

MICROSTRUCTURAL AND METALLURGICAL PROPERTIES INVESTIGATION OF WELDED IRSM 41 – 97 RAIL STEEL

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering Degree in
Mechanical Engineering

By

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**DEPARTMENT OF MECHANICAL ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY (DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE

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April 2021



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BONAFIDECERTIFICATE

This is to certify that this Project Report is the bonafide work of MALLA VENKAT (37150113) and KALLURU GIRESH REDDY (37150085) who carried out the project entitled “MICROSTRUCTURAL AND METALLURICAL PROPERTIES INVESTIGATION OF WELDED IRSM 41 – 97 RAIL STEEL” under my supervision from Nov 2020 to March 2021.

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We, MALLA VENKAT (37150113) and KALLURU GIRESH REDDY (37150085) hereby declare that the Project Report entitled "MICROSTRUCTURAL ANDMETALLURIGALPROPERITIES INVESTIGATION OF WELDED IRSM 41 – 97 RAIL STEEL" done by us under the guidance of K.R. KAVITHA, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ACKNOWLEDGEMENT

We are pleased to acknowledge our sincere thanks to Board of Management of SATHYABAMA for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks to Dr. S. PRAKASH, M.E., Ph.D., Dean, School of Mechanical Engineering and Dr. G. ARUN KUMAR, M.E., Ph.D., Head of the Department, Department of Mechanical Engineering for providing us necessary support and details at the right time during the progressive reviews.

We would like to express our sincere and deep sense of gratitude to our Project Guide Mrs. K. R. KAVITHA, M.E., (Ph.D.,) Assistant Professor for her valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

I would like to express my sincere and deep sense of gratitude to Mr. J. R. DEEPAK, M.E., (Ph.D.,) Assistant Professor for his valuable consultation, suggestions, and constant encouragement that paved way for the successful completion of my project work.

We wish to express our thanks to all Teaching and Non-teaching staff members of the Department of Mechanical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

IRSM 41-97 rail steel is corrosion-resistant structural steel. It's mostly used in railway industries construction of railway coaches, bridges & frame building structures etc. Autogenous gas tungsten arc welding (AGTAW) and laser beam welding (LBW) is a without-filter process, AGTAW is suitable for low heat input(Q), more time taken, extreme weld speed. This fusion technology using AGTAW welding was upon 2mm thickness plate dimension 30 *10*2mm cut with the help of wire cut EDM according to ASTM standard. IRSM 41-97 rail steel is low percentage carbon steel. It's highly resistance to erosion, easily weldable & stronger than mild steel. It has nickel which makes the metal easily withstand cracking and stress corrosion. IRSM 41-97 rail steel is developed to avoid paint steel for protection. It has grown opposition to environment erosion when differentiate to unalloyed steels and low cost hence mainly used in railway industries. The IRSM 41-97 Plates are used for application like art & design constructions, ship building, transport containers, railway coaches and bridge construction's etc. The major problem during welding of IRSM 41-97 grade steel is that material gets exposed to very high temperature followed by rapid cooling. Due to welding, the basic metallurgy of the IRSM 41-97 material completely changes which completely affects the mechanical, metallurgical and corrosion property of the material.

An attempt is made to prepare the GTAW, GMAW, LBW and AGTAW weldment 2mm thickness IRSM 41-97 rail steel and investigating the microstructural and metallurgical properties by macro and microstructures of IRSM 41-97 rail steel. GTAW and GMAW weldments are prepared with ER70S-6 solid filler material. The welded IRSM 41-97 plate is cut with help of WEDM according to ASTM standard. From the research on the microstructure and macrostructure on the weldments of IRSM Steel, the following conclusion can be driven fusion welding (GTAW, GMAW, AGTAW, LBW) process is better in increasing the grain structural and macrostructure characteristics of IRSM Steel hence fusion welding is suggested. By this research analysis If the cross-section area of the weld zone region (WZR) for GTAW = 17.5, AGTAW = 15.2, GMAW = 13.0, LBW= 3.2 increase with the width of heat affected zone region (HAZR) also increases

TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	v
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF SYMBOLS AND ABBREVIATIONS	xiii
1.	INTRODUCTION	1
1.1	IRSM 41-97 RAIL STEEL	1
1.1.1	TYPE OF CORROSION RESISTANCE STEEL	4
1.1.2	APPLICATION OF IRSM 41-97 RAIL STEEL	5
1.1.3	FILLER MATERIAL (ER70S-6)	7
1.2	IRSM 41-97 RAIL STEEL WELDING	8
1.2.1	CLASSIFICATION OF FUSION WELDING	8
1.2.2	GAS TUNGSTEN ARC WELDING (GTAW OR TIG)	10
1.2.3	GAS METAL ARC WELDING (GMAW OR MIG)	10
1.2.4	AUTOGENOUS GAS TUNGSTEN ARC WELDING (AGTAW)	11
1.2.5	LASER BEAM WELDING (LBW)	11
1.2.6	MACROSTRUCTURE INVESTIGATION	12
1.2.7	MICROSTRUCTURE INVESTIGATION	12
2.	LITERATURE SURVEY	14
2.1	MACROSTRUCTURE AND MICROSTRUCTURE	14

CHAPTER NO.	TITLE	PAGE NO.
3.	AIM AND SCOPE	23
3.1	AIM OF THE PROJECT	23
3.2	SCOPE OF THE PROJECT	24
4.	MATERIAL AND METHODS	25
4.1	METHODOLOGY	25
4.1.1	IRSM 41-97 GRADE STEEL WELDED PARAMETER	27
4.1.2	IRSM 41-97 GRADE STEEL WELDING PROCESS	28
4.1.3	WELDING PROCESS MEASUREMENT OF IRSM 41-97 METAL SHEET	32
4.1.4	WELDED IRSM 41-97 SHEET METAL IN (2D AND 3D) VIEW	34
4.1.4.1	AUTOGENOUS GAS TUNGSTEN ARC WELDING WELDED SPECIMEN PLATE	34
4.1.4.2	GAS METAL ARC WELDING WELDED SPECIMEN PLATE	34
4.1.4.3	GAS TUNGSTEN ARC WELDING WELDED SPECIMEN PLATE	35
4.1.4.4	LASER BEAM WELDING WELDED SPECIMEN PLATE	35
4.1.5	VARIOUS WELDING TECHNIQUES FOR WELDED IRSM 41-97 RAIL STEEL	36
4.2	MATERIAL USED	37
4.2.1	IRSM 41-97 RAIL STEEL WELDING MACHINES	37

CHAPTER NO.	TITLE	PAGE NO.
4.2.1.1	GAS METAL ARC WELDING MACHINE	37
4.2.1.2	GAS TUNGSTEN ARC WELDING AND AUTOGENOUS GAS TUNGSTEN ARC WELDING MACHINE	38
4.2.1.3	LASER BEAM WELDING MACHINE	39
4.3	SPECIMEN PREPARATION FOR TESTING	40
4.3.1	IRSM 41-97 SPECIMEN WIRE CUT EDM PROCESS	40
5.	RESULT AND DISCUSSION	42
5.1	IRSM 41-97 RAIL STEEL WELDED PARAMETER GRAPH	42
5.1.1	WELD SPEED & WELD TIME OF IRSM 41-97 RAIL STEEL	42
5.1.2	HEAT INPUT OF DIFFERENT WELDING'S IRSM 41-97 GRADE STEEL	43
5.2	MACROSTRUCTURE ANALYSIS	44
5.2.1	MACROSTRUCTURE CHARACTERISTICS OF WELDED IRSM 41-97 RAIL STEEL	44
5.2.1.1	GAS TUNGSTEN ARC WELDING WELD	45
5.2.1.2	GAS METAL ARC WELDING WELD	46
5.2.1.3	AUTOGENOUS GAS TUNGSTEN ARC WELD	47

CHAPTER NO.	TITLE	PAGE NO.
	5.2.1.4 LASER BEAM WELDING WELD	47
	5.2.2 CHARACTERISTICS OF WELDED IRSM 41-97 RAIL STEEL JOINTS	48
	5.2.3 PERCENTAGE OF CROSS- SECTIONAL AREA OF IRSM 41-97 RAIL STEEL WELDED JOINT	49
5.3	MICROSTRUCTURE ANALYSIS	51
	5.3.1 BASE METAL MICROSTRUCTURE ANALYSIS	51
	5.3.2 GAS TUNGSTEN ARC WELDING MICROSTRUCTURE ANALYSIS	52
	5.3.3 GAS METAL ARC WELDING MICROSTRUCTURE ANALYSIS	53
	5.3.4 AUTOGENOUS GAS TUNGSTEN ARC WELDING MICROSTRUCTURE ANALYSIS	55
	5.3.5 LASER BEAM WELDING MICROSTRUCTURE ANALYSIS	56
6.	SUMMARY AND CONCLUSION	58
	6.1 SUMMARY	58
	6.2 CONCLUSION	60
	REFERENCES	61

LIST OF TABLES

TABLE NO	TITLE	PAGE NO.
1.1	CHEMICAL COMPOSITION AND MELTING POINT OF IRSM 41-97 RAIL STEEL	1
1.2	FEATURES, PROPERTIES, WELDING PROCESS, SHIELDING GAS AND APPLICATION OF THE IRSM 41-97RAIL STEEL	3
1.3	CHEMICAL COMPOSITION OF ER70S-6 FILLER MATERIAL	8
4.1	INDUSTRIAL RAILWAY COMPONENTS APPLICATION OF THE IRSM 41-97 STEEL(SMALL)	26
4.2	PROCESS PARAMETER FOR WELDING IRSM 41-97 RAIL STEEL	27
5.1	MACROSTRUCTURE CHARACTERISTICS OF IRSM 41-97 RAIL STEEL WELDED JOINT	45
5.2	2 PERCENTAGE OF CROSS SECTION IN WELD ZONE	50

LIST OF FIGURES

FIGURE NO	TITLE	PAGE NO.
1.1	IRSM 41-97 RAIL STEEL APPLICATION FIELDS	5
1.2	IRSM 41-97 RAIL STEEL APPLICATIONS	6
1.3	TYPE OF FUSION WELDING USED IN IRSM 41-97	9
4.1	SCHEMATIC OF EXPERIMENT WORK DONE ON WELDED IRSM 41-97 RAIL STEEL	25
4.2	SHEAR CUT INTO TWO-PIECE OF IRSM 41-97 STEEL	28
4.3	IRSM 41-97 CLEAN WITH ACETONE SOLUTION	29
4.4	SURFACE GRADING OPERATION OF IRSM 41-97 RAIL STEEL	29
4.5	IRSM 41-97 RAIL STEEL WELDED PLATES	30
4.6	DRAWING OF AGTAW, LBW IRSM 41-97 WELDMENTS	32
4.7	DRAWING OF GTAW, GMAW IRSM 41-97 WELDMENTS	33
4.8	SECTIONAL SCHEMATIC 2D AND 3D VIEW OF AGTAW WELDMENT	34
4.9	SECTIONAL SCHEMATIC 2D AND 3D VIEW OF GMAW WELDMENT	34
4.10	SECTIONAL SCHEMATIC 2D AND 3D VIEW OF AGTAW WELDMENT	35
4.11	SECTIONAL SCHEMATIC 2D AND 3D VIEW OF LBW WELDMENT	35
4.12	COMMON METHODS OF WELDING TECHNIQUES USED IN IRSM 41-97 STEEL	36
4.13	GMAW WELDING MACHINE	38
4.14	AGTAW AND GTAW WELDING MACHINE	38
4.15	LBW WELDING MACHINE	39
4.16	IRSM 41-97 RAIL STEEL WELDED PLATES CUT USING WEDM PROCESS FOR MICRO AND MACRO EXAMINATION	40

FIGURE NO	TITLE	PAGE NO.
4.17	IRSM 41-97SPECIMENS POLISHED WITH ALUMINA POWDER	40
4.18	POLISHED IRSM 41-97 SPECIMENS BEING DRIED AT ROOM TEMPERATURE	41
5.1	COMPARISON OF WELD SPEED & WELD TIME FOR VARIOUS WELDING	42
5.2	VARIOUS TYPE OF HEAT INPUT WELDED IRSM 41-97 GRAPH	43
5.3	MACROSTRUCTURE GTAW WELDMENT	45
5.4	MACROSTRUCTURE GMAW WELDMENT	46
5.5	MACROSTRUCTURE AGTAW WELDMENT	47
5.6	MACROSTRUCTURE LBW WELDMENT	47
5.7	IRSM 41-97 CHARACTERISTICS OF THE WELDED JOINT	48
5.8	8 PERCENTAGE OF WELDED CROSS-SECTION AREA OF IRSM 41-97 RAIL STEEL	49
5.9	MICROSTRUCTURE OF IRSM 41-97 RAIL STEEL BASE METAL (a) TRAVERSE SECTION (BM) (b)LONGITUDINAL SECTION (BM)	51
5.10	MICROSTRUCTURE OF IRSM 41-97 RAIL STEEL GTAW WELDED METAL (a) TRAVERSE & LONGITUDINAL SECTION (HAZ) (b) TRAVERSE & LONGITUDINAL SECTION (WZ)	52
5.11	MICROSTRUCTURE OF IRSM 41-97 RAIL STEEL GMAW WELDED METAL (a) TRAVERSE & LONGITUDINAL SECTION (HAZ) (b) TRAVERSE & LONGITUDINAL SECTION (WZ)	53
5.12	MICROSTRUCTURE OF IRSM 41-97 RAIL STEEL AGTAW WELDED METAL (a) TRAVERSE & LONGITUDINAL SECTION (HAZ) (b) TRAVERSE & LONGITUDINAL SECTION (WZ)	55

LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Society for Testing and Material
Ar	-	Argon
AC	-	Alternating Current
AF	-	Acicular Ferrite
AISI1005	-	Carbon steel grade
BM	-	Base Metal
BMZ	-	Base Metal Zone
C	-	Carbon
Cr	-	Chromium.
CEV	-	Carbon Equivalent Values
C	-	Carbides
CO ₂	-	Carbon Dioxide.
CORTEN A588	-	Weathering steel
CG-HAZ	-	Caesar-Grained Heat Affected Zone ³
CF	-	Coarse Ferrite.
AISI1005	-	Carbon steel grade
DC	-	Direct Current.
DP780(DP)	-	Dual-Phase steel, Tensile strength 780
DP980(DP)	-	Dual Phase steel, Tensile strength 980
ER309L	-	Austenitic stainless steel filler wire
EDM	-	Electrical Discharge Machining.
ER	-	Electrode Rod
F	-	Ferrite
FM	-	Ferrite Matrix
FZ	-	Fusion Zone
FL	-	Ferrite Laths
FF	-	Fine Ferrite
FP	-	Fine Pearlite
Fe	-	Iron
GTAW	-	Gas Tungsten Arc Welding
GMAW	-	Gas Metal Arc Welding
GF	-	Grain Boundary Ferrite

GB	-	Grain Boundary
GBF	-	Grain Boundary Ferrite
GGZ	-	Grain Growth Zone
GBA	-	Grain Boundary Allotriomorph
GBF	-	Grain Boundary Ferrite
HAZ	-	Heat Affected Zone
HAZ	-	A Heat Affected Zone Ferrite Phase
HAZ-B	-	Heat Affected Zone Bainite in Ferrite Matrix
IRZ	-	In Complete Recrystallization Zone
I	-	Input Current
LBW	-	Laser Beam Welding
LM	-	Lathe martensite
L	-	Length of the Sheet
Mn	-	Manganese
MIG	-	Metal Inert Gas
MO	-	Molybdenum
MAG	-	Metal Arc Gas Welding
M	-	Martensite
N	-	Nitrogen
PTZ	-	Partially transformed Zone
P	-	Phosphorus.
RZ	-	Recrystallization Zone.

