STUDIES ON AUTOGENEOUS TIG WELDING OF MARAGING STEEL 250

A PROJECT REPORT

Submitted by

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In partial fulfilment for the award of the degree

BACHELOR OF ENGINEERING

In

MECHANICAL ENGINEERING

PSG INSTITUTE OF TECHNOLOGY AND APPLIED RESEARCH

ANNA UNIVERSITY: CHENNAI 600 025

APRIL 2021

BONAFIDE CERTIFICATE

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ACKNOWLEDGEMENT

With immense pleasure and gratitude, we wish to thank the management of our college for providing us with a vision of strives for excellence.

We wish to express our sincere thanks and warm regards to our beloved **Principal Dr. G. CHANDRAMOHAN B.E, M.Tech, Ph.D.,** for giving this opportunity to undertake this project and for providing us the facilities needed in the preparation of the project.

We would like to express our sincere thanks to our **Professor and Head Dr.N. SARAVANAKUMAR M.E, Ph.D., Department of Mechanical Engineering**, for his support and guidance for our project.

We would like to express our sincere thanks to our Project Supervisor **Dr. V. RAJKUMAR, Associate Professor, Department of Mechanical Engineering,** for his dedicated guidance, ideas and timely advice in the completion of this project.

We also express our in debt thanks to our **Teaching and Non-Teaching Staffs, Parents and Friends** for their support towards the completion of our project.

ABSTRACT

The present work investigates on the metallurgical and mechanical property of the Maraging Steel (250 grade) butt joints performed using gas Tungsten Arc welding in Autogenous mode. The research characterizes the structure property relationship prevailing in the weldments in order to understand the behaviour and performance of the Maraging steel when subjected to the above processes. Comprehensive mechanical property investigations carried out on the weldments prove successful choice of weld parameters and weld conditions thereby achieving sound weld. The aim is to test its performance when subjected to various loading conditions (Tensile load, Impact load & Fatigue load).Joints were evaluated through comprehensive metallurgical and mechanical characterization procedures and results are reported.

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CHAPTER 1

1. INTRODUCTION

Maraging steel 250 is an age-hardenable iron-nickel steel. Alloy 250 combines ultra-high strength (1800MPa), good toughness, readily machinable in pre-aged condition, excellent transverse properties and resistance to crack propagation. Maraging steel is used for missile and ejector systems, slat tracks and drive shafts. Maraging steel differs from other steel alloys in that it is not hardened by the presence of carbon but by the precipitation of a special selection of other inter metallic compounds. The absence of carbon and the use of inter metallic precipitation allows maraging steel to achieve combinations of high strength and toughness while maintaining relatively high ductility. Maraging steels are used in aircraft, turbine blades and other industrial applications that require materials with a high strength-to-weight ratio. Due to their properties and wide range of applications, including widespread use in the aerospace industry, maraging steels have recently been demonstrated to be suitable for the fabrication of parts via 3D printing.. The rare combination of high strength and toughness found with maraging steel makes it well suited for safety-critical aircraft structures that require high strength and damage tolerance. There are few other studies in the process of Autogenous TIG welding of this material, making it important to study the feasibility of welding these steels.

CHAPTER 2

MARAGING STEEL 250

Maraging Steels based on iron–nickel–cobalt–molybdenum system have emerged as an outstanding family of materials with exceptional combination of characteristics, making them the best choice for specialized applications.

The term 'Maraging' is derived from the combination of the words Martensite and Age-hardening. Maraging steel offers an unusual combination of high tensile strength and high fracture toughness. Most high-strength steels have low toughness, and the higher their strength the lower their toughness. The rare combination of high strength and toughness found with Maraging steel makes it well suited for safety-critical aircraft structures that require high strength and damage tolerance. Maraging steel is strong, tough, low-carbon martensitic steel which contains hard precipitate particles formed by thermal ageing.

Maraging steel contains an extremely low amount of carbon (0.03% maximum) and a large amount of nickel (17–19%) together with lesser amounts of cobalt (8–12%), molybdenum (3–5%), titanium (0.2–1.8%) and aluminium (0.1–0.15%). Maraging steel is essentially free of carbon, which distinguishes it from other types of steel. The carbon content is kept very low to avoid the formation of titanium carbide (TiC) precipitates, which severely reduce the impact strength, ductility and toughness when present in high concentration. Because of the high alloy content, especially the cobalt addition, Maraging steel is expensive.

Due to the low carbon content Maraging steels have good machinability. Prior to aging, they may also be cold rolled to as much as 90% without cracking. Maraging steels offer good weld ability, but must be aged afterward to restore the original properties to the heat affected zone. When heat-treated the alloy has very little dimensional change, so it is often machined to its final dimensions. Due to the high alloy content Maraging steels have a high hardenability. Since ductile FeNi martensites are formed upon cooling, cracks are non-existent or negligible. The steels can be nitrided to increase case hardness and polished to a fine surface finish.

Non-stainless varieties of Maraging steel are moderately corrosion-resistant and resist stress corrosion and hydrogen embrittlement. Corrosion-resistance can be increased by cadmium plating or phosphating.

Maraging steel is produced by heating the steel in the austenite phase region (at about 850 °C), called Austenitising, followed by slow cooling in air to form a martensitic microstructure. The slow cooling of hypoeutectic steel from the austenite phase usually results in the formation of ferrite and pearlite; rapid cooling by quenching in water or oil is often necessary to form martensite. However, martensite forms in Maraging steel upon slow cooling owing to the high nickel content which suppresses the formation of ferrite and pearlite. The martensitic microstructure in cooled Maraging steel is soft compared with the martensite formed in plain carbon steels by quenching. However, this softness is an advantage because it results in high ductility and toughness without the need for tempering. The softness also allows Maraging steel to be machined into structural components, unlike hard martensitic steels that must be tempered before machining to avoid cracking.

