294(2011).
16. C.Balaji, S.V.Abinesh Kumar, S.Ashwin Kumar and R.Satish, IJEST**4**(5) 2053-2056 (2012).
17. Sanjay Kumar, Pravin K. Singh, D. Patel and S. B. Prasad, IMSE978-981.
18. Kosaraju, Satyanarayana, M. Vijay Kumar, and N. Sateesh. Material Today 5,2 5343-5348. (2018).
19. Rajagiri A, MN Sandhya, Nawaz S, Suresh Kumar T, *E3S Web of Conferences* 87 01004 (2019).
20. Sudhansu Ranjan Das, Debabrata Dhupal and Amaresh Kumar, JMST **29**, (10) 4329–4340 (2015).
21. A.R. Khalifeh, A. Dehghan and E. Hajjari, Acta Metall. Sin **26** 6 721—727 (2013).
22. Shanthi Lal Meena, Ravi Butola, Qasim Murtaza, Hardhik Jayantilal, M.S. Niranjane, MTP**4** 8240–8249 (2017).
23. Nabendu Ghosh, Pradip Kumar Pal, Goutam Nandi and Ramesh Rudrapati, MTP**5** 1620–1625 (2018).
24. Xiao-yong WANG, Da-qian SUN, Shi-qiang YIN, Dong-yang LIU, TNFMS252533−2542(2015).
25. Satyanarayana, Kosaraju, Anne Venu Gopal, and Popuri Bangaru Babu., ijmmm. 13(2-3), 191-202. (2013).
26. Nabendu Ghosh, Ramesh Rudrapati,Pradip Kumar Pal, Gotam NandicICMPC 42213–2221 (2017).
27. Pradeep Khanna and Sachin Maheshwari ICMPC 54939–4947 (2018).