S35512W + N/S355J2W - European Standard Steel

Si	-	Silicon
S	-	Sulphur
STT	-	Surface Tension Transfer
S	-	Solid Wire.
SAG	-	Submerged Arc Welding
TIG	-	Tungsten Insert Gas
TZ	-	Tempering Zone.
UA	-	Unaffected Area.
UB	-	Upper Bainite
UBM	-	Unaffected Base Metal
US	-	United state

V	-	Vanadium.
70	-	No Less Than 70,000 Kilos of Tensile Energy.
20X20	-	Time Bigger Than Original Real Specimen.
100x 100	-	Time Bigger Than Real Specimen.
200x 200	-	Times Bigger Than Real Specimen.
16MNDR	-	Pressure vessel grade steel plate

CHAPTER 1

INTRODUCTION

1.1 IRSM 41-97 RAIL STEEL

IRSM 41-97 rail steel is conquest steels. This IRSM 41-97 grade steel is more applied to Indian Railway Industries application. This steel consists alloy element of copper, nickel & chromium in a parent metal and benefit of IRSM 41-97 has increased due to long-life span, oxidation resistance, fewer costs & unpainted. The chemical composition and meting point of each element of IRSM 41-97 rail steel as shown in Table 1.1

Table 1.1 Chemical composition and melting point of IRSM 41-97 rail steel

Element	Si	P	Ni	Cr	Mn	S	V	C	Fe	Cu
Composition (%)	0.298	0.087	0.218	0.548	0.391	0.013	0.10	0.120	-	0.302
Melting point	1410	44.1	1453	1857	1245	115.2	1890	3500	1535	1083

IRSM 41-97 rail steel provides higher safety due to fire accident conditions. It is widely used in industries like petrochemical, mining, aerospace, oil fields, refineries, pipe fabrication, sugar mills factories. This IRSM 41-97 steel mainly used in railways, chemical, fertilizer, power plants, marine, defence, automobiles sectors. IRSM 41-97 grade steel consists of low carbon 0.09% without difficult weldable as stronger than mild steel. It mainly consists of nickel elements that can easily withstand cracking and stress corrosion. These materials have the unique function of rust - curing- rust (patina). The colour of patina formation depends on the environment and exposure condition. The dark reddish-brown coloured patina will be quickly formed in a heated zone where sulphur(s) content is higher. The corrosion resistance property is 4-8 times higher than that of conventional steel. In IRSM 41-97 steel has unstable organic compounds formed making the material eco-friendly.

This material makes a low price and construction is easy in fewer days as compared to other conventional steels. If % carbon added more it can resist oxidation better.

The metallurgical distinction between IRSM iron mineral 41-97 and other development prepares that join copper, nickel and chromium components can improve erosion opposition. The development of the sun. Light and dry/wet cycles are fundamental for the arrangement of a solid and durable layer, albeit rust will develop without the arrangement of a defensive bronzer under moist conditions.

The non-grating patina isn't simply simple to oppose the consumption of IRSM 41-97 metal, yet additionally has a rural and older style appearance, which makes these compounds especially alluring in development and development. Lately, the primary applications incorporate unfamiliar public structures, like extensions and barricades, electrical spaces, portable pinnacles, rail routes, improving models and tops of present-day building locales. It very well may be said that because of the presence of serious gas toxins (SO₂, NO_x, and so on), the arrangement of the defensive layer may likewise be influenced by various ecological elements (like temperature and moistness)[9].

It has high rupture strength, good bending properties and high toughness [32]. In Table 1.1 we observe that carbon(C), vanadium(V) and iron (Fe) have high melting points compared to other elements in chemical composition (%). The feature, properties, welding process, shielding gases and IRSM 41-97 rail steel application as shown in Table 1.2

Table 1.2 Features, properties, welding process, shielding gas and application of the IRSM 41-97 rail steel

Grade	Features	Properties	Welding process	Shielding Gas	Application
IRSM 41-97	Corrosion resistant	High strength	GTAW / GMAW	Ar	Railway coaches
	Durability	High toughness	Laser beam welding / Laser MAG hybrid welding	CO ₂	Frame work structure
	Longer lifespan	Good bending property	Autogenous GTAW	N	Transport Containers

The weldability of IRSM 41-97 rail steel will be welded and gas cut identical like that of regular structural steel. The carbon content material is saved very less than 0.3 wt. % to provide good high-quality weld IRSM 41-97 steel can be welded use of steel active gasoline is Tungsten Inert Gas (TIG), Metal Inert Gas (MIG), AGTAW, Laser Beam Welding (LBW), Laser-Mag Hybrid Welding, Submerged Arc Welding (SAG). All IRSM 41-97 steel joints which include fillet welds, must be welded continuously to keep away from moisture and corrosion along with crevices. The welding of IRSM 41-97 steel is much like that of normal structural steels, Carbon Equivalent Values (CEV) of IRSM 41-97 rail steel are relatively better result, excellent deal care needs to be taken even as the welding method is distinctive. ER70S-6 filler wire is used to weld IRSM 41-97 grade weld steel for various programs. square facet butt weld can be organized for the usage of the unmarried-skip method. This IRSM 41-97 plate follows the ASTM A242 standard cut with help of Wire Cut Electrical Discharge Machining (WEDM) follows [2,30].

The IRSM 41-97 metal issue ID has genuine blemishes in the utilization of the metal, and the microstructure structure itself isn't proof of consumption. In the event that water is permitted to gather taken care of, the degree of consumption there will be higher. The metal is delicate to tropical and subtropical environments, and the overall environment on the ground can likewise cause rust close to the

surface. The rate at which certain barometrical precipitation fluctuates enormously with the presence of air poisons that advance consumption [16].

IRSM 41-97 indicates fatigue crack in between the coated surface and rust strain in the vicinity of the crack. After welding few years, it started to crack on the welded region look like micro-crack structures because while welding region grain becomes slowly weak near to grain boundaries so, that it can form like micro-crack structure will form in the welded region [8].

1.1.1 Type of Corrosion Resistance Steel

CORTENA588 grade steel has received lightweight metal plates and steel plates in the assembling of train vehicles to decrease weight, and on the grounds that they are presented to sun, dampness, mechanical and environmental contamination, consumption will influence the presence of traveler vehicles, and along these lines erosion of the biological system, which is related with the arrival of energy and innovation for the rebuilding of steel. To build the assistance life of train traveler vehicles, it is important to lessen erosion by utilizing suitable measures inside the support range [2,16].

The S355J2W + N/S355J2W steel range is a kind of environment steel, which is a great European steel with high strength. These composites are broadly utilized on spans, railroads, vehicles, ships, structures, steel structures and different fields, prompting a mix of genuine climate execution and complete mechanical gear. The metal is vigorously founded on iron and is somewhat joined with P, Cu, Cr and Ni, consequently framing a film of mass and attachment under the actual metal, which can keep outer erosion from creating and growing inside. On account of consumption, the lattice assurance is the last surface of the example, and a steady decline in environmental pressing factor will create a steady layer of oxide insurance after openness to air. As indicated by the renowned European EN10025, the development of oxide hull can essentially lessen rust levels[30].

Weathering /Dual-phase metal structures a layer to forestall consumption on the outside of the climate metal, so it has a higher erosion obstruction than carbon steel. This resource is profoundly related with the expansion of specific mixtures.

Broad exploration has been done on these added substances to improve erosion of metals, including copper, chromium and nickel. Barely any filaments have detailed that silicon positively affects erosion of the metal, and there are sure combinations materials, synthetic properties of ecological elements are likewise thought of. It affects the arrangement of a layer that secures against rust. Consequently, for instance, in the most elevated regular habitat of chloride (like marine climate), the consumption pace of the metal of the environment is double that of the homegrown climate. The reason for this work is to efficiently consider the impact of Si alloying against the erosion of the climate. Uncommon consideration will be given to the arrangement, improvement and development of iron oxides that structure a layer of erosion, just as their relationship to the consumption pace of duplex metals [17,40].

1.1.2 Application of IRSM 41-97 Rail Steel



Fig: 1.1 IRSM 41-97 grade steel applications

IRSM 41-97 is mostly applicable for Indian Railway Industries. This steel construction building good look with unpainted in Fig: 1.1. It is protected from fire accident condition, corrode in dry/wet climate condition this steel mostly used in shipbuilding, bridges, railway coaches, frame body Structural works, transport tanks, vehicles and equipment constructions, freight wagons, industrial chimneys, etc. IRSM 41-97 steel are widely selling in foreign countries because less price, good maintenance, high strength it withstands any climate condition. In the future, they will use a lot of advantages with IRSM 41-97 rail steel in industrial applications [8].

To take advantage of IRSM 41-97 steel with higher atmospheric corrosion resistance than unalloyed steel, welded joints must be designed square, built and

revert joint as well as good maintenance work. The way that prevents formation of regeneration protective rust layer for the performance of goods produced from this IRSM 41-97 rail steel, the entire application technology is critical. Not only general climate conditions, but also particular unfavourable local climate conditions in the broadcast context as well as specifics of a situation must be considered. The corrosion behaviour of unprotected weathering steel can be affected by joints of the WZR.

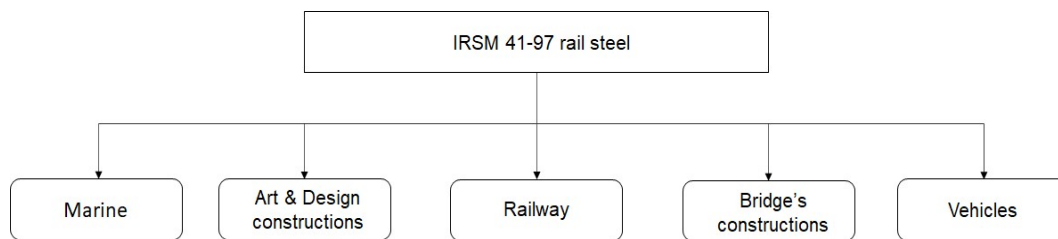


Fig:1.2 IRSM 41-97 rail steel applications

In Fig: 1.2 application field of IRSM 41-97 rail steel in marine field like ship building, containers, crane booms etc. Art& design constructions field like building, ornamental sculptures. Railway field rail coaches, rail containers etc. vehicles field like trucks, railway wages, cranes in all these fields IRSM 41-97 rail steel is used. Steel substrate preparation before use of paints and other related materials. The quality check of the cleanliness of the soil, rust grades and uncoated steel of grades preparation substrates which have their previous coating withdrawn completely lot of advantages from IRSM 41-97 steel.

In marine industries in which Ni element is added to improve corrosion resistance this IRSM 41-97 steel mostly improves the building bridge in USS and it is capable of continuously moist exposure state where high protective patina misty occurs in marine atmospheric conditions. IRSM 41-97 stable for construction industries and marine exposures deck of the bridge, roof and any other structure.

In the construction fields, it is easy to design complex columns, beams, tubes, architectural cladding, fencing and aesthetic beautification. In Bangladesh city using complex deck slabs, roads and bridges etc due to that IRSM 41-97 grade steel is very effective for the bridges & construction structural works.

IRSM 41-97 steel is the best material for urban, rural, seashore and industrial areas and it has easy to construct a U-LOOP flyover. In Bangladesh, this IRSM 41-97 steel is used in the government sector to constrict electric poles, city corporation fences and billboard support structures etc. In the private sector IRSM 41-97 steel focuses on factory sheds, factory buildings and tall buildings etc.

1.1.3 Filler Material (ER70S-6)

Abbreviation

ER: an electrode rod

70: no less than 70,000 kilos of tensile energy according to square inch of weld.

S: solid cord.

6: chemical composition of the wire.

ER70S-6 is a filler generally utilized in the iron and steel industry of IRSM 41-97. The hardware is intended to give lightweight welding smooth execution, from hefty welding, rapid, shower move bundling to light weight, low speed short bend activity. It is generally utilized in the filling of IRSM 41-97 metal additions, on the grounds that under wet/dry conditions with stale water, this filling material can't forestall barometrical contamination and will consume further, so it will demonstrate the development of an unprotected erosion layer. The presence of chlorides, just as the presence of discrete corrosive instigated pollutions in the climate, can improve erosion execution. The rust layer structures drop, free skin and compound ER70S-6 filling material, as demonstrated in Table 1.3.

Table1.3 Chemical composition of ER70S-6 filler material

Elements	Mo	Cr	Si	Cu	Ni	S	C
Composition%	0.15	0.15	1.15	0.035	0.15	0.035	0.5

This filler material is a first-rate mild steel strong cord generally utilized in applications on structural steel, carbon metal plate, pipe and fittings etc. It performs outstanding arc ignition, high price, low fume emission and clean finishing. ER70S-6 is filler material for various gas combinations inclusive of 100%CO₂ & 80% / 20% CO₂/Ar are used. It's far a mild metallic stable wire used for excellent power, right welds and trouble-loose in excessive temperature and high velocity [2].

This filler material wire in this category contains the highest mixture of deoxidizers within the form of Si and Mg. This allows them to be used for welding all types of carbon steel, even rimmed steels, use of CO₂ as a shielding gas. They produce easy, well-shaped beads especially well applicable for welding sheet steel. This filler metal is also usable for out-of-function welding with the short-circuiting transfer unrested forms. This filler material stable for percentage of carbon content steels. IRSM 41-97 steel has a low carbon const 0.10% compared to conventional steel and it is the best weldable efficiency [30].

1.2 IRSM 41-97 RAIL STEEL WELDING

1.2.1 Classification of Fusion Welding

In fig: 1.3 flow chat belong to two type of fusion welding electric gas arc and radiant energy. In electrical gas arc welding we using GTAW,GMAW,AGTAW welding and radiant energy using LBW welding

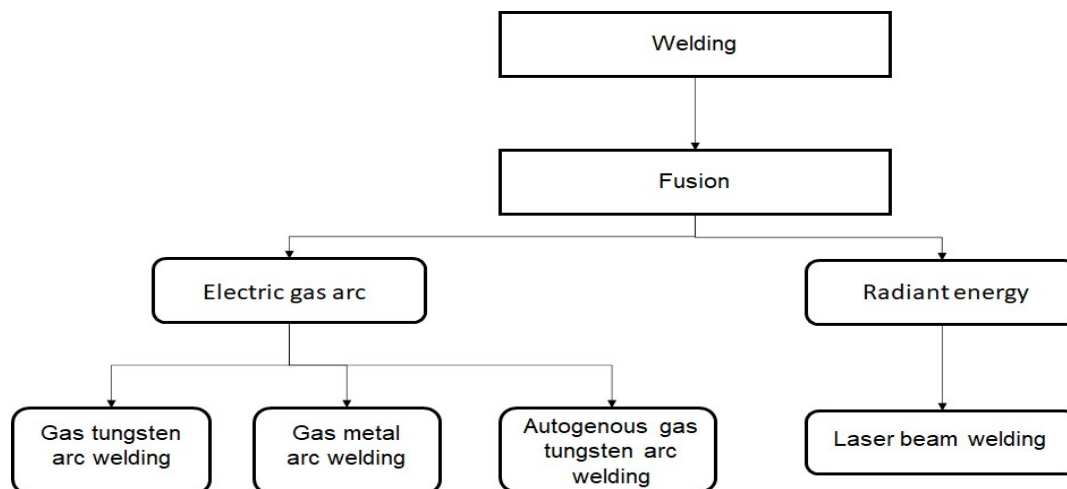


Fig: 1.3 Type of fusion welding used in IRSM 41-97 railway steel

In GTAW used shielding gases argon, carbon dioxide with ER70S-6 filler material and this argon and carbon dioxide gas mixture are used as the shielding gas to protect the welding provides the strong bonding between two similar IRSM 41-97 steel and the filler rod diameter takes with respect to the thickness of the IRSM 41-97 rail steel.

In GMAW used shielding gases argon, carbon dioxide with ER70S-6 filler material we selected filler rod wire is preferred by welders due to fewer fumes, practically no slag and easy manipulation of welding torch with smooth wire flow during corrosion repair attention when compared to flux-cored wire. this welding is to fix bonding between two similar IRSM 41-97 steel.

In AGTAW used shielding gases argon, carbon dioxide without filler material process it is heated with high expose on two edges of the IRSM 41-97 steel applying both side force to fix the bond of two-parent metal.

In LBW nitrogen gas is used the advantage of laser beam welding are less heat input, extreme depth penetration and extreme weld velocity, less damages for the two-bond joint of weldment IRSM 41-97 steel. By this research analysis to understand which welding have good weldability of IRSM 41-97 rail steel.

1.2.2 Gas Tungsten Arc Welding (GTAW or TIG)

Gas tungsten curve welding is likewise called argon bend welding (AAW). This IRSM 41-97 tempered steel welding tungsten cathode utilizes the ER70S-6 filler pole to convey the liquid metal. The defensive gas is a combination of argon (Ar) and carbon dioxide (Co₂). Stay away from air contamination in the welding territory and defensive pool. It is the obvious metal of the filling cycle, broadly utilized in rail development, auto body and body structure, and so on, to associate a similar IRSM 41-97 steel plates. Notwithstanding the non-combination welding, this technique additionally has a decent hold, so GTAW stays the best option of IRSM 41-97 railroad steel. Tungsten idle gas curve welding is broadly utilized in the assembling of different kinds of materials, like tempered steel, carbon steel and second rate carbon steel of different sorts. Contingent upon the welding contortion, co-activity and mechanical properties, the advancement of TIG welding measure

boundaries assumes a significant part in the nature of the eventual outcome. Since the welding interaction performs warmth and cooling measures unevenly, mutilation is unavoidable. Welding is the improvement of various deformities brought about by inconsistent warming and cooling during the welding interaction, for example, long, sidelong or rakish vacillations [30,16].