After quenching, Maraging steel undergoes a final stage of strengthening involving thermal ageing before being used in aircraft components. Maraging steel is heat-treated at 480–500 °C for several hours to form a fine dispersion of hard precipitates within the soft martensite matrix. The main types of precipitates are Ni_3Mo, Ni_3Ti, Ni_3Al and Fe_2Mo, which occur in a high volume fraction because of the high alloy content. Carbide precipitation is practically eliminated owing to the low carbon composition. Cobalt is an important alloying element in Maraging steel and serves several functions. Cobalt is used to reduce the solubility limit of molybdenum and thereby increase the volume fraction of Mo-rich precipitates (e.g. Ni_3Mo, Fe_2Mo). Cobalt also assists in the uniform dispersion of precipitates through the martensite matrix. Cobalt accelerates the precipitation process and thereby shortens the ageing time to reach maximum hardness. Newer grades of Maraging steel contain complex $Ni_{50}(X, Y, Z)_{50}$ precipitates, where X, Y and Z are solute elements such as Mo, Ti and Al.

The precipitates in Maraging steel are effective at restricting the movement of dislocations, and thereby promote strengthening by the precipitation hardening process. Figure 11.10 shows the effect of ageing temperature on the tensile strength and ductility of Maraging steel. As with other age-hardening aerospace alloys such as the 2XXX Al, 7XXX Al, β-Ti and α/β-Ti alloys, there is an optimum temperature and heating time to achieve maximum strength in Maraging steel. When age-hardened in the optimum temperature range of 480–500 °C for several hours it is possible to achieve a yield strength of around 2000 MPa while retaining good ductility and toughness. Over-ageing causes a loss in strength owing to precipitate coarsening and decomposition of the martensite with a reversion back to austenite. The strength of Maraging steels is much greater than that found with most other aerospace structural materials, which combined with ductility and toughness, makes them the material of choice for heavily loaded structures that require high levels of damage tolerance and which must occupy a small space on aircraft.

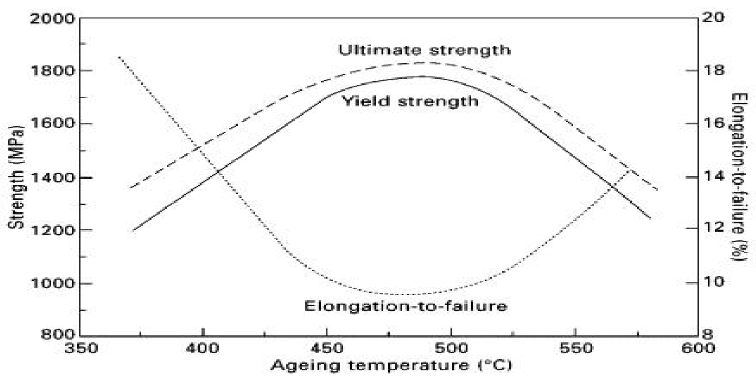


Fig 2.1: The above diagram shows how the mechanical property of Maraging Steel is varied in ageing process

Physical Properties:

1) Density: 8.00 g/cc (0.289 lb/ in^3)
2) Specific Heat Capacity: 293 J/kg-°K (0.108 BTU/lb-°F)

Mechanical Properties:

1) Tensile Strength, Ultimate: 965 MPa (140000 psi)
2) Tensile Strength, Yield: 655 MPa (95000 psi)
3) Bulk Modulus: 140 GPa (20300 ksi)
4) Shear Modulus: 73 GPa (10600 ksi)
5) Elastic Modulus: 190 GPa (27600 ksi)
6) Percent Elongation at break : 17%
7) Impact Energy :52 Joules

Thermal Properties:

1) Thermal Conductivity: 19.6 W/m-°C (136 BTU-in/hr-ft^2-°F)
2) Thermal expansion: 9.72 µm/m-°C (5.4 µin/in-°F)

CHAPTER 3

TIG WELDING

Gas tungsten arc welding (**GTAW**), also known as **tungsten inert gas** (**TIG**) **welding**, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area and electrode are protected from oxidation or other atmospheric contamination by an inert shielding gas (argon or helium). A filler metal is normally used, though some welds, known as autogenous welds, or fusion welds do not require it. When helium is used, this is known as heliarc welding. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

3.2 AUTOGENOUS TIG WELDING

infusible electrode and inert gas protection (commonly called more briefly TIG, from the English designation Tungsten Inert Gas) is an autogenous welding process in which heat is produced by an arc that strikes between an electrode that is not consumed (then said infusible) and the work piece. The electrode is made of tungsten or tungsten alloys, means a material at very high melting temperature, with excellent properties of thermionic emission that is used to facilitate the operation of the electric arc.

The welding is performed by bringing to melting the edges of the work piece to be welded, creating the joint eventually also with chopsticks filler material.

The electrode, the solder bath, the bow, the filler material and adjacent areas of the piece are protected from atmospheric contamination by a flow inert gas that escaping from the torch.

This process has among its main features to use an infusible electrode; consequently, the welding can be performed for small thicknesses without filler material and, when this is used, always allows a good control of the solder bath due to the good visibility during the welding process and the absence of metal transfer phenomena in the arc. The process is suitable for any working position and can also be applied on the laminations of a few tenths of a mm thick.

The TIG process is widely used for the realization of joints of high quality on materials sensitive to heating imposed by the welding. Because of the limited productivity, the process is rarely used to perform the welding process of high thickness. With the TIG welding is suitable for all types of carbon steels, low alloy steels, alloyed, stainless, nickel alloys, aluminium and its alloys, copper and its alloys, titanium, magnesium, and other non-ferrous alloys.

TIG welding is excellent to weld thicknesses of a few millimetres, because its heat source, intense and concentrated, allows discrete welding speed and then allows it melt the edges of the work piece without excessive risk of breakthrough; also the possibility of using modulated current increases still these characteristics.

CHAPTER 4

LITERATURE REVIEW

4.1 MARAGING STEEL

Additional merits owing to the speciality of this unique process are feasibility of automation and autogenous welding capability. The heat transferred by the tungsten arc is sufficient enough to melt any hard material (low to high carbon steels, HSLA, HTLA etc), the usage of filler materials could even be obviated.