The benefit of GTAW is the significant expense, as the cooler is utilized to associate the ER70S-6 filling bar with a breadth of under 5mm. Notwithstanding, air particles can hold fast to the filling bar and contain welds.

1.2.3 Gas Metal Arc Welding (GMAW or MIG)

The gas of the circular segment welding metal utilized is harmed in the ingot. The cathode melts and conveys extra liquid metal to the weld. The indoor gas utilizes Ar and CO₂, which is the way toward filling the metal. This sort of MIG welding is quite possibly the main exercises that considers the support of the train during time of capacity (POH). furthermore, air contamination will influence the existences of train travelers. To broaden the functioning existence of significant distance transports, fitting measures ought to be taken during upkeep to diminish rust [1]. The creation proficiency of the MAG welding measure is higher than that of welding with bar anodes. The way toward welding the circular segment steel bend (for instance, welding with welding wire) is generally done when associating portions of the undercarriage. The weld is appropriate for rails, planes and lines. The benefit of GMAW is minimal effort, as there is no cooling, any air particles sticking to the cathode can be eliminated with an elastic cushion. It tends to be associated with anodes that can be utilized on a 5mm thick plate, so the expense of GMAW is lower than that of GTAW[30,3].

1.2.4 Autogenous Gas Tungsten Arc Welding (AGTAW)

We use AGTAW welding with high force CO₂ laser radiate and decrease power supply. Autogenous gas tungsten circular segment welding (AGTAW) is a bend welding measure that interfaces two indistinguishable metals by building up a curve between the idle tungsten anode and the work piece. Apply heat with or without filling iron. It can undoubtedly create top notch welds and can precisely

control welding boundaries, yet effectiveness is low because of weld infiltration. It assists with expanding the infiltration pace of the liquid lake and the profundity of the profundity estimation [30]. Welding plates, plates, cylinders, aviation and different enterprises are entirely reasonable in this day and age. It has progressed properties. Preceding welding, a combination of lifeless materials suspended in an adaptable climate will frame this gas, and a dainty layer of gas will be mellowed to the outside of the joint to be embedded.

1.2.5 Laser Beam Welding (LBW)

Laser welding is a fast and energy-efficient process that conduction welding joins workpieces at their surfaces, while keyhole welding creates deep welded seams. The laser beam melts of two sections to be joined along joint in conduction welding. From the molten metals of the two pieces, a welded seam coalesces and hardens. Laser welding is used to join thin-wafers together as compared to arc and plasma welding, laser welding has a quicker movement speed. Laser welding can build a wide range of joints in metals with thicknesses ranging from 0.01mm to 50 mm. A deep narrow keyhole is created by high-power density, resulting in a deep narrow penetration weld [37]. LBW can be done with a limited amount of material due to high energy density of the laser beam, it has less heat input than with arc welding. As a consequence, weld with a small heat affected zone and minimal shrinkage is possible [5]. Deep welding penetration, low heat input and high strength, advantages of all fusion welding technology. Welding efficiency which gaps adaptability, it has become an effective thick plate development path gradually fusing for two factors, the microstructure of multi-layer welded joint is inhomogeneous first and foremost, the microstructure was influenced by different heat input and cooling speed. Different layers have structural inhomogeneity within inter-laminar zones, thermal cycles occur at various locations. Resulting in a number of microstructure transformation and more in-depth intensified the multilayer's microstructural inhomogeneity at welded joint [30,5].

1.2.6 Macrostructure Investigation

It's far external surface characteristics of a material that can be found beneath in microscope at low magnification up to 25X of IRSM 41-97steel specimen. It shows

WZ, Unaffected Areas (UA) and Heat Affected Zone Region (HAZR) consist of Grain Growth Zone (GGZ), Recrystallisation zone (RZ) [1]. And also, cross section area of the weld and percentage how much they occupy while welding, width of the HAZR clearly visible.

1.2.7 Microstructure Investigation

It's far the inner shape information of material we observed in this microstructure testing at a range of 20micrometer. This microstructure mostly investigated in base metal (BM), heat affected zone region (HAZR) & weld metal (WM) include shielding gas with or with-out filler material process [8]. A framework based on composition, properties, manufacturing history and efficiency of IRSM 41-97 material are all affected by its structure. The microstructure of material may reveal details about its composition and processing as well as its properties and results. Understanding the processes by which various structures are formed is needed for microstructure interpretation [38]. The microstructure of BM, HAZR and WZR of steel Joints is observed using optical metallurgical microscope at a magnification of 200 X as shown. Grains are draw out along rolling direction on the BM. IRSM 41-97 steels microstructure with different volume fractions of martensite are studied after fusion welding a commercial. IRSM 41-97 steel was selected as specimen for testing microstructures by suitable welding. The IRSM 41-97 grade steel was in the form of 2 mm thick sheet plate and Initial microstructures ranging from fully to partially recrystallized structures prior to austenite transformation. Such variety of initial microstructures affected austenite distribution that subsequently transforms by this we observe grain orientation, phases and zone regions. By input temperature and grain analysis, we can conclude which phase the steel belongs

CHAPTER 2

LITERATURE SURVEY

2.1 MACROSTRUCTURE AND MICROSTRUCTURE

Byju John et al., 2016 deduced in this exploration work that the size and length of Corten steel are 130mm and 125mm, individually, and the curve welding measure is utilized, and the filler material ER70 S with a width of 1.2mm is utilized for welding. The base material with a more modest construction expansion of 200x shows ferrite (light stage), and pearlite (dark stage) has low carbon and low iron substance. Pearlite contains 8% of the ASTM grain size of the base metal 6 to 7 grain bend bound metal circular segment Corten steel has an organization construction of polygonal ferrite (PF) microphase, grain limit ferrite (GF) and needles Ferrite (PF) pearlite and existing carbides. The approaching gas is utilized via carbon and argon separately. Under unadulterated CO₂, the level of oxidation is exceptionally high. In pearlite, ferrite, and carbides in the space influenced by local temperature dendrites, the indoor gas Ar + CO₂ is blended in with 80% argon and 20% carbon dioxide. The metallic region shows pearlite in the ferrite grid of the fine space of acicular ferrite, the grain ferrite limit beneath the acicular ferrite, and a little piece of GF searches for a high level of acicular ferrite. The 90%/10% compound gas entering Ar/CO₂ arrives at the influenced ASTM size, where 4 to 5 of the coarse construction contains ferrite and pearlite, and the metal region shows pearlite, carbide and polygonal ferrite. At higher temperatures, the ferrite and carbides (FC) in the acicular ferrite are decreased. In the composite region, the level of CO₂ in the unadulterated microstructure is 36% for AF, 60% for GF, and 4% for (PF&FC). The showed 80% Ar/CO₂ contains AF% 56%, GF 40%, (P&F FC) 3%, 90/10 Ar/CO₂ contains AF% 32%, GF 28%, (PF&FC) 40% [2].

Shu Zhen et al., 2014 it was deduced in the examination paper that utilizing S355J2W + N laser to quantify laser curve half breed welding, the distance across of the layout plate is 300 * 100 * 16 mm³ NiCu 1-IG welding wire to the metal filler with a breadth of 1.2 mm thick. It contains welding zone (WZ), heat influenced zone (HAZ) and base metal zone (BMZ). In the warmth influenced zone made out of the

incredibly hot zone (OHZ), the recrystallization zone (RCZ) and the incomplete recrystallization zone (PRCZ) close to the coordinated mixture zone where the state of the great temperature zone (OHZ) is diminished. The breadth and space of the mixture joint are 10.3mm and 90.0mm², individually, and the space of the MAG weld and joint are 18.8mm and 260.0mm², separately. Contrasted and MAG welded normal joints, the rates of cross breed welded joints are 45% and 65%, separately. In MAG welded normal joints, the decrease of welding hot inclusion in MAG welded joints has an influenced region at a temperature of 13.6mm and 4.70mm The middle width. The S355J2W + N steel equiaxed metal substrate shows the nature of ferrite (brilliant) and pearlite (dull earthy colored) in the vertical moving course similarly as the microstructure. AZ comprises of a hot surface, a recuperation zone and a recuperation zone. The microstructure of the warming zone shows fine ferrite. During the welding interaction, a modest quantity of pearlite totally changes over α - γ carbides into insoluble solids and gems. The grain size is minuscule the adjustment in cooling produces a fine-grained structure, ferrite-the pearlite staying in the grain limits is wealthy in carbon and is changed into pearlite [30].

Zhang et al., 2004 deduced in the exploration paper, utilizing environmental change 09CuPCrNi for FZ, HAZ, high temperature, absolute territory, all out region and two-stage treatment of the contained region. The trademark construction of the combination zone is made out of supportive of eutectoid ferrite, ferrite granular ferrite and pearlite. An ordinary nearby part is made out of equivalent ferrite grains and few pearlite settlements. Contrasted and the more fragile space of the welded joint territory, the ferrite grain network has a similar strength [40].

D. Westerbaan et al., 2014 deduced in this examination paper in 2014 that the organization of DP980 metal is made out of ferrite (F, dark territory) and martensite (M, white region). In BM, HSLA metal contains a ferrite framework (F), which contains carbides (c) near as far as possible. In the SEM break of the weld of DP980 steel, a cup-molded opening was framed. The martensitic slat with no commitment of the interlayer grain limit to the nano-hardness and bainitic ferrite stage shows the plastic progression of the material [5].

M. Ramadan et al., 2017 in this research paper concludes Laser Welded Dual Phase and Mild Steel joints that the fusion zone contains Grain Boundary Ferrite (GBF), Acicular Ferrite (AF), Bainite (B) and Little Martensite (M). The dual-phase steel grain structure contains mainly bainite, martensite and acicular ferrite phases. micrographs of dual-phase laser welds show narrow dark areas with fine grains representing supercritical and subcritical HAZ areas with microstructures contain tempered martensite, bainite and acicula ferrite [17].

X. H. Zhang et al., 2015 in this research paper concludes weathering steel laser-MAG hybrid welded filler material NiCu1-IG (80%Ar + 20%CO₂) shielding gas of the sample has a micro size of 100% and 50 micrometers. In the WD 14.9 mm good penetration shows formation of a high amount of a circular ferrite[11].

Ai-Min Zhao et al., 2018 in this research paper consist laser welding of low carbon hot rolled steel macroscopic images of the laser-welded joint. They consist three regions Fusion Zone (FZ), Heat Affected Zone (HAZ) and Base Metal Zone (BMZ) In HAZ region can be subdivided into 3 areas Tempering Zone (TZ), Incomplete Recrystallization Zone (IRZ) and Recrystallization Zone (RZ). When comparing the morphology of TZ and BMZ shows lath bainite because number of dispersed carbides was reduced and ferritic major axis in a twist and near boundaries small dispersed carbides of lath bainite. The microstructure of IRZ and it can find that lath bainite transformed into the ferrite and coarse cementite in a left direction, martensite was formed in the group like structures ferrite cementite and martensite together. lathe bainite was transformed into austenite[6].

V K Bupesh Raja et al., 2019 in his research work concluded Gas Tungsten Arc Welding (GTAW) Corten A588 steel with filler material ER70S-6 ferrite grains present in HAZ ranges from 15 to 20 microns. The left side of area Heat-Affected Zone (HAZ) ranges found uniform fine grains. There is no distinct interface layer between weld zone rapid heat filler metal at WZ forms a dendritic pattern of grains in the form of varying pools of ferrite. Large dendritic grain found cold weld region large grain size dendrites from due to slow cooling in room temperature[16].

Xiong et al., 2018 in his research attempted to think about 16MnDR steel mass acicular martensite (AM), modest quantities of polygonal ferrite (PF) with

carbide (c), bainite (B) and machine martensite (LM) Multi-layer laser welding is close to the grain limit. A lot of acicular ferrite (AF), PF and LM are shown [39].

Gokulanathan et al., 2015 He deduced in a recent report that MAG welding of Corten A588 steel was multiple times the austenite amplification brought about by heat treatment during welding. Austenite is left on a metal base between the warmth influenced zones, and the interface has an exceptionally little temperature-delicate territory (HAZ). Degenerate grain HAZ CGHAZ is near the weld. An elegantly composed HAZ.FGHAZ is near the parent metal. Contains grain arrangements WM, FGHAZ, CGHAZ and BM immaculate. At higher temperatures, ferrite will shape austenite [3].

Muniraju M et al., 2020 in his research work on dual-phase steel concludes metal inert gas welding process with a colorless specimen of dimension 350mm*150mm*16mm heat treatment using gas carbon furnace held at different inter critical temperature (720, 750, 780, 810,830 and 8500C) for 60minutes time taken. the parameters of plate 16mm thickness AWS 5.18 ER 70S6 (E7018) electrode wire is 1.2mm in diameter with inert gas carbon dioxide (CO₂) with heat input 0.4kw to 0. 7kw. Microstructure of base metal dual-phase steel at magnification 100X and 500X Nikon microscope LV150 image consist of fine grains of ferrite in 90% with the characteristic of pearlite in rolled direction. The volume fraction of martensite is with increase growth in the welded inter critical range. The microstructure dual steel in critical temperature (720,750, 780, 810,830, and 8500C) for 60minutes time taken to consist of light brown(martensite) and white(ferrite)phases has an equiaxed grain structure. In dual-phase steel at 20 micrometers, 720 deg is 10 percent, 780 deg is 15 percent, 810 deg is 20 percent, 850 deg is 35 percent magnification 100x and 500x shows ferrite and martensite in all critical temperature regions. In welded joint consists of three different zones WM, HAZ and BM in each zone will have different microstructural characteristics in high-temperature region dendritic structure consist ferrite, pearlite and martensite with precipitates and carbides. HAZ consists of regions martensite, tempered martensite, ferrite and few amounts of carbides. In a normalized region and transition, region consist of fine grains in which some alloying boron, molybdenum and vanadium present during welding [23].

Hussein A. Hussein et al., 2020 in his research work low carbon steel of Tungsten Inert Gas Welding (TIG) ,In this inert gases used Argon (Ar) and welded metal shows microstructure ferrite and pearlite found slow cooling of the metal during welding But here ER70S-3 filler rod is used he concludes Base Zone, HAZ and WZ using a metal filler to strengthen corrosion performance in the same amount of metal. TIG welding is a great alternative for welding low carbon steel because it prevents the weld zone from oxidation [13].

Yilbas B.S et al., 2010 secured the nitrogen cooling pace of the gas utilized in this space in an exploration paper on laser welding of low carbon steel. Notwithstanding, around here, if there are no obvious weld joints, fine grains can be gotten. Because of the wide temperature slope, the high cooling rate will influence the grain refinement. The fine grains are generally made out of round ferrite and fine pearlite structure. The most brilliant territory is ferrite, and the more obscure region is pearlite. Moreover, pearlite nucleation prompts the development of a piece of the design of cementite drops. The core along the limit of austenite frames a pearlite modulus, and a solitary province of ferrite and cementite pieces is shaped in the pearlite structure. The austenite stage is straightforward in the weld opening, permitting bigger grains to develop. For this situation, fine pearlite gives off an impression of being a blend of ferrite and ferrite/carbide limit components. Also, there are gems in the liquid territory , and fine grains and huge grains dispersed in this space can be seen[38].

Elisabetta Di Francia et al., 2018 utilized enduring steel and hostile to erosion coatings in a recent report to make against rust and defensive item layers that are influenced by climate and metal surface openness conditions. Also, it should be conceded that, truth be told, certain regions can never shape a defensive layer, or so they may spread at the speed of a snail, so it is imperative to follow long haul development. Then again, another steel rooftop construction ought to be ensured. Long haul protection [9].

K.Y. Benyounis et al., 2005 the aftereffects of the 2005 examination show that welding speed (S) and central region (F) are the most powerful factors. The width of the fringe territory (W). Accordingly, speeding up (this) will diminish (W).

This is on the grounds that the laser bar is straight. As the welding speed expands, the welding speed is higher than the welding line. The warmth scattering is diminished, the water content is decreased because of the dissolving of the base metal, and the width of the warming territory is decreased. Notwithstanding the characterized light, the conveyance of laser power is likewise brought about by the bigger laser shaft. The area of the base metal will be uncovered (W). This warmth will be moved from the combination zone to the mass metal through the warmth influenced zone, making it more extensive and more grounded [18].

Mahmud Sarkari Khorrami et al., 2014 examined carbon steel and ferritic treated steel in their examination paper, and prepared the gas tungsten terminal of ER309L tempered steel in the example furnished with hardened steel duplex ferrite-martensite Arc welding (GTAW), and the programmed mineral design is altogether ferrite-martensite. Ferrite is a metal oxide, and the cost of filler metal is higher than that of programmed metal welds. The sum and organization of martensite and carbides rely upon the welding temperature setting and the cooling rate that happens [24].

Zakaria Bounmerzoug et al., 2010 appeared in an examination paper on consuming low carbon steel that in HAZ iron metal, Widmanstätten ferrite and other pearlite provinces have gone through a strong stage change, for example, grain development and remaking. , Phase change, coordination and burning. . The stone surface in the warmth influenced zone is near the weld combination point, and the gem grains are bigger than those on the steel substrate. It has been tracked down that this action has two phases. During cooling, the warmth influenced zone varies. Since the cooling rate is quick, it is portrayed by fake precious stone grains and lopsided microstructure. This territory is generally ferrite with some pearlite states. This examination assists with understanding the impact of safe utilization of bend welding in the cryogenic business. Low carbon steel (0.9% by weight C). From the lower part of the metal to the highest point of the metal, little designs in various positions are cut. The metal is welded. The focal point of the microstructure of the weld is altogether different from the temperature touchy region. The states of ferrite and pearlite show the development of thicker groups, and the crystallographic reference was chosen. In the layer (base metal), the microstructure is made out of

ferrite ($\alpha\text{-Fe} + \text{Fe}_3\text{C}$) and a modest quantity of pearlite territory ($\alpha\text{-Fe} + \text{Fe}_3\text{C}$). The limits, edges and corners of the base metal for the most part contain ferrite highlight Isometric [41].

Mohamed Mahd et al., 2013 deduced in their examination paper that a large portion of the beginnings in the low-carbon combinations fitted with TIG and MIG were found to contain ferrite. Because of fast cooling, welding can be brought about by a fine perlite structure. Tests after MIG and TIG welding are somewhat affirmed, in light of the fact that there are numerous kinds of perlite microstructure, and tests after MIG and TIG welding have less imperfections[28].

S.Ravikumar et al., 2017 in his research paper consists of Corten steel with TIG welding cut 1.6mm on dimension 300 * 150mm by the shear cutting process 2mm electrode filler rod GR-ER70S2. In base metal. The microstructure shows low carbon steel with uniform grains of pearlite in a ferrite matrix Fine dispersion of carbides of chromium present in the ferrite matrix. In recrystallization grain region shows pearlite and ferrite grain size at 25-30 microns ASTM grain size is 6.dendritic pattern of grains due to rapid cooling from liquidus to solidus state.

Rolled longitudinal direction grain shows uniformly formed pearlite in ferrite grains with grain boundary carbides of chromium. In the heat-affected zone of the parent metal with grains of pearlite recrystallized to a bigger size compared to parent metal due to heat of the weld. The high temperature welded zone shows the dendritic pattern structure of grains weld deposit due to the rapid cooling region.

Yonglin Kang et al., 2015 his exploration paper contained DP780 steel-stage steel and tungsten dormant gas welding (TIG), which showed that the microstructure of tempered tempens in DP780 welds is typically made out of cementite particles that are equally circulated, the particles covered in the consistent lattice of ferrite with tungsten steel. Obviously, in the basic locale of HAZ of the TIG welding strategy, the best piece of martensite treating in the DP780 heat-influenced territory shows martensite and fissite ferrite microstructure unharmed, like BM. The most delicate territory influenced by the warmth turns into another kind of strip martensite with a limited quantity of ferrite, on the grounds that the temperature of this space is between the softening temperatures of Ac3line and DP780. Contrasted

with BM, more martensite is seen at a higher temperature-influenced territory when the temperature of the FZ surpasses the dissolving point. Because of the quick cooling of the weld pool during TIG welding, the more modest construction shows a higher martensite stage. Different obstructions to acicular ferrite and past austenite grains have likewise been found in FZ, demonstrating substance connections. In the space influenced by the warmth, incomplete ferrite and gentle martensite were found. The level of hardness diminishes the development of the microstructure of the warmth influenced territory (smooth surface) FZ, which has a martensitic structure with a specific acicular ferrite[31].

Yuki Ohkura et al., 2013 consolidated a low-carbon welding measure into his exploration paper, which utilizes a metal-protecting (MIG) gas, utilizing BM, HAZ, WM argon (Ar) and based on a strengthened (AF) metal surface. Four characters. Aside from the way that grain size isn't ordinary, the little structure of BM and AF tests is a typical ferrite. The normal size of a BM grain is 10mm, while the normal size of an AF grain is 125mm. The bainite condition of the side plates controls the arrangement under the WM test. Because of the quick cooling of the welding pool through welding, moderate martensite was shaped from the WM test. In a warmth influenced region, you can see the arrangement of two unmistakable components: (I) ferrite stage (HAZ-A); (ii) the development of bainite part of the body of the ferrite lattice (HAZ-B). Inside the warmth influenced territory, the volume of machine molded bainite pieces increments. Ferrite-g-austenite-ferrite is a mix of α -ferrite and g-austenite. In AISI 1005 steel welding, some little constructions of the warmth influenced region are appeared, incorporating areas with thick and fine leaves [25].

Xiaonan Wang et al., 2017 in his research paperwork concludes fiber laser welding joints between DP780 and DP980 steels in FZ and the HAZ make up a weld joint. FZ formation was formed by melting the weld metal at a high temperature and rapidly solidifying it, while the HAZ formation was heated and cooled without melting into four zones shows coarse-grained HAZ (CG-HAZ), fine-grained HAZ (FG-HAZ), and very fine-grained HAZ (VF-HAZ). In DP780 steel BM consisted of ferrite (F) and martensite (M) at the ferrite boundary if you equate it to the base metal was fully austenitized to form equiaxed austenite grain structure and transformed into lath martensite (LM) through FG-HAZ when the local peak temperature was above Ac3

transformation by shear, the microstructure of CG-HAZ shows lath martensite (LM) consist [14].

M.J. Hadianfard et al., 2019 in this research paperwork consists dual phase steel consists. Heat-Treated Sheet of DP600 dual-phase with a thickness of 3 mm. The martensite phase's volume fraction was determined. Optical and electron microscopy as well as image processing tools, were used. At least 25 fields on the polished surfaces at an appropriate magnification, etched specimens were examined. Metallography and image analysis of this steel in 25 different fields revealed that it was made up of a 22 percent martensite in a ferrite matrix. The size and shape distributions of martensite particles were extremely broad as shown [36].

CHAPTER 3

AIM AND SCOPE

3.1 AIM OF THE PROJECT

- To investigate metallurgical and micro-structure of welded specimens.
- To know of weldability IRSM 41-97 rail steel material.
- To understand microstructure character IRSM 41-97 steel of heat-affected zone (HAZ)&weld zone (WZ).
- To understand the microstructure of welded IRSM 41-97 grade steel in the longitudinal and transverse regions (WZ, HAZ).
- To perform microstructure analysis on GTAW, GMAW, LBW and AGTAW process with better weldment of IRSM 41 - 97 steel.
- To obtain the macrostructure characteristics of IRSM 41-97 steel at heat input and current GTAW, GMAW & AGTAW.
- To perform macrostructure analysis cross-section area of the weld zone and width of the heat-affected zone can be obtained.
- To perform GTAW, GMAW, LBW and AGTAW welded region parameter of the square butt joint of the IRSM 41 - 97 steel.
- To perform external surface characteristics of a material that can be observed under microscope level.
- To perform internal structure details of IRSM 41-97 steel material range of 20 micrometres can be obtained.
- To perform shielding gas of TIG Welding, MIG Welding, AGTAW&LBW can be obtained.
- To understand weld speed and weld time taken for GTAW, GMAW, AGTAW, & LBW.

- To perform without cracks on the welded corrode layer surface region.
- To perform causing high exposure of fusion during the welding process can be obtained.
- To understand welded IRSM 41-97 rail steel to resist the corrosion and rust strain that occurs in the welded zone region.
- To perform this investigation welded IRSM 41-97 steel improves macrostructures and microstructure for the local regions (HAZ, WM and BM) of the welded joints caused by the different welding processes (GTAW, GMAW, LBW & AGTAW) can be obtained.

3.2 SCOPE OF THE PROJECT

- The outcome will be a detailed report of all the macrostructure characteristics, microstructure analysis. In this investigation information about macrostructure and microstructure will be most useful to all the Indian railway factories and some industries with low percentage carbon contained steel manufacturing fields.
- The scope is to improve weldment of IRSM 41-97 steel in rail coaches applications without corroding and rust strain after welding.
- The outcome will be the advantages of IRSM 41-97 rail steel in the field of high welding applications. The above-given analyses will fetch a huge amount of information in knowing the welded IRSM 41-97 grade steel application better result.
- A comparison between macro and microstructure of different welding weldment IRSM 41-97 rail steel is done with include a better weld is recommended.

CHAPTER 4

MATERIAL AND METHODS

4.1 METHODOLOGY

IRSM 41-97 rail steel is low carbon material. It's better than mild steel but mainly applicable to Indian railway construction. This IRSM 41-97 steel alloy element consists of copper, nickel & chromium in a parent metal. Its unpainted structural steel rate of corrosion depends on the wet/ dry moisture welded region that forms the dark reddish-brown layer(patina). Generally, focuses on construction railway coaches, bridges, building constructions and containers, etc. Indian railway using fusion gas welding. The major problem during welding of IRSM 41-97 grade steel is that the material gets exposed to very high temperatures followed by rapid cooling. Due to this welding process, the basic metallurgy of the material completely changes which completely affects the mechanical metallurgical and corrosion property of the material. IRSM 41-97 steel consists of low carbon 0.09% with-out difficult weldable It mainly consists of nickel elements it has easily withstand cracking and stress corrosion. The corrosion resistance property is 4-8 times higher than that of conventional steel.

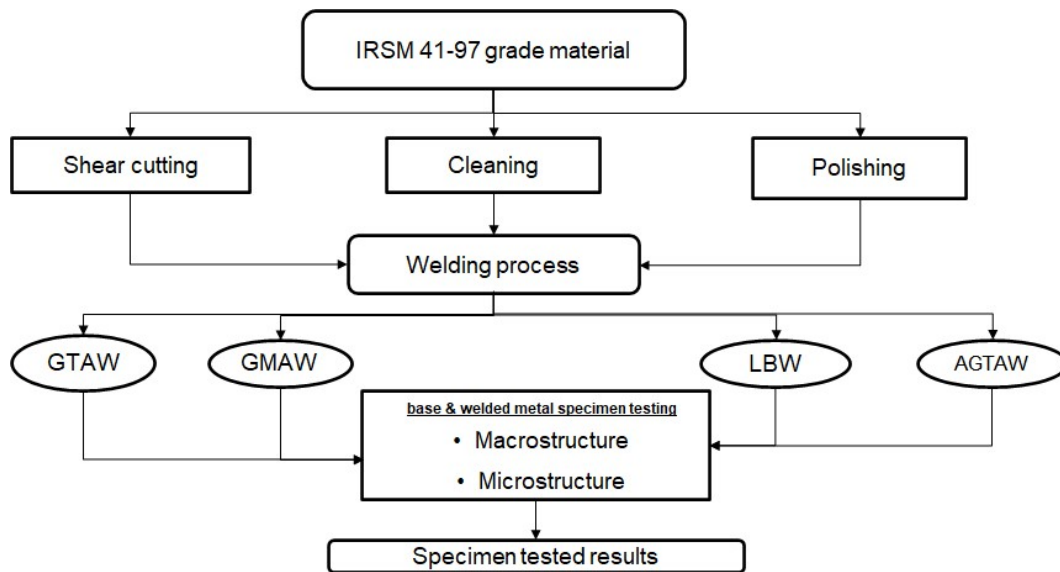


Fig: 4.1 Schematic of experiment work done on welded IRSM 41-97 rail steel

In Fig: 4.1 inform total experiment work done by IRSM 41-97 grade steel specimen include with testing methods.

First, we have taken IRSM 41-97 rail steel metal cut into two pieces with help of shear cutting operation after cleaning with acetone solution full of IRSM 41-97 steel metal then polish by using surface grading 120 energy wheels.

Then another step we will go to (GTAW, GMAW, AGTAW and LBW) welding process as shown in Fig: 4.1 after done with four fusion welding. Weldment IRSM 41-97 metal steel cut with the help of WEDM on dimension length is 20mm, width is 10mm and thickness is 2mm. Four weldments and one base IRSM 41-97 metal specimen testing with microscopic to identify grain phases. This weldment and base metal of IRSM 41-97 steel testing explain detailly about macrostructure and microstructure.

By this analysis it helps to know weldments of IRSM 41-97 steel behaviour with different heat input temperature due to this understand which welding weldment withstand corrosion and life span without cracks on the welded surface. Table 4.1 shows the railway components application of the IRSM 41-97 grade steel.

Table 4.1 Industrial railway components application of the IRSM 41-97 steel(small)

Grade	Railway Application
IRSM 41-97 steel	carline
	sole bar
	can trail
	roof sheet
	body pillar

4.1.1 IRSM 41-97 Grade Steel Welded Parameter

This investigation report full penetration of 2mm of a square butt joint on 30 * 10*2 mm IRSM 41-97 grade steel welding process of gas tungsten arc welding (GTAW), autogenous gas tungsten arc welding (AGTAW) has good width of the weld zone region. In both GTAW & GMAW is filler material process 80 % Ar + 20% Co2 shielding gas used with 1.6 filler rod diameter (mm), root gap(mm)is 2 other parameters shown in Table 4.2. In LBW & AGTAW both are non-filler material process, LBW using shielding gas nitrogen(N) in 2 % whereas it does not use the parameters such as current(A), voltage(V), root gap(mm), as shown in the table 4.2.

Table 4.2 Process parameter for welding IRSM 41-97 rail steel

Description	IRSM 41-97 RAIL STEEL			
Type of Welding	GTAW	GMAW	LBW	AGTAW
Current(A)	174	170	-	181
Voltage(v)	18	21	-	17
Filler wire	ER70S-6	ER70S-6	No filler	No filler
pulse	-	-	51	-
Output power (KW)	-	-	3	-
Continuous power (KW)	-	-	2.29	-
Pulse Energy(J)	-	-	0.302	-
Frequency (Hz)	-	-	5000	-
Laser source	-	-	CO2 laser	-
Power (%)	-	-	70	-
Filler rod dia(mm)	1.6	1.6	-	-
Shielding gas	Argon+CO2	Argon+CO2	Nitrogen	Argon+CO2
Gas flow rate(lpm)	80: 20	80:20	2	80:20
Root gap(mm)	2	2	NIL	NIL
Time taken(sec)	64	49	100	65
Weld speed(mm/sec)	2.34	3.06	33.33	2.31
Weld width(mm)	4.25	3.25	1.6	4.5
Penetration(mm)	2	2	2	2
Heat Input(Q)joule/mm	1338.4	1174.34	71.99	1332.3

AGTAW welding applies both sides of high heat to the joint IRSM 41-97 specimen piece. In this non-parameter pulse, output power (KW), continuous power (KW), pulse energy (J), frequency (Hz) & root gap(mm). In this welding shielding gas 80 % Ar + 20 Co2 with parameter current(A) = 181, voltage(V)= 17 with weld width 4.5 mm other parameters are shown in Table 4.2. In the AGTAW, GTAW, GMAW, LBW square butt joint.

4.1.2 IRSM 41-97 Grade Steel Welding Process

After cutting to the IRSM 41-97 metal sheet with help of shear cut machine into 2-piece sheet metal as shown in Fig: 4.2. The surface of IRSM 41-97 steel material cleaning with an acetone solution because It is an organic compound noncolor and flammable liquid for before testing macrostructure and microstructure.