Mohandas et al [3] conducted a comparative evaluation of gas tungsten and shielded metal arc welds of AISI 430 ferritic stainless steel and found that greater ductility and strength of gas tungsten arc welds as compared to those of shielded metal arc welds could be attributed to the equiaxed morphology of the fusion zone grains in the gas tungsten arc welds, and also to inert gas shielding .
The effect of autogenous arc welding processes on tensile and impact properties of AISI 409M ferritic stainless steel were studies and was found that the PAW joints of ferritic stainless steel show superior tensile and impact properties when compared with CCGTAW and PCGTAW joints, and this is mainly due to lower heat input, finer fusion zone grain diameter, and higher fusion zone hardness.
Maraging steels are strategically important material used in the manufacturing of satellite launch vehicles. It is apparent that these high strength materials require fabrication techniques which are robust in terms of strength and

performance. Gas tungsten arc welding is a unique joining technique used in joining of alloy steels and high strength materials. This is due to the considerable heat input (70-80%) imparted to the work material. Thus, this welding technique is a highly resorted one to weld materials ranging from lighter to high strength ones. In order to weld these materials to other super alloyed or any aerospace material, the parameters are to be optimized for individual materials and thus an optimized parameter is chosen for obtaining a sound weld.

Mr. Rajkumar has worked on the welding of maraging steel to AISI 4340 and have reported on welding of the above combination using super alloyed filler. It is worthwhile to note that GTAW technique is one of the few welding techniques available, which facilitates autogenous welding due to its process characteristics.Whilst the presence of other autogenous welding processes like Laser and plasma arc welding, which render more energy to the work piece, the tungsten inert gas welding carries maximum heat input to the weld metal. This narrows down to the fact that the parameters are to be effectively handled for getting a sound weld. Optimization of process parameters are utmost necessary in any manufacturing process as it brings maximum benefit of the part manufactured. In addition it obviates the occurrence of adverse residual stresses and distortion of the work piece.

4.2 TIG WELDING

A. Kumar, et al. [10] (2009), Presented work which pertains to the improvement of mechanical properties of AA 5456 Aluminium alloy welds through pulsed tungsten inert gas (TIG) welding process. Taguchi method was employed to optimize the pulsed TIG welding process parameters of AA 5456 Aluminium alloy welds for increasing the mechanical properties. Regression models were developed. Analysis of variance was employed to check the adequacy of the developed models. The effect of planishing on mechanical properties was also studied and observed that there was improvement in mechanical properties. Microstructures of all the welds were studied and correlated with the mechanical properties.

Akhilesh Kumar Singh, et al. (2016), This experiment denotes the Tungsten Inert Gas (TIG) welding process which is an arc based welding process that uses the arc between a non-consumable tungsten electrode and a work piece with the help of a shielding gas. The TIG welding is used to produce high quality welds and is one of the most popular technologies for welding in manufacturing industries. The main disadvantage of TIG welding process is low weld penetration. The purpose of this review was to look into various techniques that may improve the weld penetration and weld quality in a TIG welding. In this review we discuss the influence of various types methods such as ATIG (Activated Flux TIG), FBTIG (Flux Bounded TIG), PCTIG (Pulsed

Current Tungsten Inert Gas) Welding. It was observed during the review that use of flux or fluxes and pulsed current method improve the weld penetration with weld quality

Guo-qing WANG, et al. [12] (2016), the procedure of Tungsten inert gas (TIG) welded joints for 2219-T87 aluminium alloy are often used in the fuel tanks of large launch vehicles. Because of the massive loads these vehicles carry, dealing with weld reinforcement on TIG joints represents an important issue in their manufacturing and strength evaluation. Experimental and numerical simulation methods were used to investigate the effects of weld toe shape and weld toe position on the tensile behaviour and mechanical properties of these joints. The simulation results indicated that the relative difference in elongation could be as large as 96.9% caused by the difference in weld toe shape. The joints with weld toes located in the weld metal or in the partially melted zone (PMZ) exhibited larger elongation than joints with weld toes located at the juncture of the weld metal and the PMZ .

T. Ramkumar, et al. [13] (2017), This article addresses about the joining of 4 mm thick plates of Inconel 718 and ferritic stainless steel (S.S) 316L by Tungsten Inert Gas (TIG) welding process without using the activated flux. Trial experiments were conducted to find the influence of welding current on the depth of penetration and depth to width (D/W) ratio. The studies proved that a complete penetration could be achieved in multi pass. Microstructure examination using optical and Scanning Electron Microscope (SEM) clearly exposed the development of unmixed zone and also the Heat Affected Zone (HAZ) of Inconel 718. The chemical components of the Inconel 718 and SS316L were determined using Energy Dispersive Analysis (EDAX). Tensile and bend failures were observed at the parent metal of Inconel 718, SS316L and Inconel 718 & SS316L dissimilar joints. It was indicated from the notch tensile studies that the notch strength ratio was better than unity, which established that the weldments were ductile in all circumstances. The corrosion studies were carried out in the Nacl solution and it was found that Inconel 718 and SS316L dissimilar joint possess less corrosion resistance than similar SS316L weldment. It was inferred from the current study that the ultimate tensile strength of dissimilar weldments was better compared to similar weldments and the failure was observed in the parent metal for all the cases. Bend test results portrayed that dissimilar weldments possess better strength compared to SS316L weldments.

Jaiteerth R. JOSHI, et al. [14] (2016), Experimented the influence of different welding processes on the mechanical properties and the corresponding variation in the micro structural features have been investigated for the dissimilar weldments of 18% Ni maraging steel 250 and AISI 4130 steel. The weld joints are realized through two different fusion welding processes, tungsten inert arc welding (TIG) and laser beam welding (LBW), in this study. The dissimilar steel welds were characterized through optical microstructures, micro hardness survey across the weldment and evaluation of tensile properties. The fibre laser beam welds have demonstrated superior mechanical properties and reduced heat affected zone as compared to the TIG weldments

4.3 AUTOGENOUS WELD

A. Natasha, et al. [1] (2019), this paper presents that machining significantly influences surface integrity, metallurgical structure, grain size and thereby the mechanical, chemical and physical properties of the component. The presented investigation concentrates on grain refinement in turning of AISI 4340 alloy steel in dry and cryogenic turning. With cutting temperatures below 950◦C, the resulted surface layer consists of a microstructure with ultrafine white globular particles in all samples. A higher percentage of these particles was observed when using cryogenic flushing. It resulted in improved surface and subsurface properties in terms of ultrafine microstructure concentration, higher micro hardness, influence on the thickness and composition of the surface and subsurface layers and thermal stability.