Removing small dark reddish-brown colours on the surface of sheet metal before going to welding. Polishing with surface grading using mat finishing wheel 120 emery wheel

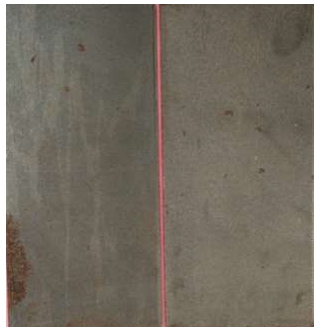


Fig: 4.2 Shear cut into two-piece of IRSM 41-97 steel

Step-1 We taken IRSM 41-97 grade steel material cut into the two-piece with the shear cutting process as shown in Fig: 4.2

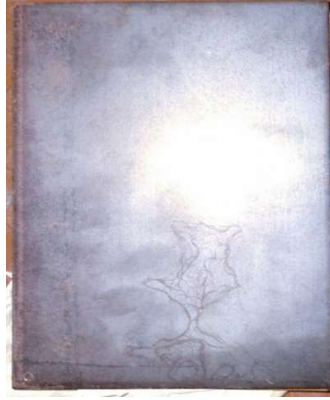


Fig: 4.3 IRSM 41-97 clean with acetone solution

Step-2 Cleaned with acetone solution entire IRSM 41-97 sheet after shear cutting, acetone is also called dimethyl ketone. it is an organic substance; it is used to shine the metal piece before going to testing method as shown Fig: 4.3.



Fig: 4.4 Surface grading operation of IRSM 41-97 rail steel

Step-3 We are using the surface grinding operation to remove the patina on surface of the IRSM 41-97 metal steel in Fig: 4.4. It uses 120 emery wheels, it's polished using a mat finishing wheel while going to testing to microstructure because the level of grain visible to me crystal clear in microscope.

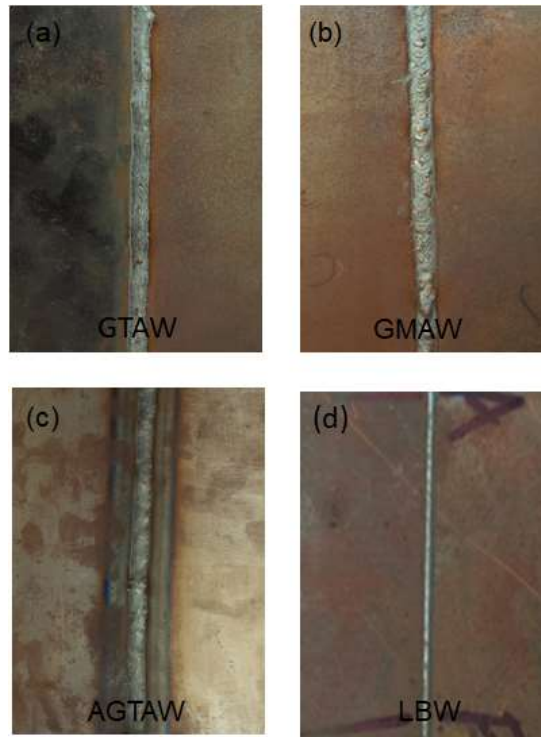


Fig: 4.5 IRSM 41-97 rail steel welded plates

(a) GTAW (b) GMAW (c) AGTAW (d) LBW

In Fig: 4.5 weldments of IRSM 41-97 rail steel in gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), laser beam welding (LBW) and autogenous gas tungsten arc welding (AGTAW).

In gas tungsten arc welding (GTAW) square butt joints with weld gap are 2mm Fig: 4.5(a) shown that it's highly welded. it is joined by two IRSM 41-97 metal sheets without any gap area in the weld zone region (WZR). In thickness of WZR area increases after welding as we conclude Base metal of IRSM 41-97 steel before welding have less than that weldment IRSM 41-97 after welding in the welding zone region in Fig: 4.5 (a).

In gas metal arc welding (GMAW) is also a square butt joint curve-like structure manner on top of the welded surface visible Fig: 4.5(b) comparing to gas tungsten arc welding (GTAW) than that gas metal arc welding (GMAW) welded unclearly welded so, maybe chance after few years starts small micro-cracks forms in WZ region easy by wet/dry climate areas. In Table 4.5 conclude Gas tungsten arc

welding is greater than gas metal arc welding in heat input temperature given Fig: 4.5(b).

In autogenous gas tungsten arc welding (AGTAW), we know that the work-piece for joining two identical or dissimilar metals with the application of heat on both side edges of sheet metal with a non-consumable tungsten electrode. In above Fig: 4.5(c) autogenous gas tungsten arc welding (AGTAW), gas tungsten arc welding (GTAW) both are the same shape of the welded but difference AGTAW we welded by the edge of the welded region due to amount of high temperature black colour is formed while welding AGTAW seen is not very well than the GTAW. In above we conclude autogenous gas tungsten arc welding is greater than gas metal arc welding according to input temperature given.

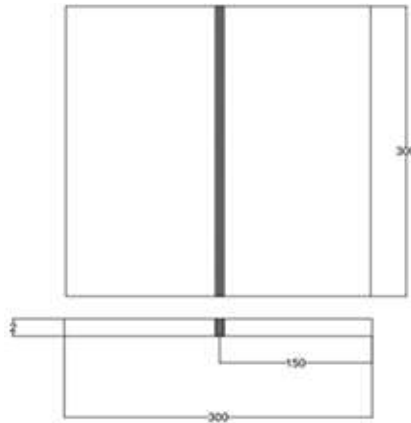
In laser beam welding (LBW) thin welded bead region comparing to GTAW, GMAW, AGTAW as shown in above Fig: 4.5(d) we know that LBW have high intense heating with temperature, high concentration focuses in welded region area here LBW is thin welded bead other than GTAW, GMAW, AGTAW. It looks like a very good high strength welded bead without any unclear gap. Hence, we conclude Laser Beam Welding is less than autogenous gas tungsten arc welding according to input temperature given.

In IRSM 41-97 welded sheet of laser beam welding very thin weld gap comparing to gas tungsten arc welding (GTAW), gas metal arc welding (GMAW) and autogenous gas tungsten arc welding (AGTAW) Fig: 4.5(d).

Autogenous gas tungsten arc welding (AGTAW) and gas tungsten arc welding (GTAW) both weld gap very same equal width but difference in partially transformed zone. AGTAW near partially Tran zone with high amount temperature slightly sheet colour changes. Gas Metal Arc Welding (GMAW) welded sheet design looks very nice but GTAW and AGTAW to get corroded it take less time because both weld gap zone are highly width of weldment assuming on that area more strength comparing other than the diameter of the filler rod is 1.6mm determined by using the thickness of the IRSM 41-97sheet. As a result, the sample sheets are 2mm thick, 2mm weld gaps a 1.6mm filler rod diameter might be the proper length for the filler rod. Those 1.6mm sheets might be perfect for them at this Welding

process the parameter values play a vital role, it comes to a decision how strong the material's bonding, in addition to the welding efficiency.

4.1.3 Welding Process Measurement of IRSM 41-97 Metal Sheet



All dimension are in mm

Fig: 4.6 Drawing of AGTAW, LBW IRSM 41-97 weldments

From figure 4.6 IRSM 41-97 sheet measurement welding phase of welding process measurement metal sheet of LBW and AGTAW without any weld gap in black colour region in middle of the weldment IRSM 41-97 sheet in welded area with sheet metal length(mm) is 300, breadth (mm) is 300, half of the breadth(b/2) is 150.

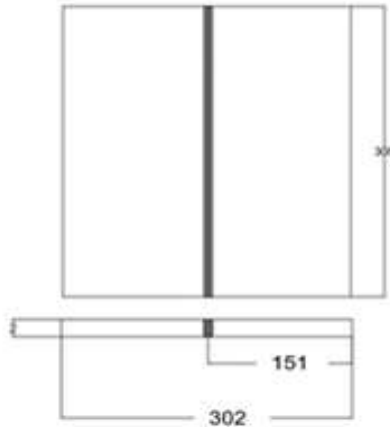
Total area of weldment IRSM 41 - 97 rail steel sheet = length of the sheet * breadth of the sheet

$$= l * b$$

$$= 300 * 300$$

$$= 60,000 \text{ mm square}$$

Hence, the total area of IRSM 41-97 rail steel sheet taken autogenous Gas tungsten arc welding and Laser beam welding is 60,000 mm square.



All dimension are in mm

Fig: 4.7 Drawing of GTAW, GMAW IRSM 41-97 weldments

This is the welding process taken measurement of IRSM 41-97sheet GTAW and GMAW welding process without any weld gap in Fig: 4.7 black colour region in middle of weldment IRSM 41-97 area with length of sheet metal (mm) is 300, breadth (mm) is 302, half of the breadth(b/2) is 150.

The total area of IRSM 41 - 97 rail steel sheet = length of the sheet * breadth of the sheet

$$= l * b$$

$$= 300 * 302$$

$$= 90,600 \text{ mm square}$$

Hence, the Total area of IRSM 41-97 rail steel sheet taken Gas Tungsten Arc Welding and Gas metal arc welding is 90,600 mm square.

By this we can infer that total area of IRSM 41-97 steel taken in AGTAW and LBW welding process is more than the total area of IRSM 41-97 steel taken in GTAW and GMAW welding process. But here thickness of sheet metal is 2mm sheet colour is light brown.

4.1.4 Welded IRSM 41-97 Sheet Metal in (2D and 3D) View

4.1.4.1 Autogenous gas tungsten arc welding welded specimen plate

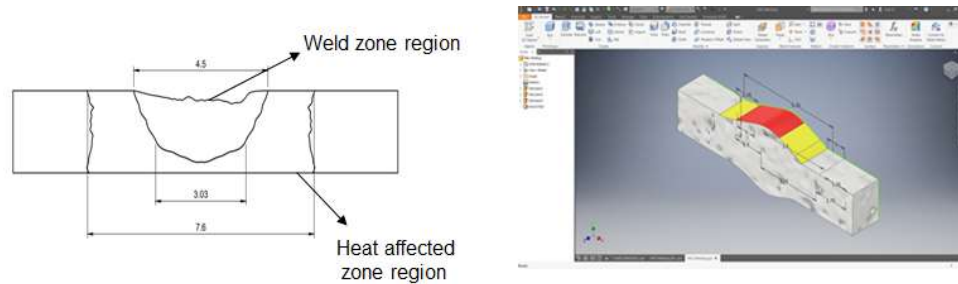


Fig: 4.8 Sectional schematic 2D and 3D view of AGTAW weldment

From this Fig: 4.8 depth of the weld IRSM 41-97 grade specimen is 2mm, welded region under at the end of curve region is 3mm, welded area cover is 7.00mm approximate and thickness of plate is 2mm as shown in Fig: 4.8.

4.1.4.2 Gas metal arc welding welded specimen plate

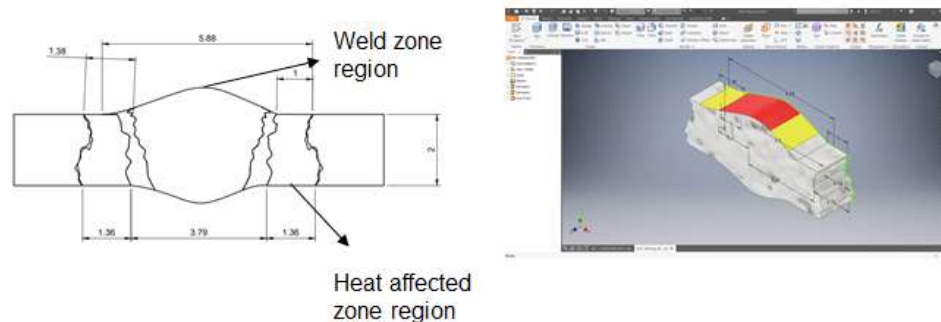


Fig: 4.9 Sectional schematic 2D and 3D view of GMAW weldment

From this Fig: 4.9 depth of the weld IRSM 41-97 grade specimen is 2mm, in top of the surface look like convex shape heat affected region is 1.75mm beside the welded region. Weld region is placed at the centre of the convex curve shape of the upper surface.

4.1.4.3 Gas tungsten arc welding welded specimen plate

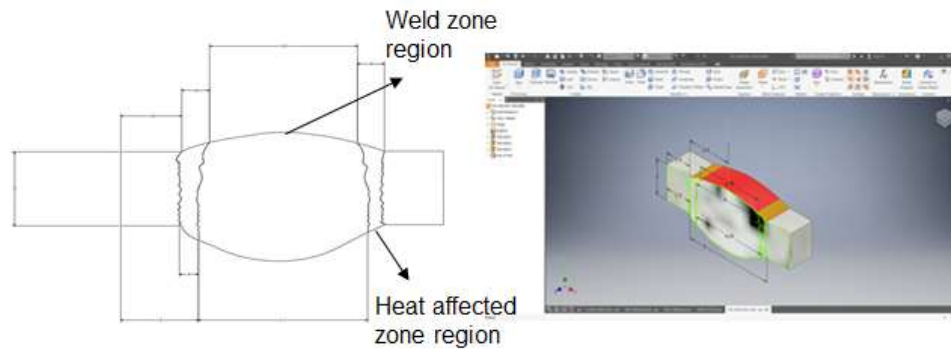


Fig: 4.10 Sectional schematic 2D and 3D view of AGTAW weldment

From this Fig: 4.10 depth of the welded IRSM 41-97 specimen is 2mm slight convex space at the top of the layer but here heat affected region 5mm unaffected zone is located 1.5 mm in both sides as shown in Fig: 4.10.

4.1.4.4 Laser beam welding welded specimen plate

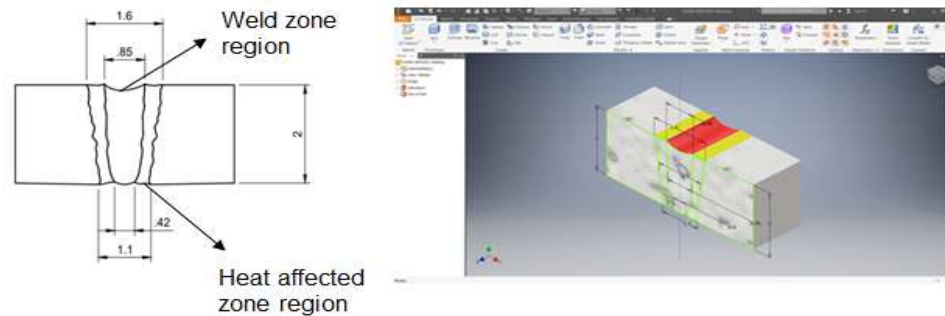


Fig:4.11 Sectional schematic 2D and 3D view of LBW weldment

From this Fig: 4.11 depth of the weld IRSM 41-97 specimen is 2mm very narrow curve shape in heat affected region is 1.1mm and weld region is 1.5mm as shown in Fig: 4.11

4.1.5 Various Welding Techniques for Welded IRSM 41-97 Rail Steel

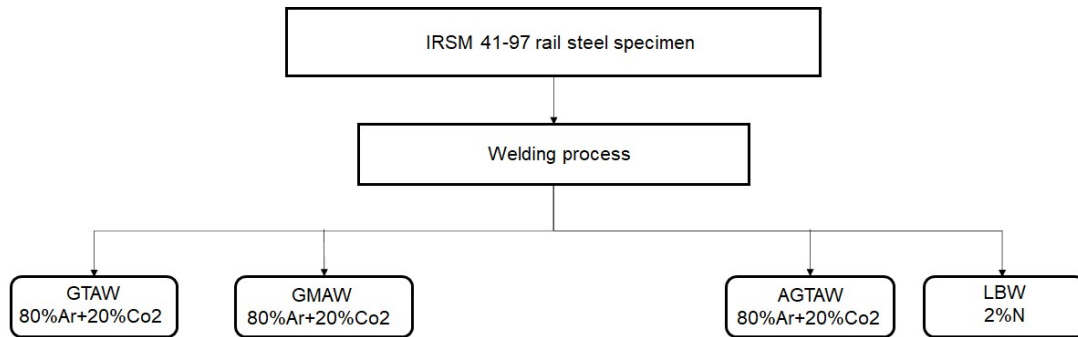


Fig: 4.12 Common methods of welding techniques used in IRSM 41-97 steel

The above picture ER70S-6 filler utilizes the defensive gas 80% Ar + 20% CO₂ absolute 100% gas tungsten bend welding (GTAW), as demonstrated in Figure 4.12. ER70S-6 carbon arc electrode contains IRSM 41-97 metal to secure the terminal, and a combination of argon and carbon dioxide is utilized as the protecting gas. To warm without emanating radiation from the climate, the size of the IRSM 41-97 sheet is 2mm, and the size of the 1.6mm filling bar is chosen. The meager plate has a welding space of 2mm, while the root space of the enormous metal plate is 2mm. The boundary esteems are significant in the welding interaction since they decide the mix of two steel powers.