Arun Kumar, et al. [2] (2019), this research work encompasses the response of AISI 4340 steel towards high temperature thermomechanical treatment (HTMT) and bake hardening (BH) studied. During HTMT, steel was austenitized to

1100°C and plastically deformed up to 30% with the help of rolling and immediately quenched in water, followed by tempering at 310±5°C for 2 hours. Optical microstructure, toughness and tensile strength, hardness were evaluated and compared with conventionally hardened and tempered (CHT) steel samples. Observations of HTMT process clarified no alterations in hardness, but a significant improvement in UTS in comparison to CHT samples. Charpy V-Notch (CVN) impact toughness drastically decreased in HTMT samples. Impact toughness of HTMT samples was 13 Joules, but 199 Joules for CHT samples. In HTMT samples, effect of deformation source on process investigated and found that rolling is an effective in improving properties than hammer forging. In addition, significant isotropic properties developed in the case of rolling, compared to hammer forging. Effect of amount of deformation studied; observed 30% deformation was the optimum deformation to achieve the best properties.

During bake hardening (BH) flat tensile AISI 4340 steel specimens were pre-strained to 2% and baked at 170°C for 20 minutes a headed with uniaxial tensile testing in which there was no improvement in yield strength after bake hardening observed. This might be because of the low amount of pre-straining or may be the lack of availability of interstitial atoms near to the dislocations generated during pre-straining. Bake hardened specimens were tested at different strain rates; it was observed that yield strength decreases with increasing strain rate, while UTS remains unaffected. FESEM images showed no significant structural changes.

F. Souza Neto, et al. [3] (2015), this experiment has denotes metallic materials have received special attention in the aerospace and defence areas. A few decades ago, Brazil was faced with technological challenges concerning the production and processing of ultra-high strength steels, such as AISI 4340 and SAE 300M steels. The AISI 4130 steel had been also considered, since it is applied in landing gears, small aircrafts engine cradles, and besides general industries. In this work, as a comparative welding process, Laser Beam Welding (LBW) was used as an alternative to the traditional TIG (Tungsten Inert Gas) welding. For the mechanical characterization of laser and TIG welds, tensile and hardness tests were performed. Micro structural characterization through optical microscopy was realized as well, in the fusion zone (FZ) and heat-affected zone (HAZ). Martensite was found in the fusion zone for both processes. However the average grain sizes were different due to different heating and cooling rates. In the present study, the weld was autogenous and a post weld heat treatment was conducted to evaluate its influence on mechanical properties. This treatment proved to improve the ductility of the steel and reducing the embrittlement in the welded region. It was observed that the thicknesses of the FZ and HAZ in the TIG welds were ten times larger than in the laser. The hardness values observed in FZ and HAZ were similar in both cases. Tensile strength after heat treatment remained at levels similar to the base material. After the heat treatment, there was a recover in the material ductility, particularly after the laser welding, demonstrating the usefulness of the process.

A K Lakshminarayanan, et al.(2008), Detaily explained effect of autogeneous arc welding processes on tensile and impact properties of ferritic stainless steel conformed to AISI 409M grade is studied. Rolled plates of 4 mm thickness have been used as the base material for preparing single pass butt welded joints. Tensile and impact properties, micro hardness, microstructure, and fracture surface morphology of continuous current gas tungsten arc welding (CCGTAW), pulsed current gas tungsten arc welding (PCGTAW), and plasma arc welding (PAW) joints are evaluated and the results are compared. It is found that the PAW joints of ferritic stainless steel show superior tensile and impact properties when compared with CCGTAW and PCGTAW joints, and this is mainly due to lower heat input, finer fusion zone grain diameter, and higher fusion zone hardness.

CHAPTER 5

PROBLEM IDENTIFICATION

5.1 WELDING OF MARAGING STEEL

Maraging steel is used in aircraft, with applications including landing gear, helicopter undercarriages, slat tracks and rocket motor cases – applications which require high strength-to-weight material. Maraging steel offers an unusual combination of high tensile strength and high fracture toughness.

However, the detailed analysis need to done for developing the defect free weld by optimizing the weld process parameters. From the available literature, it is evident that only very few works have been reported on weld ability of maraging steel. The metallurgical and mechanical properties have direct relevance and correlation of these properties becomes important in critical applications and needs further study.

5.2 OBJECTIVE OF THIS WORK

The main objective of this work is

1. To characterise the butt joint performed by Autogenous Tig Welding source in order to test its performance when subjected to various load conditions.
2. To obtain the change in strength of the material after the welding.
3. To analyse
    - ✓ Mechanical characterisation:
        - ➢ Tensile test
        - ➢ Impact test
        - ➢ Fatigue test
    - ✓ Metallurgical characterisation:
        - ➢ Microstructure & Macrostructure
        - ➢ Fatigue Fractography

CHAPTER 6

EXPERIMENTAL PROCEDURE

6.1 Materials and processes:

Maraging steel (250 grade) was the base metal selected which are predominantly used in manufacture of solid rocket boosters. The material was in solution annealed condition when welded. The weld parameters used are shown and the robotic TIG welding setup is shown.

6.2 Weld joint characterization:

2.2.1 Macro and microstructure analysis were performed using DeWinter metallurgical microscope. The SEM/EDAX analysis was performed using Carl Zeiss scanning electron microscopy. Modified Fry's reagent (scaled to 4:1 ratio) was used as the etchant for revealing microstructure of Maraging steel.

The tensile tests were performed at room temperature of 24 celsius. The samples were EDM wire cut to 5mm thick plates of +/- 0.005 mm conforming to E8 E8M ASTM standards for a sub size specimen. INSTRON 8801 Dynamic UTM was used for testing as shown in Fig. X. Three samples were tested for accuracy in repeatability and loading conditions. Micro hardness studies were done using Mitutoyo Vickers hardness tester equipped with microscope to capture the micrograph of the indented region to facilitate structure – property relationship analyses. Impact studies were executed using Charpy V- notch testing machine. Fatigue test was performed using INSTRON 8801 Advanced dynamic fatigue testing machine.