In the curve welding metal welding with filler material (ER70S-6), the protecting gas 80% Ar + 20% CO₂ measure in Figure 80.20 is utilized, which requires a modest quantity of hot inclusion, and the weld delivers the most clear weld infiltration 2mm, and there is a root hole weld likeness and astounding situation level will happen.

In autogenous gas tungsten bend welding (AGTAW), the material filling measure with the assurance level of 80/20 Ar/CO₂ as demonstrated in Figure 80 isn't done: Figure 4.12. This paper contemplates AGTAW welding and high CO₂ laser radiates with low energy input. Autogenous gas tungsten circular segment welding (AGTAW) is performed on a framework with a photocurrent of 181 amperes, a voltage of 17 volts and a welding rate of 2.31 millimeters each second.

In the above figure, during the laser bar welding measure without 2% nitrogen (N) filling material, 4.12 is appeared. It gives a little region influenced by heat (HAZ), accordingly improving the construction and execution of the weld. This is identified with the high temperature and cooling temperature of the welding region. During the trial, 2% actuated nitrogen was utilized for assurance, the filling width was 1.6 mm, and an exhaust distance of 2 mm was chosen to expand the entrance profundity. The laser pillar is like the outside of the work object, with a 90-degree point between the circular segment light and the work surface. Utilizing the "laser bend" mode, there is a hole of 2 mm between the laser light point and the welding plate of the metal plate. In this examination, the laser welding mode was applied to square joints of 2 mm steel plates.

4.2 MATERIAL USED

4.2.1 IRSM 41-97 Rail Steel Welding Machines

4.2.1.1 Gas metal arc welding machine

Welding bend welding measure This cycle prompts the creation of a productive and progressed curve welding measure. Metal latent gas (MIG), otherwise called GMAW, is a limited cycle that includes warming, liquefying, and cementing base metals and fillers (wire cathodes) to utilize transitory warmth sources to build up associations between parent metals. The anode made of persistent wire will break down the feeder by its inner obstruction, and afterward utilize the contact head in the welding firearm to take care of it. The warmth from the welding bend is moved. Warmth moved from the liquid anode to the liquid weld pool

The treatment runs without making some updates to the voltage settings due to temperature being changed by managing current with consideration to the wire feed speed as a consequence, changing the electrode length has no effect on heat value. STT devices present a range of functionality. Any use of electronic technology enables the success of the organizations. For more application and arc function were provided. Moreover, relevant factors, like such as the type of joint, the material and thickness of the joint, and the rate of travel size and type between electrodes, as well as arc shielding a source of energy between various method on that one

conventional GMAW welding method was metal transfer mode feature of the welding current (A) and voltage (V) outputs.



Fig: 4.13 GMAW welding machine

Compared to the traditional GMAW system, this one has been fully deployed in the production of steam boilers, with reasonable joint operation quality and higher efficiency in the root pass as shown in Fig: 4.13 GMAW machine.

The wire feeder was used to help provide current and keep electrode wire moving at a constant pace. Filler wire use has evolved to the point that it is now completely incorporated into the welding process. The filler wire's total motion is forward, but it can be reversed at a given time to help in the molten metal's breaking detachment of metal from the molten tub. As a result, an inverter welding current source is used for this purpose and the electrode wire is attached to the control.

4.2.1.2 Gas tungsten arc welding and Autogenous gas tungsten arc welding machine

Gas tungsten curve warming is a filling cycle. To accomplish the best welding impact, this sort of filling metal is dismal. Both virus wiring and hot wiring GTAW need to move heat from the welding danger to the welding wire to finish the wiring interaction, as demonstrated in Figure 4.14. The strength of the bend and the size of the liquid metal in the liquid lake are connected.



Fig: 4.14 AGTAW and GTAW welding machine

Gas tungsten arc welding is a filling cycle. To accomplish the best welding impact, this sort of filling metal is dismal. Both virus wiring and hot wiring GTAW need to move heat from the welding danger to the welding wire to finish the wiring interaction, as demonstrated in Figure 4.14. The strength of the bend and the size of the liquid metal in the liquid lake are connected.

4.2.1.3 Laser beam welding machine

Laser shaft welding deficient material innovation can improve welding execution and effectiveness. There are two kinds of welding that require consideration in heat move and welding for profound entrance. Working welding is performed with high welding rate and low force. Warmth conduction moves energy to the remainder of the body. The outcome is a huge and shallow pool of liquid material in the workpiece. In Figure 4.15, this laser is utilized for profound welding infiltration.

The shaft is set in a little territory with a force of 5×10^3 watts for each square meter. Give sufficient breathing energy made by the arrangement of a smoke channel where the laser force can enter profound into the profound opening of the work of art, along these lines improving the ingestion proficiency and making the gear more steady. As demonstrated in the image: 4.15 LBW machine



Fig: 4.15 LBW welding machine

Other warm medicines for laser radiates incorporate solidifying of the earth, compaction, and vaporization, which don't include liquefying of material and require high energy thickness. Boring and cutting, which requires high strength and material evacuation. Make openings and limits in the content. For each situation, a standard size is utilized. The machine has great conduction mode welding and the best welding mode section. The above welding machine is finished by 90 degree cutting of two bits of IRSM 41-97 steel, as demonstrated in Figure 4.15 [41].

4.3 SPECIMEN PREPARATION FOR TESTING

4.3.1 IRSM 41-97 Specimen Wire Cut EDM Process



Fig: 4.16 IRSM 41-97 rail steel welded plates cut using WEDM process for micro and macro examination



Fig: 4.17 IRSM 41-97specimens polished with alumina powder

Step 4&5 - Take a cutting sample with a dimension 30 * 10*2 mm polishing with alumina powder to test on a microscope to identify the grain structure are shown in Fig: 4.16& 4.17.



Fig: 4.18 Polished IRSM 41-97 specimens being dried water at room temperature

Step 6 - After polishing we placed 4 together to dry the sample while coming to the microstructure characteristic and microstructure analysis in Fig: 4.19.

CHAPTER 5

RESULT AND DISCUSSION

5.1 IRSM 41-97 RAIL STEEL WELDED PARAMETER GRAPH

5.1.1 Weld Speed & Weld Time of IRSM 41-97 Rail Steel

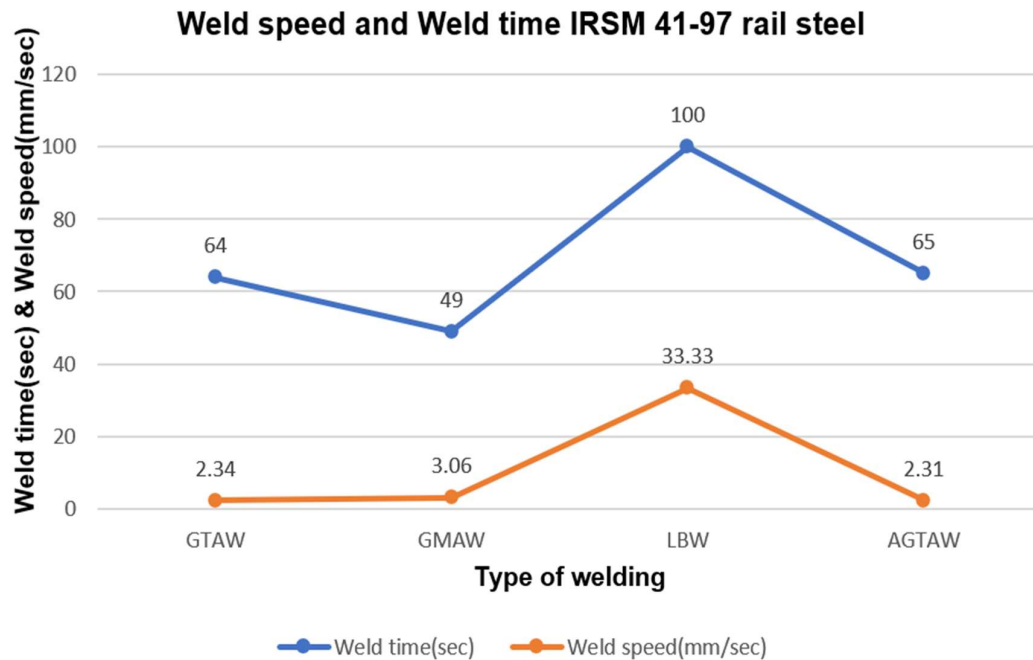


Fig: 5.1 Comparison of weld speed & weld time for various welding

Laser Beam Welding (LBW) has more weld speed 33.33 mm/sec due to the large amount of time taken to weld IRSM 41 - 97 rail steel. Second highest welding speed 3.06 mm/sec but less time taken 49 sec compared to other time taken for Gas Tungsten Arc Welding (GTAW) and Autogenous Gas Tungsten Arc Welding (AGTAW).

In Autogenous Gas Tungsten Arc Welding (AGTAW) and Gas Tungsten Arc Welding (GTAW) limit (GTAW) limit weld time taken and weld speed, 64 sec 2.34 mm/sec and 65 sec 2.31 mm/sec.

From this graph we observe that weld speed(mm/sec) is
LBW>GMAW>GTAW>AGTAW

From this graph we observe that weld time (sec) is
LBW>AGTAW>GTAW>GMAW

5.1.2 Heat Input of Different Welding's IRSM 41-97 Grade Steel

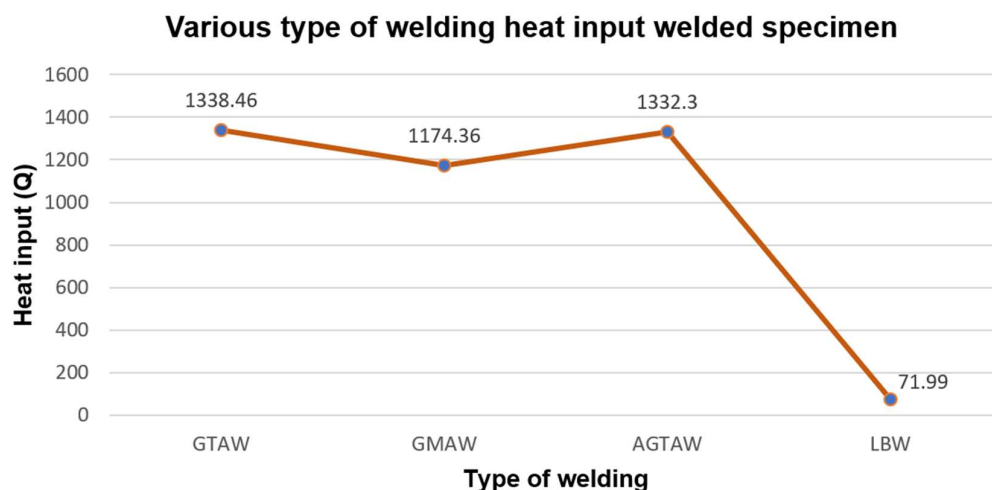


Fig: 5.2 Various type of heat input welded IRSM 41-97 graph

In Fig: 5.2 Gas Tungsten Arc Welding (GTAW) with filler material ER70S-6 high heat input(Q) is 1338.6 Joule/mm. AGTAW absents of filler material with temperature heat input(Q) is 1332.3 joule/mm. Both Gas Tungsten Arc welding (GTAW) and Gas Metal Arc Welding (GMAW) have totally different heat input. Gas Metal Arc Welding (GMAW) having heat input (Q) is 1174.34 joule/mm as shown in Fig: 5.2.

Laser beam welding (LBW) is without filler material CO2 laser high concentration to penetration 2mm with heat input given 71.99 joule/mm.

By this heat input welding analysis conclude GTAW > AGTAW >GMAW >LB. But from the graph point of view, we shown in LBW given less heat input but high strong bond between two IRSM 41-97 metal joints but maintenance cost is more comparing to (GTAW, AGTAW and GMAW).

From this Fig: 5.2 GTAW has high heat input 1338.6 joule/mm, LBW has low heat input 71.99 joule/mm.

5.2 MACROSTRUCTURE ANALYSIS

5.2.1 Macrostructure Characteristics of Welded IRSM 41-97 Rail Steel

It shows the characteristic microstructure at low magnification up to 25X of IRSM 41-97 specimen. It can be found near welded joints exhibit short peening weld bead surface with lack of lateral fusion. It consists weld zone (WZ), Grain Growth zone (GGZ), Recrystallisation zone (RZ), Partially Transformed Zone (PTZ) at both sides after the Heat Affected Zone (HAZ) regions unaffected base metal formed. These are all in the alpha-phase region and latent heat input 1332.3 joule/mm in the weld region.

The welding region and warmth influenced region are created through AGTAW welding innovation to show the region isolated from the welding territory, the width of the influenced region, and the welding shape and size. The naturally visible surfacing construction of the two welded joints is appeared in the qualities below. The situation of the AGTAW weld between the decreased warmth influenced region and the straight line over the little bend in the weld region and underneath the bend shape is appeared in Figures 5.3, 5.4, 5.5, and 5.6.6. Grain development show region. Toward the finish of a little bend, a slow down station will be set up when the two square prepares are consuming between the different sides.

It very well may be seen that the most limited region (mm) of the welding region is 15.2, and the width (mm) of the temperature-influenced region is 7.6. We say that the width and position of the AGTAW welds have been decreased by about 87% and 13%, separately. It can likewise be seen that the AGTAW joint diminishes this cross-sectional territory in the warmth influenced zone (HAZ). The welding region is higher than the uncovered warmth touchy region.

The temperature-influenced zone (HAZ) incorporates the grain development (CGZ), the recrystallization zone (RCZ), and the fractional change zone (PTZ)

Table 5.1 Macrostructure characteristics of IRSM 41-97 rail steel welded joint

Characteristics of Welded Joint	GTAW	GMAW	LBW	AGTAW
The cross-section area of the weld zone(mm)	17.5	13.0	3.2	15.2
Width of the heat-affected zone(mm)	8.75	6.5	1.6	7.6
Cross-sectional area (%)	-	25	81	13

In Table 5.1 shows macrostructure characteristic of IRSM 41-97 rail steel welded joint we observed that the cross section of the weld zone more in GTAW is 17.5mm and very low cross section LBW is 3.2 similar to width of the heat-affected zone region.

5.2.1.1 Gas tungsten arc welding Weld

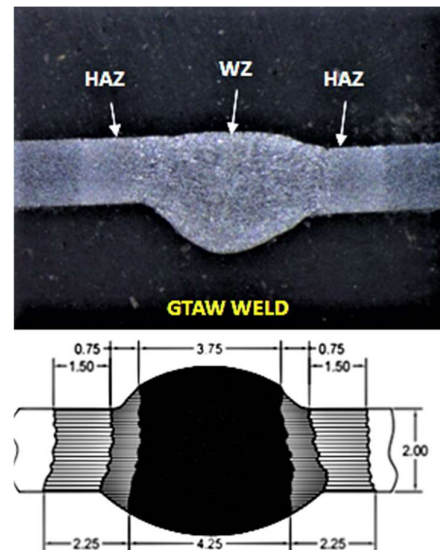


Fig: 5.3 Macrostructure GTAW weldment

In tungsten bend welding, contrasted and the treated steel gas circular segment welding that is influenced by heat, it appears to have a bigger bend shape. The welding territory is appeared in the figure: 5.3 There are many influenced spaces of the joint that are more modest than the state of the GTAW joint. The state of the weld, the warmth circulation in the weld territory (WZ) and the temperature of the

influenced region (HAZ) are completely influenced by the adjustment in the absolute force contribution during IRSM-41-97 GTAW. The width and territory WZ of the HAZ weld are 8.75 mm and 17.5 mm, as demonstrated in Table 5.1.

5.2.1.2 Gas metal arc welding weld

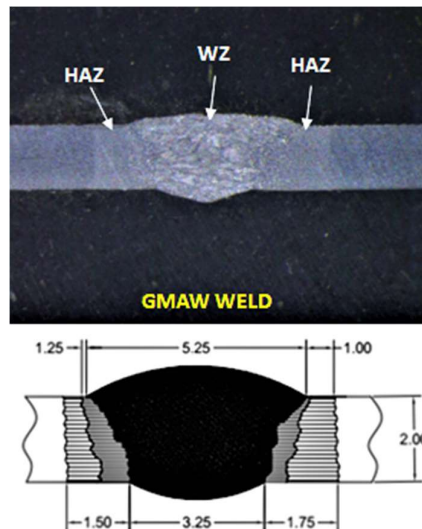


Fig: 5.4 Macrostructure GMAW weldment

It can likewise be seen that in the welded joint with a more modest warmth touchy territory (HAZ) than the consolidated weld MAG, the width and weld space of HAZ and WZ are 6.5 mm and 13.0 mm, individually, which is to a great extent identified with the decrease of Thermal protection. As indicated by the full scale structure attributes of MAG Weld Figure 5.4, it can improve item execution, yet in addition decrease creation expenses and increment profitability. It is significant that the decompression will aggregate and stay in the change zone of the metal in the curve zone, the laser position because of the presence of various materials, and the cooling level during the steel support measure. It very well might be quite possibly the most perilous zones with a smaller shape than the weld metal circular segment welding shape (curve region) in Figure 5.4.