CURRENT (in Ampere)	**SPEED (in mm/min)**
180	150
180	200
180	220
190	150
190	200
190	220
200	150
200	200
200	220

Table 6.1 Parameters for TIG Welding of Maraging Steel 250

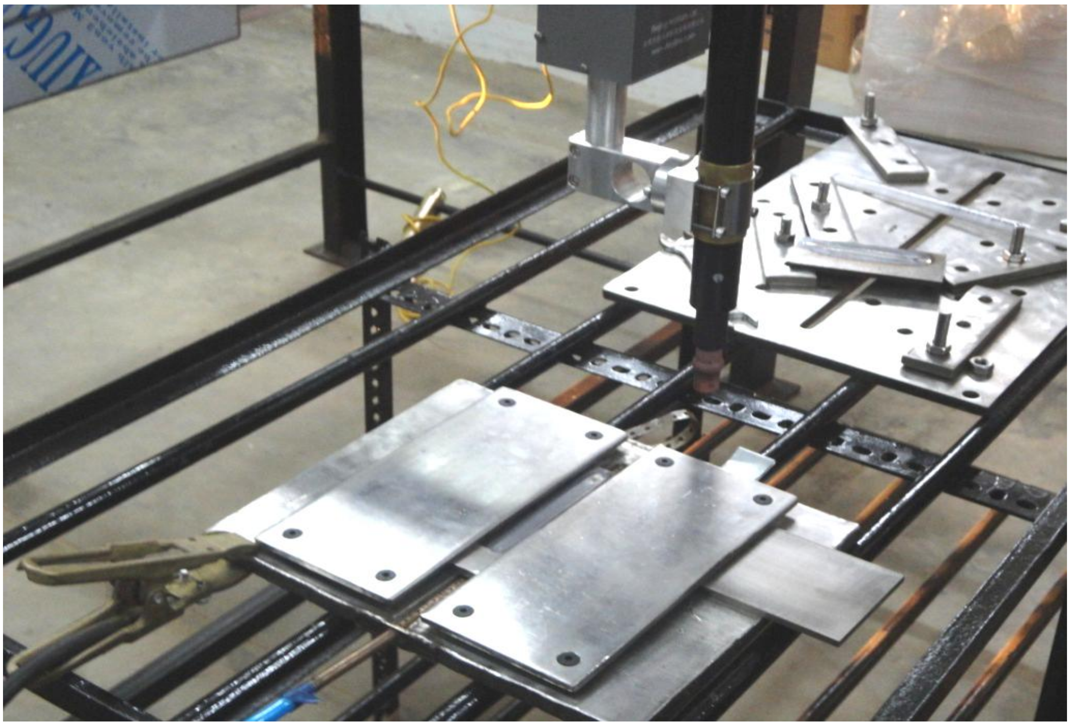


Fig 6.1 Robotic TIG Welding set up

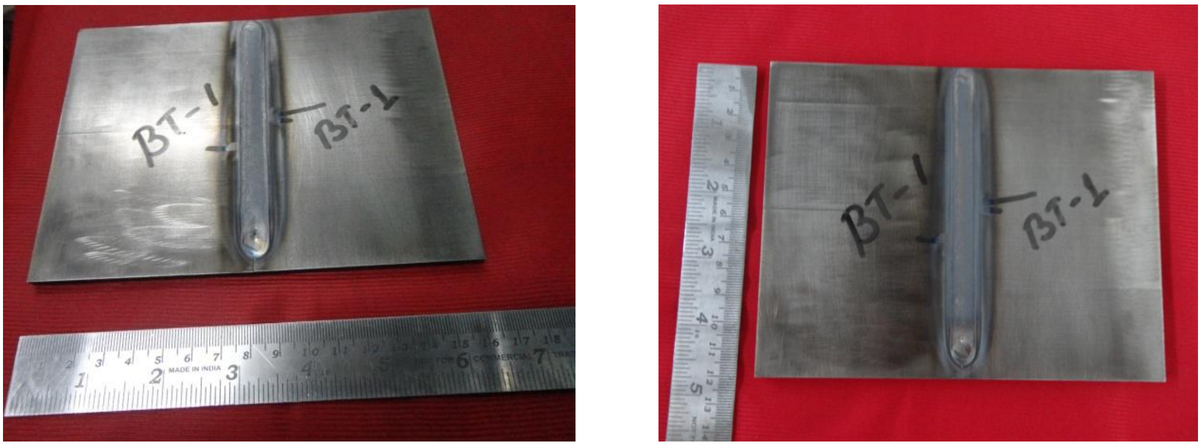


Fig 6.2 As welded sample of 250 grade Maraging steel butt joint

CHAPTER 7

RESULT AND DISCUSSION

7.1 TENSILE TEST

After Autogeneous Tig Welding, a tensile test is performed on Butt welded Maraging Steel 250 in order to determine its two parameters (i.e.) Ultimate Tensile strength and Yield strength.

This test is performed

- To select a material for an application.
- To predict how a material will perform under normal and extreme forces.