5.2.1.3 Autogenous gas tungsten arc weld

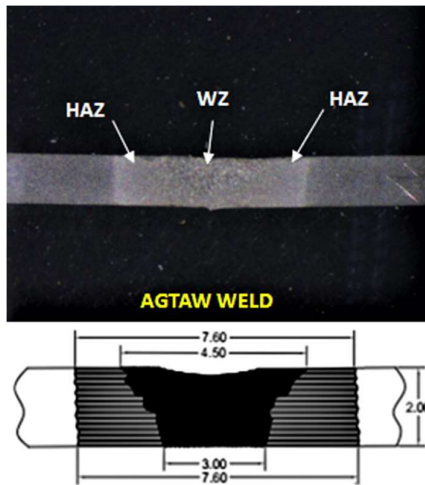


Fig: 5.5 Macrostructure AGTAW weldment

The weld and weld space of HAZ and WZ in AGTAW welding are 7.6 mm and 15.2 mm, separately. The region influenced by the warmth of the buildup point is more modest than that of the joined AGTAW. At the point when the IRSM-41-97 steel AGTAW circuit is influenced by heat, the info heat scattering will influence the state of the weld, the warmth conveyance (WZ) and the temperature touchy zone (HAZ) of the weld region. . Contrasted and other welding techniques, the AGTAW cycle territory is influenced by heat in a bigger reach, and AGTAW has a wide scope of warmth influenced (HAZ) Figure: 5.5.

5.2.1.4 Laser beam welding weld

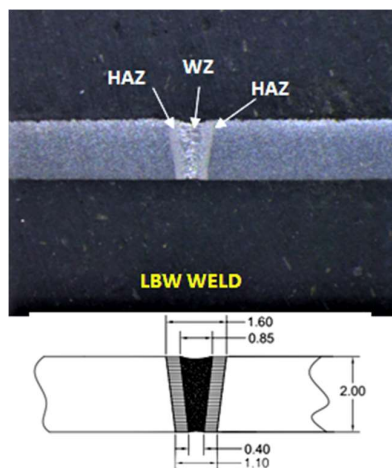


Fig: 5.6 Macrostructure LBW weldment

The width and space of the HAZ and WZ welds on the laser weld are 1.6 and 3.2, individually. We have a run of the mill "challis" shape with a more extensive upper surface, for example, bend welding (circular segment territory), while the limited center region has the capacity of laser welding (laser region). There are different welding modes during welding, for example, welding mode, activity mode, switch mode, passage mode, and keyhole mode. The information got from this examination can be utilized as a logical reason for deciding if it has the state of a nail head and comprises of three unique territories: weld metal (WM), heat touchy region (HAZ) and base metal (BM)). The breadth of the space influenced by heat is 1.6mm in Figure 5.6

5.2.2 Characteristics of Welded IRSM 41-97 Rail Steel Joints

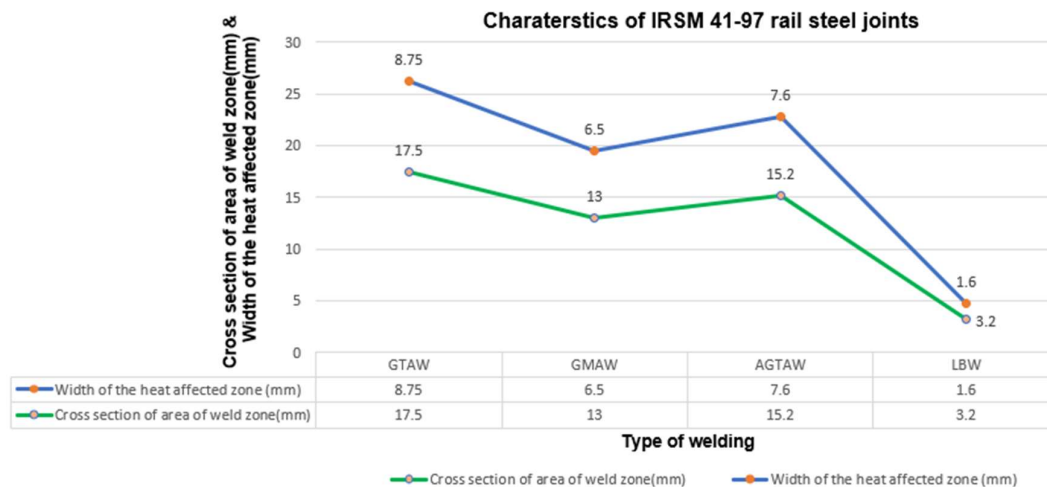


Fig: 5.7 IRSM 41-97 characteristics of the welded joint

In this graph Fig: 5.7 analysisist he cross-section area of weld zone covers high weld bead in 17.5mm Gas Tungsten Arc Welding (GTAW). Autogenous Gas Tungsten Arc Welding (AGTAW) having a cross-section of weld zone of 15.2 mm. cross-section area of weld bead region is very less Laser Beam Welding (LBW) is 3.2mm for GMAW have cross-section surface on weld zone covers 1.3mm as shown Fig: 5.6

In Table: 5.1 shows details 4 types of welding used IRSM 41-97 rail steel investigation Cross-section area of welded zones. We observe that the above graph

LBW having a very low cross-section area of the weld zone below we show clearly GTAW > AGTAW > GMAW > LBW.

In this width of the heat-affected zone shown here also Laser Beam Welding shows very less compared to others in Fig: 5.6 But GTAW have a width of the heat affected zone highest peak 8.75 as shown Fig: 5.6 In Gas Metal Arc Welding (GMAW) 6.5 mm width of the heat-affected zone. Shows GTAW > AGTAW > GMAW > LBW

5.2.3 *Percentage of Cross-Sectional Area of IRSM 41-97 Rail Steel Welded Joint*

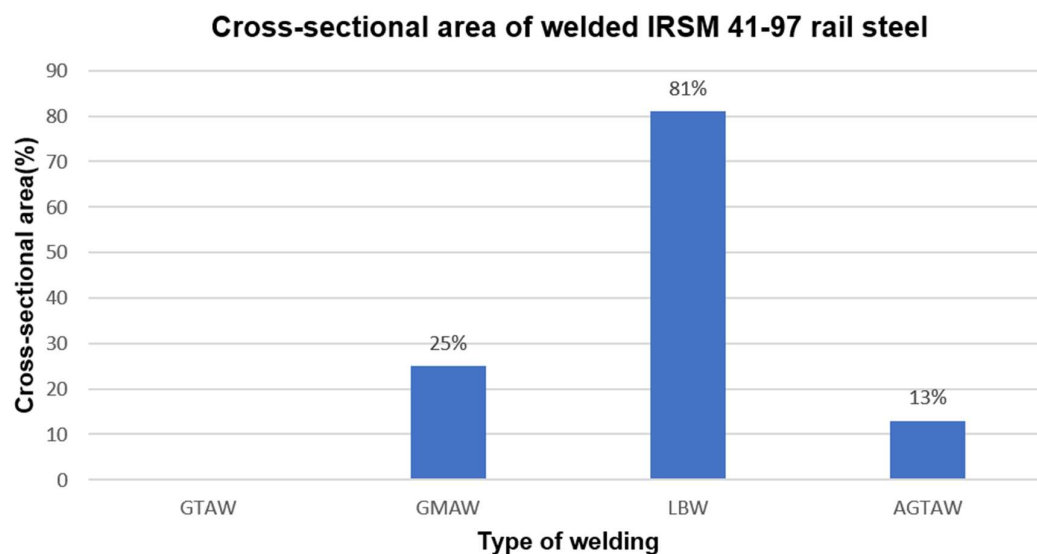


Fig: 5.8 Percentage of welded cross-section area of IRSM 41-97 rail steel

In the bar graph Fig: 5.7 we analyse that the cross- sectional area is more in laser beam welding (LBW) in 81%. Gas Metal Arc Welding (GMAW) has 25% cross-sectional area. Autogenous Gas Tungsten Arc Welding (AGATW) has very less percentage of cross-sectional area 13 as shown above graph. In Gas Tungsten Arc Welding of cross -sectional area is none as shown Table 5.2 percentage of cross section in weld zone.

Table 5.2 Percentage of cross section in weld zone

Sl.no	Type of welding	Cross-sectional area
1	GTAW	-
2	GMAW	25/100
3	LBW	81/100
4	AGTAW	13/100

In both 5.7 and 5.8 graph we can conclude that cross sectional area of weld zone gas tungsten arc welding is 17.5mm and width of heat affected zone 8.75mm. In autogenous gas tungsten arc welding cross section area of weld zone is 15.2 in 13% occupy and width of heat affected zone is 7.6mm.

In gas metal arc welding cross section area of the weld zone is 13.0 mm in 25% occupy and width of heat affected zone is 6.5mm. In laser beam welding cross-section area of the weld zone is 3.2mm in 81% occupy and width of weld zone is 3.2mm in 81% occupy and width of heat affected zone is 1.6mm.

If cross section area of the area of the weld zone is decrease simultaneously width of heat affected zone decrease similarly cross section area of the weld zone is increase, width of the heat affected zone increase

AGTAW has 13 percentage, LBW has 81 percentage and GMAW has 25 percentage has Fig: 5.8. by this percentage we can easily conclude cross section area WZ & HAZ occupy.

5.3 MICROSTRUCTURE ANALYSIS

5.3.1 *Base metal microstructure analysis*

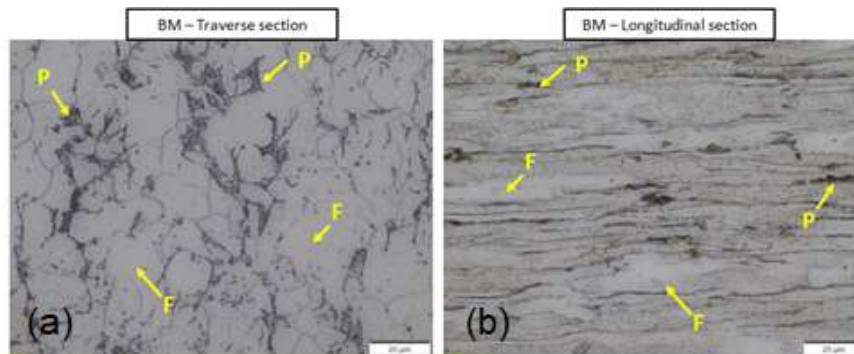


Fig: 5.9 Microstructure of IRSM 41-97 rail steel base metal (a) traverse section (BM) (b)longitudinal section (BM)

The microstructure of IRSM 41-97 rail steel in the base metal has an equiaxial structure more amount pearlite and ferrite in Fig: 5.9(a). The metallurgical microscope with a magnification of 200X and micro size 20-micrometer elongated along rolled direction.it consisted of ferrite (light etching) and pearlite (dark etching) uniformly.

In both traverse and longitudinal section consists pearlite and ferrite in above Fig: 5.9(a). In transverse region the grains which are parallel to longitudinal direction are not texturing[equiaxed].

In longitudinal section it looks like thread structures in Fig: 5.9(b). The grain boundaries are irregular to each other here also pearlite (dark colour) and ferrite (light colour) as shown in fig: 5.6(b).

It typical showing low carbon steel with uniform grain of pearlite in ferrite matrix manner present fine dispersion of chromium carbides. Pearlite recrystallization grains in ferrite range in size from 25 microns meter in Fig: 5.9 The

ASTM grain size number six corresponds to the grain number. Rapid cooling from liquid to solidus state results in a dendritic pattern of grain weld deposit. A phenomenon of liquid metal solidification is finer dendrites in Fig: 5.6. In a longitudinal direction, the direction of rolling. Gain identifies uniformly shaped pearlite in ferrite grains with chromium carbides at grain boundaries in Fig: 5.9(a&b).

5.3.2 Gas tungsten arc welding microstructure analysis

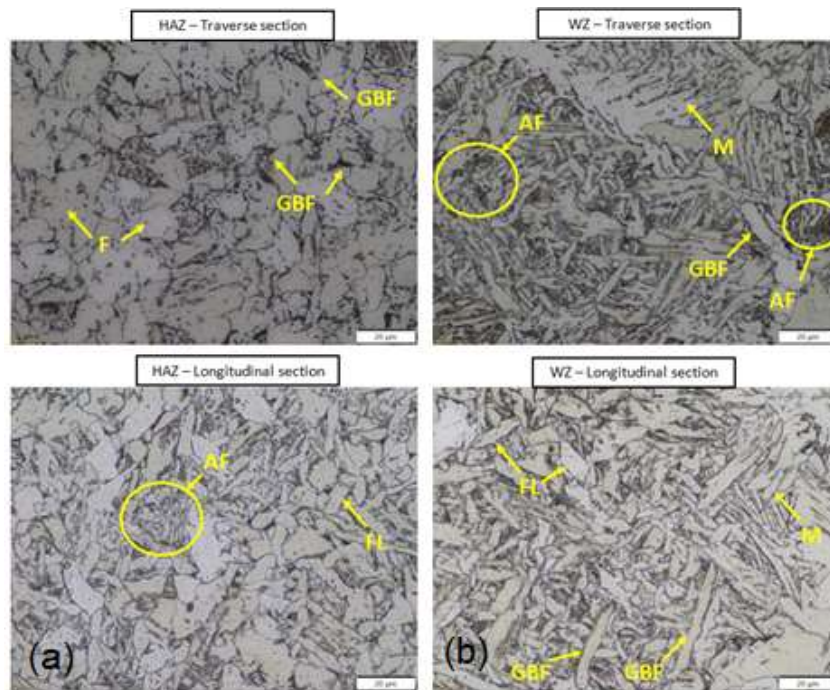


Fig: 5.10 Microstructure of IRSM 41-97 rail steel GTAW welded metal (a) traverse & longitudinal section (HAZ)(b) traverse & longitudinal section (WZ)

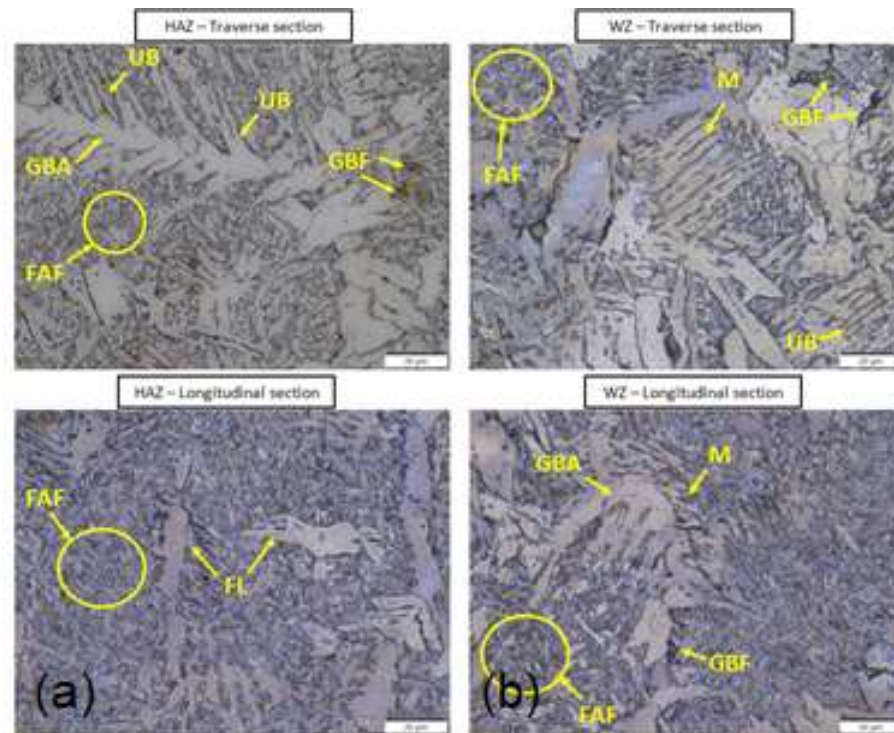
It consists of Ferrite, Grain boundary ferrite, Acicular ferrite, Ferrite laths & Martensite at metallurgical microscope at a magnification of 200 X as shown in Fig: 5.10 There is no distinct interface layer between the weld zone and the Heat affected zone (HAZ). Grains are elongated along rolling direction on the welded material. The grain sizes of the ferrite in the base metal are 25 microns meter. When the weld is done, it is allowed to cool quickly.

At the weld zone, rapidly solidified filler metal forms a dendritic pattern of grains with varying pools of ferrite in Fig: 5.10(b). Due mainly to the slower rate of cooling since it is not in contact with the base metal, the weld metal region in the middle has coarse grained dendrites. The slow cooling rate at the core weld region causes these large dendrites to forms.

The grain size of the ferrite is reduced to 20 microns in the LBW process, forming fine grains matrix with ferrite grains. At the weld zone, rapidly solidified filler metal forms a dendritic pattern of grains with varying pools of ferrite ranging in size from 30 to 40 microns .Between the weld zone and the HAZ, there is no distinct interface sheet. These zones' bifurcation could not be overcome.

When the weld is done, it is allowed to cool quickly and This results in fine pearlite grains of precipitated pearlite. The ferrite grains contained in HAZ have a grain size of 15 to 20 microns.as shown Fig: 5.10.

5.3.3 Gas metal arc welding microstructure analysis



**Fig: 5.11 Microstructure of IRSM 41-97 rail steel GMAW welded metal
(a) traverse & longitudinal section (HAZ) (b) traverse &
longitudinal section (WZ)**

It is consisting Microstructure of GMAW IRSM 41-97 rail steel grade steel weldments Grain boundary ferrite (GBF), Fine acicular ferrite (FAF), Upperbainite (UB), Ferrite laths (FL), Grain boundary Allotriomorph (GBA) & Martensite(M) as shown in Fig: 5.11(a&b)

In Fig-5.11(a&b) Phases of light brown (martensite) and white (ferrite). IRSM 41-97 rail steel has primarily equiaxed. Each zone will have different micro structural characteristics, including weld metal (WM) and Heat Affected Zone (HAZ). Precipitates and carbides, as well as the dendritic structure of ferrite and martensite as shown in Fig-5.11.

GBF (light colour), FAF (light brown structure) circle with yellow colour as shown in Fig-5.11(b). UB (light region) only in traverse section both weld zone and heat-affected zone Fig: 5.11(a&b). In heat-affected zone (HAZ) in transverse section and weld zone (WZ) in longitudinal section consist light region of Grain boundary Allotriomorph (GBA) Martensite, tempered martensite, ferrite, and a few carbides made up the areas. The fine grains were found in the longitudinal regions and traverse regions.

In IRSM 41-97 rail steels, the volume fraction of martensite (VFM) increases as the temperature of heating in the inter-critical range rises during welding.

5.3.4 Autogenous Gas Tungsten Arc Welding Microstructure Analysis

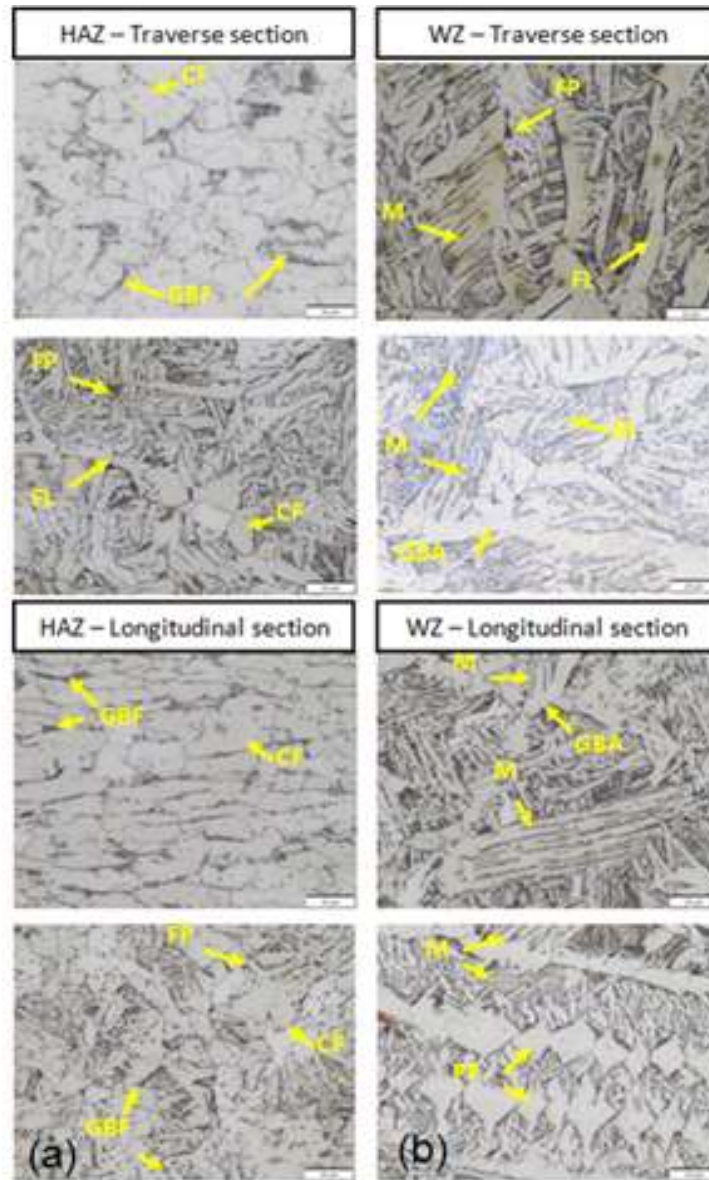


Fig: 5.12 Microstructure of IRSM 41-97 rail steel AGTAW welded metal
(a) traverse & longitudinal section (HAZ) (b) traverse & longitudinal section (WZ)

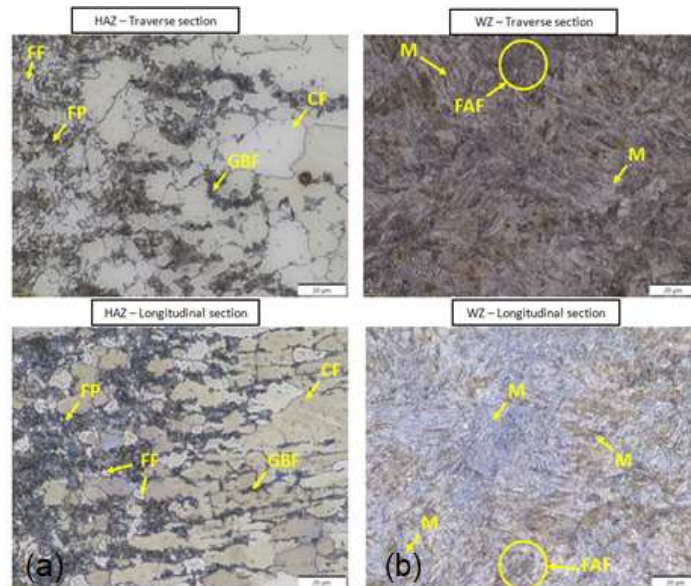
It consists of Coarse ferrite (CF), Grain boundary ferrite (GBF), Fine pearlite (FP), Ferrite Lath (FL), Grain boundary Allotriomorph (GBA), Polygonal Ferrite (PF) & Martensite(M) Fig:5.12 (a&b).

Autogenous GTAW welding, as well as a high-power intensity CO₂ laser beam with lower energy input. The austenitic phase of IRSM41-97 content shows a small rise. The high peak temperature during the welding process causes this rise in the austenitic phase. In heat-affected zone (HAZ) More nucleation and coarsening of the austenite process are the results. Pearlite grains are uniformly fine, with precipitated fine pearlite ranging in size from 20-micron meters Fig: 5.12(a).

In weld zone (WZ) Dendrites of 20 microns in size with varying pools of ferrite make up the microstructure of the weld zone in the phase. The weld zone closer to the HAZ, which is an imperfect weld zone, contains pearlite.

In heat-affected zone (HAZ), welded zone (WZ) consists FP. martensite (light brown region) in welded zone large amount of ferrite visible Fig- 5.12(b).

5.3.5 Laser Beam Welding Microstructure Analysis



**Fig: 5.13 Microstructure of IRSM 41-97 rail steel LBW welded metal
(a) traverse & longitudinal section (HAZ) (b) traverse
&longitudinal section (WZ)**

It consists of Coarse ferrite (CF), Grain boundary ferrite (GBF), Fine ferrite (FF), Acicular ferrite (FAF), Fine pearlite (FP) & Martensite(M) as shown Fig: 5.13(a&b).

The IRSM 41-97 grade steel grain structure contains more amount of martensite (M, white regions) and acicular ferrite (light mix of white and brown) phases in Fig: 5.13(b). Micrographs of IRSM 41-97 laser welds show narrow dark areas with fine grains representing supercritical and subcritical HAZ areas with microstructures containing tempered martensite and acicula ferrite Fig: 5.13(b).

a huge amount of pearlite and a small amount of pearlite Widmannstatten structure numbers that were meant to be a type of low-temperature transformation product that was discovered cooling rate is in the centre. The ferrite within along with the crystal Widmannstatten structure formed with plane originating at the grain boundary Fig: 5.13(a).

In LBW process has a well-resolved centre coring region with ferrite grains less than 5 microns in size. Due to the high heating and rapid cooling rate, fine dendrites with coring have been observed in the weld region. In the interior of the coarse austenite grain, parallel ferrite sheets form, followed by residual austenite. One of the most significant factors may be the Widmannstatten structure distributing within the overheated region.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

The IRSM 41-97 rail steel full penetration of 2mm of a square butt joint on 30*10*2 mm welding process (GTAW, GMAW, LBW & AGTAW) gas tungsten arc welding (GTAW), gas tungsten arc welding (AGTAW) in GTAW& GMAW is filler material process 80 % Ar + 20% CO₂ shielding gas are used.

Autogenous Gas Tungsten Arc Welding (AGTAW) and Laser Beam Welding (LBW) shielding gases are used 2%N and 80%Ar + 20%CO₂. Gas Tungsten Arc Welding (GTAW) and Gas Metal Arc Welding (GMAW) are filler material used ER70S-6. weldment of IRSM 41-97 rail steel observed with input temperature LBW <GMAW, GMAW < AGTAW, AGTAW < GTAW by research analysis GTAW is a good weld bead area with high temperature.

While welding input current is given to IRSM 41-97 rail steel consisting of AGTAW < GTAW < GMAW < LBW by this observation we given high input current given Laser Beam Welding and less current input given Autogenous Gas Tungsten Arc Welding and input voltage is given to IRSM 41-97 steel conclude GMAW > GTAW > AGTAW > LBW. In Laser Beam Welding given very little voltage input given comparing to other, more voltage input is given in Gas Metal Arc Welding.

Weld speed taken IRSM 41-97 steel while welding LBW > GMAW > GTAW > AGTAW > LBW In the welding process, Laser Beam Welding takes high weld speed and Autogenous Gas Tungsten Arc Welding takes less weld speed actually weld speed depends on the surface of weld bead. Weld time taken of IRSM 41 - 97 rail steel while welding observed LBW > AGTAW > GTAW > GMAW. Here laser beam welding is having a high time compared to others. In this testing, GMAW takes less time to take weld but it is getting good weldability.

By heat input graph analysis, we get GTAW>AGTAW>GMAW>LBW Gas Tungsten Arc Welding given high heat input compared to others, laser beam welding given less heat input.

HAZ consists of the grain growth zone (GGZ), recrystallisation zone(RZ) partially transformed zone, unaffected zone beside the heat-affected zone at end of the specimen.

The macrostructure analysis alpha-phase region in the heat-affected zone. in AGTAW convex curve shape in between narrow regions IN HAZ width and area of the AGTAW weld decreased by about 87 % & 13 % and macrostructure characteristic of welded IRSM 41-97 rail steel cross-section area of weld zone GTAW is 17.54 mm, GMAW is 13.0 mm, LBW is 3.2 mm & AGTAW is 15.2 mm.

The macrostructure characteristic welded IRSM 41 - 97 rail steel width of the heat-affected zone consists of GTAW is 8.75 mm, GMAW is 6.5mm, LBW is 1.6 mm, AGTAW is 7.6 mm and macrostructure cross-sectional area in percentage consists of GMAW is 25 %, LBW is 81 %, AGTAW is 13 %.

The microstructure base metal of IRSM 41 - 97 rail steel consists of ferrite(F) & pearlite(p) equiaxial structure in 20 micrometres. more amount pearlite and ferrite are formed. The metallurgical microscope with a magnification of 200X and micro size 20-micrometer elongated along rolled direction and microstructure weldment IRSM 41 - 97 steel GTAW consist ferrite(f), grain boundary ferrite (GBF), acicular ferrite (AF), ferrite laths (FL) & martensite(M). Grain boundary ferrite and less acicular ferrite forms.

The microstructure of GMAW welded IRSM 41 - 97 steel consists of grain boundary ferrite (GBF), fine acicular ferrite (FAF), upper bainite (UB), ferrite laths (FL), grain boundary allotriomorph (GBA) & martensite(M). In HAZ has dendritic structure ferrite shows % Acicular ferrite(AF) is found high with less fraction of (GBF) and microstructure of LBW weldment IRSM 41-97 rail steel consists of Coarse ferrite (CF), Grain boundary ferrite(GBF), Fine ferrite(FF), Acicular ferrite(FAF), Fine pearlite(FP) & Martensite(M) in both transverse and Longitudinal section weld zone(WZ), heat affected zone(HAZ), Micrographs of IRSM 41-97 laser welds show

narrow dark areas with fine grains representing supercritical and subcritical HAZ areas with microstructures contain tempered martensite and acicular ferrite.

The Microstructure of AGTAW welded IRSM 41-97 steel consists of Coarse ferrite (CF), Grain boundary ferrite (GBF), Fine pearlite (FP), Ferrite Lath (FL), Grain boundary Allotriomorphic (GBA), Polygonal Ferrite (PF) & Martensite(M) In weld zone of a microstructure of weld zone in AGTAW process size of dendrites with varying pools of ferrite.

6.2 CONCLUSION

Based on the investigation behaviour of IRSM 41-97 steel weldments obtained results. this steel having good metallurgical properties. The microstructure characteristics of IRSM 41-97 are better in heat affected zone region and weld zone region area. In the microstructure of base metal analysis base metal IRSM 41-97 rail steel consists of ferrite and pearlite by the theoretical study of iron-carbide phase diagram analysis and equiaxial structure. BM of IRSM 41-97 steel consists of ferrite (light etching) and pearlite (dark etching) uniformly. GTAW IRSM 41-97 weldment shows more grain boundary ferrite and less acicular ferrite are shown, GMAW IRSM 41-97 weldment grain structure consists HAZ has dendritic structure ferrite of percentage Acicular ferrite (AF) is found high with less fraction of GBF, LBW of IRSM 41-97weldment grain structure form supercritical and subcritical HAZ areas with microstructures contain tempered martensite and acicular ferrite, AGTAW process size of dendrites with varying pools of ferrite shows. AGTAW of IRSM 41-97 weldment consistHAZ More nucleation and coarsening of the austenite process form and martensite (light drown region) in welded zone large amount of ferrite are shown.

By this research investigation macrostructure and microstructure analysis IRSM 41- 97 steel is best suitable for fusion welding and IRSM 41 - 97 steel capable of all weathering conditions. It has good weldability condition and metallurgy properties.

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APPENDIX

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Materials Today: Proceedings
Microstructure and Metallurgical Property Investigation of Welded IRSM 41-97 Rail Steel Joints
 --Manuscript Draft--

Manuscript Number:	MATPR-D-21-04132
Article Type:	SI: FRESM'21
Keywords:	IRSM 41-97; AGTAW; metallurgical; Macrostructure characters; Microstructure analysis
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Abstract:	IRSM 41-97 rail steel is corrosion-resistant structural steel. It's mostly used in railway industries construction of railway coaches, bridges & frame building structures etc. Autogenous gas tungsten arc welding (AGTAW) is a without-filter operation suitable to low heat input(Q), more time taken, extreme weld speed. This fusion technology using Autogenous GTAW welding was upon 2mm thickness plate on dimension 30 *10*2mm cut with help of wire cut EDM according to ASTM size. This research paper reveals the study of metallurgical, macrostructural characters, microstructural analysis.

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Date: Sat, Apr 10, 2021 at 9:28 AM

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