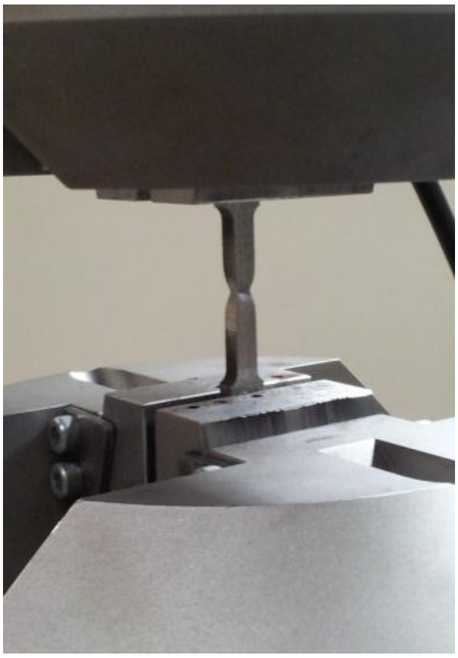


Fig 7.1.1: Tensile Test Setup

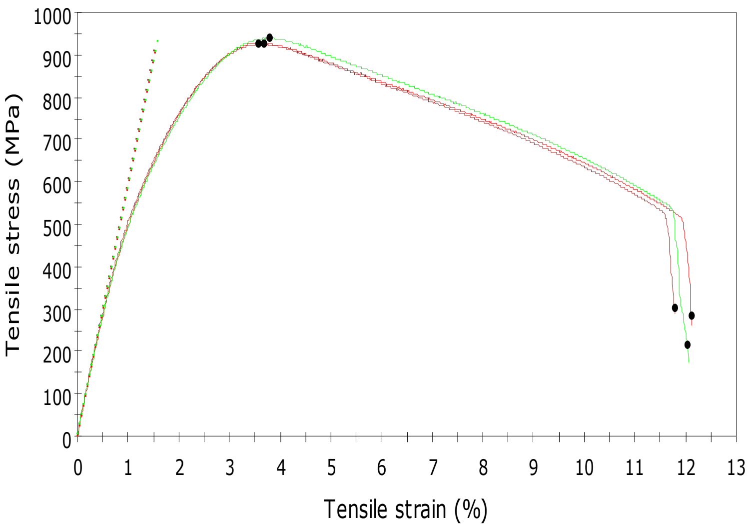
Fig 7.1.2: Welded sample after Tensile Test

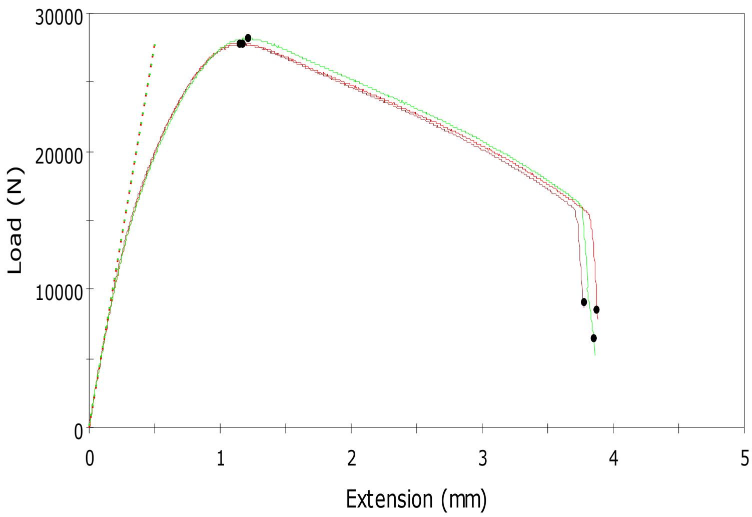
Sample No	Load at break (kN)	Maximum Load absorbed (N)	UTS (MPa)	Tensile stress at break (MPa)	Tensile strain at break (%)	% Elongation at Break (%)
Sample 1	8.48	27841.73489	928	282.60	12.108	11.51374
Sample 2	9.14	27774.36972	926	304.58	11.791	11.17504
Sample 3	6.41	28177.75011	939	213.83	12.044	11.59002

Table 7.1: Tensile Test experiment values

Ultimate Tensile Strength = 931 MPa (Average value)

% Elongation at break = 11.4262 % (Average value)





7.2 Impact Test

Impact test is performed for 3 samples made of butt welded Maraging Steel 250, to determine how much energy is absorbed by the specimen to break (during fracture), such that this absorbed energy is the measure of material toughness.By this test, we can predict the material's nature whether ductile or brittle.

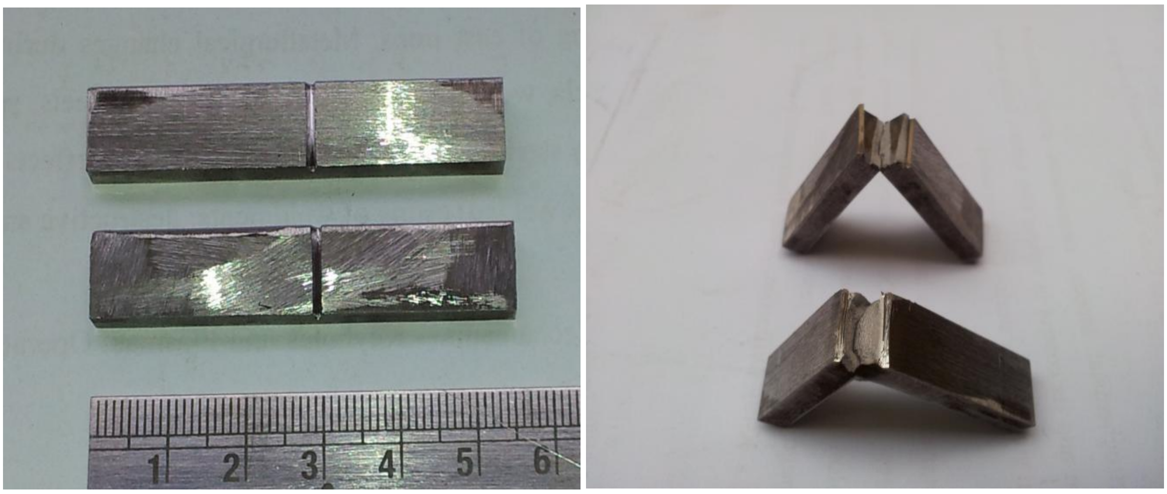


Fig 7.2: Welded sample after Impact test

Impact test	Impact energy (Joules)
Sample 1	42
Sample 2	40

Table 7.2: Impact test Energy values

Impact energy = 41 Joules (Average value)

7.3 FATIGUE TEST

Fatigue test is performed on 3 different samples of same material butt welded Maraging steel 250 to analyse its ability to withstand cyclic loading conditions. This test helps to determine the fatigue life of the material and crack growth data. It also helps to identify critical locations that may be susceptible to fatigue.

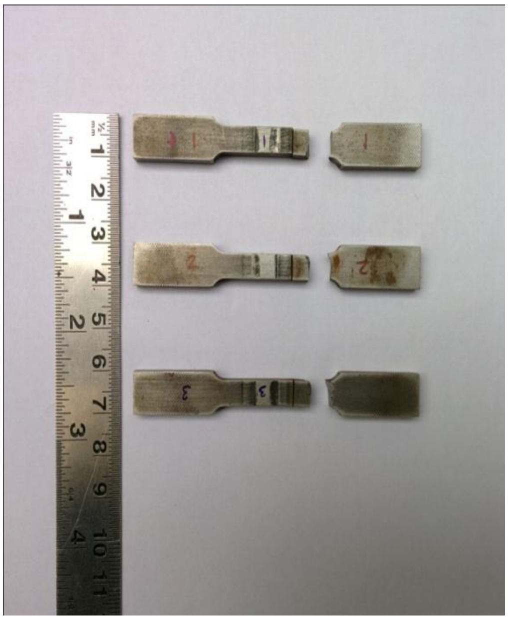


Fig 7.3: Welded sample after Fatigue Test

Amplitude = 3kN

	Load (kN)	Stress Ratio	Total number of cycles
Sample 1	7	-1	1,23,135
Sample 2	7	-1	1,25,635
Sample 3	7	-1	1,22,387

Table 7.3: Fatigue test for total number of cycles

7.4 MICROSTRUCTURE & MACROSTRUCTURE

After Autogenous Tig welding , the area that undergone welding is examined using Microscope to evaluate the structure in various region in weldment.

The various region are :

- Heat Affected Zone
  - Primary Heat Affected Zone
  - Secondary Heat Affected Zone
- Overlapping weld region
- Interface of regions

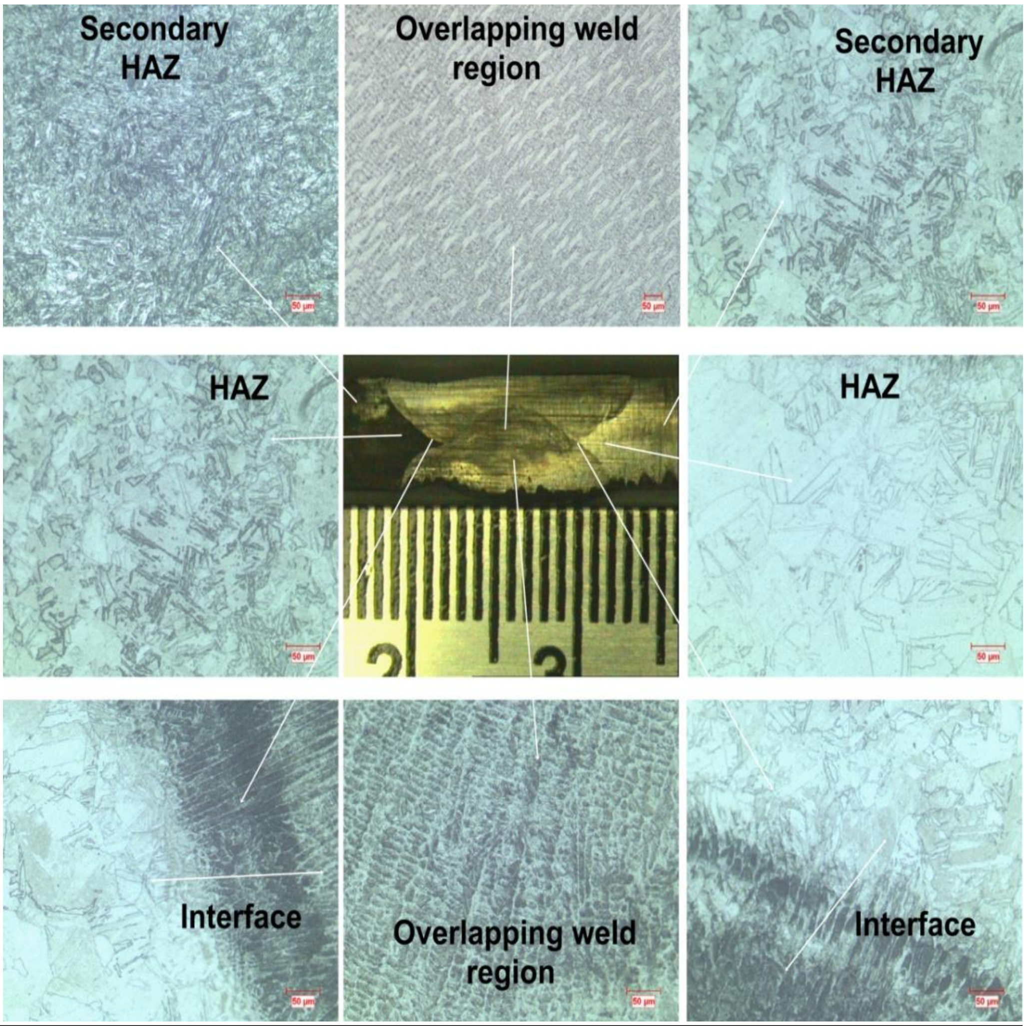
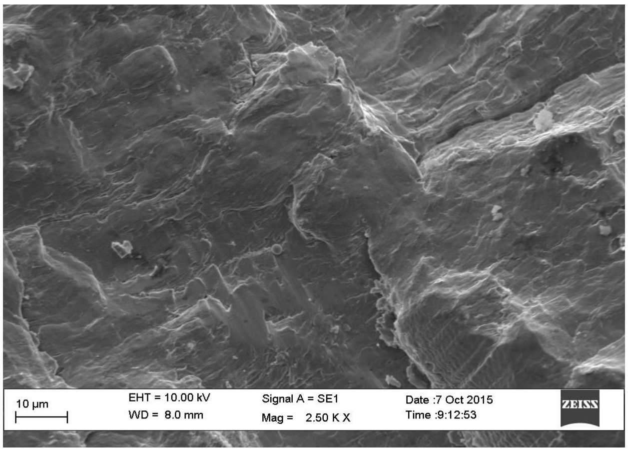


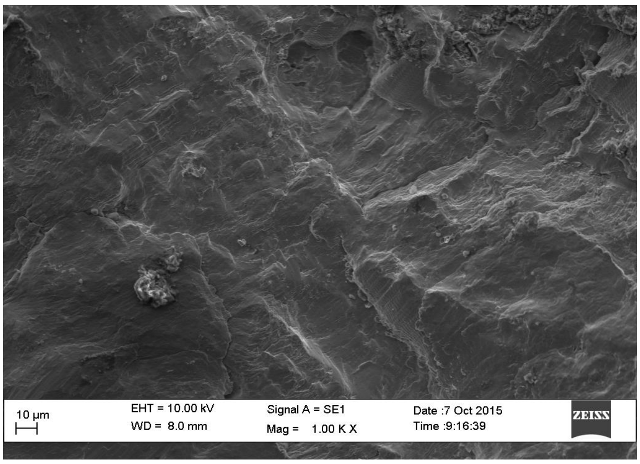
Fig 7.4: Microstructure and Macrostructure view of Weld zone

7.5 FATIGUE FRACTOGRAPHY

Fractography is the study of the fracture surfaces of materials. Fractographic methods are routinely used to determine the cause of failure in engineering structures, especially in product failure and the practice of forensic engineering or failure analysis.

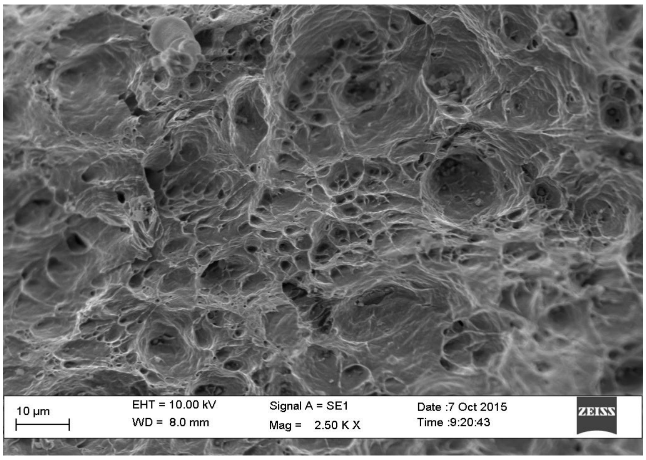
SAMPLE 1

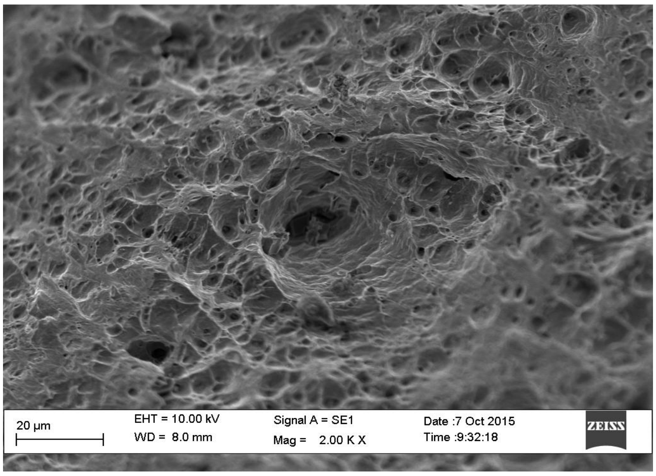




Results of sample 1 when loaded with 7 kN for 1,23,135 cycles

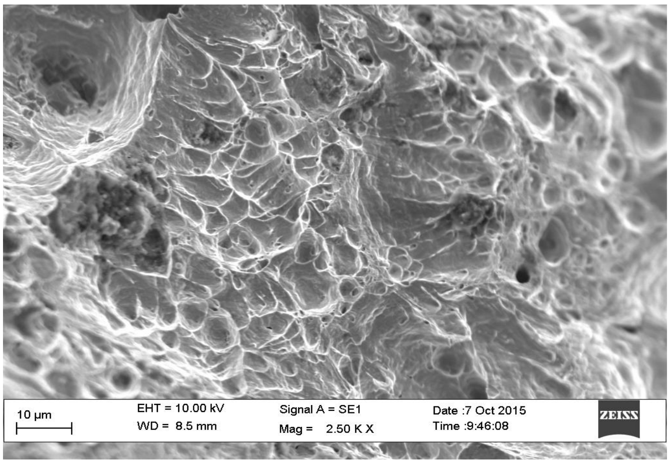
SAMPLE 2

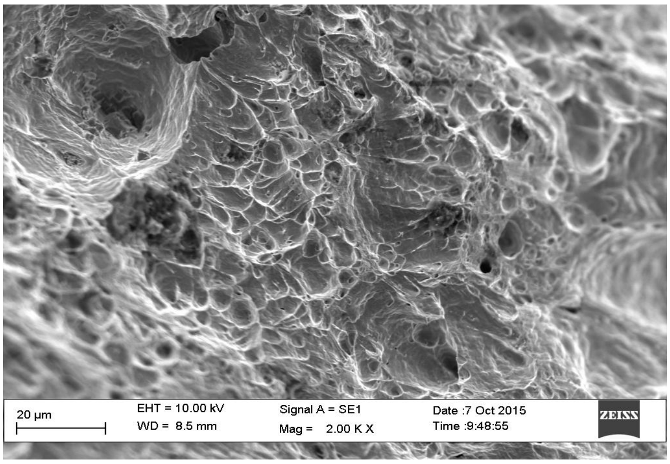




Results of sample 2 when loaded with 7 kN for 1,25,635 cycles

SAMPLE 3





Results of sample 3 when loaded with 7 kN for 1,22,387 cycles

Fig 7.5:Fatigue Fractography test

CHAPTER 8
APPLICATION AND ADVANTAGE

8.1 APPLICATION

- Rocket Motor Casings
- Light Aircraft Landing Gear
- Power shafts
- Low temperature tooling

8.2 ADVANTAGES

- It has high yield and ultimate tensile strengths.
- It has high toughness, ductility and impact strengths.
- It has hardness and wear resistance sufficient for many tooling applications.
- It is good weld ability w/o preheating or post heating.

CHAPTER 9

CONCLUSION

1. The results of Butt welded Maraging Steel grade 250 :

Parameters	Maraging Steel	Butt welded Maraging Steel
Ultimate tensile strength (MPa)	965	931
% Elongation at break (%)	17%	11.4262%
Impact Energy (Joules)	52	41

2. From the Fatigue Factography , after comparing the samples with parent material, it is evident that the fracture is **DUCTILE FRACTURE**.

CHAPTER 10
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