Structural analysis of TIG generated chromoly welds

Sreejith Mohan, Boby George, Akarsh A, Amal Mohan P, SharanC.P, Sreyas A

Abstract—This work presents the results of investigation on the material characterization of a TIG-welded A-4130 Chromoly steel. A single V-groove butt joint weld was laid using ER70S-2 as the filler metal and Ar as the shielding gas. The tension test on the resultant weld was carried out using a Universal Testing Machine and its microhardness was measured using a Rockwell Microhardness Tester. Further, the weld microstructure was investigated using an optical microscope. All results were compared with that of a mild steel weld laid under similar conditions. The results of the investigation showed that under similar conditions, the chromoly welds exhibited superior properties compared with the mild steel welds.

Index Terms—Chromoly, Gas tungsten arc welding (GTAW), Microstructure,Tungsten inert gas (TIG),Tungstone, Weld, Stainless steel, Etc.

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1. INTRODUCTION

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapors known as plasma.

GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. Chromoly is stronger than normal steel, weight for weight, and is commonly used to make high-end bicycle frames, roll cages for race cars, and for fuselages on small aircraft. Chromoly's high strength-to-weight ratio and high tensile strength makes it an ideal choice for these particular applications. In addition, 4130 is utilized in a variety of applications because of its weldability, formability, ductility and toughness. Overall it is considerably stronger and more durable than standard 1020 steel. While this particular grade of steel does contain chromium, it is not in enough quantities to provide the corrosion resistance found in stainless steel.

Regarding the manufacturing of high-end bicycle frames, chromoly is typically used to make bikes lighter rather than stronger. This means that manufacturers use less of the steel so the strength is the same, but the weight is reduced.There are just additional considerations to keep in mind when welding with chromoly. Research has been done that indicates that TIG welding is the fastest, cleanest and best way to weld 4130 chromoly tubing without risk of compromising material properties.TIG welding chromoly gives better overall properties, offers advantages in terms of versatility and amperage use because it uses less energy than other welding methods. A clean weld is also achieved by making a low-profile weld bead, and there is no slag left over after the welding is complete. The largest advantage of TIG welding is control, both in terms of the electrode itself and the current.TIG welding uses less amperage than other welding methods, which might seem like a disadvantage at first, but it really helps the TIG welder. When a torch uses a high amperage amount, it is great for large and thick metal bars but not so good for thin pieces of metal. With a low-amperage torch, the TIG welder is able to work on thin pieces of metal and other metals that cannot take high amperages.

1.2 Scopes and Objectives

The overall scope and objectives of the study is the material characterization of TIG generated chromoly steel welds and its comparison with that of the TIG generated mild steel welds.The following are the specific objectives:

- To find out the ultimate tensile strength of the chromoly weld and compare it with that of mild steel.
- To find out the microhardness of the chromoly weld and compare it with that of mild steel.
- To carry out microstructural analysis of the chromoly welds and compares it with that of mild steel.

* Dr.Sreejith Mohan ,Assosiate Professor,*VimalJyothi Engineering College Chemperi,Kannur,India,PH-+919486680488.E-mail-sreejithmhan@vjec.ac.in*
- *Boby George, AssiatantProfessor,Mechanical Engineering Department, VimalJyothi Engineering College,Kannur,India,PH-+919495426167.E-mail-bobygeorge@vjec.ac.in*
* *Co-Author Mechanical Engineering,VimalJyothi Engineering College, Chemperi,Kannur*

2. MATERIALS AND METHODS

2.1 AISI 4130 Chromoly

4130 steel is a family of SAE steel grades, as specified by the Society of Automotive Engineers (SAE). Alloying elements include chromium and molybdenum, and as a result these materials are often informally referred to as chromoly steel (common variant stylings include chrome-moly, cromoly, CrMo, CRMO, CR-MOLY, and similar). They have an excellent strength to weight ratio and are considerably stronger and harder than standard 1020 steel. The chemical composition of 4130 Chromoly steel is given in Table.2.1.

TABLE 2.1

Chemical Composition of Chromoly 4130

Element	**% Composition by Weight**
Iron	97.3 - 98.22
Carbon	0.28 - 0.33
Chromium	0.8 - 1.1
Manganese	0.7 - 0.9
Molybdenum	0.15 - 0.25
Phosphorus	0.035
Silicon	0.15 - 0.35
Sulphur	0.04

AISI 4130 is a low alloy steel containing molybdenum and chromium as strengthening agents. The carbon content is nominally 0.30% and with this relatively low carbon content the alloy is excellent from the fusion weldability standpoint. The alloy can be hardened by heat treatment.

This alloy is readily machined by conventional methods. Machinability is best with the alloy in the normalized and tempered condition. Although the alloy may be machined in the fully heat treated condition, machinability becomes more difficult with increasing strength (hardness) of the alloy. Formability of this alloy is best in the annealed condition for which the ductility is very good.Chromoly 4130 alloy is noted for its Weldability by all of the commercial methods.

2.2 Applications

Typical applications for 4130 low alloy steel include. Structural use such as aircraft engine mounts and welded tubing applications. Chromoly find application in various fields. Some of the applications of Chromoly are given below.

- Structural tubing
- Bicycle frames
- Tubes for transportation of pressurizes gases
- Firearm parts
- Clutch and flywheel components
- Roll cages
- Aircraft parts

2.3 Welding of Chromoly

SAE 4130 Chromoly can be welded using different processes such as Manual Metal Arc Welding (MMAW), Tungsten Inert Gas (TIG) Welding, Gas Metal Arc Welding (GMAW) etc. Among these TIG is the most commonly employed one and so was employed in the present work. The following section outlines the basic principle and applications of the TIG welding process.

2.2.1. Tig welding

Similar to torch welding, TIG welding normally requires two hands, since most applications require that the welder manually feed a filler metal into the weld area with one hand while manipulating the welding torch in the other. Maintaining a short arc length, while preventing contact between the electrode and the workpiece, is also important.

To strike the welding arc, a high frequency generator (similar to a Tesla coil) provides an electric spark. This spark is a conductive path for the welding current through the shielding gas and allows the arc to be initiated while the electrode and the workpiece are separated, typically about 1.5–3 mm (0.06–0.12 in) apart.Once the arc is struck, the welder moves the torch in a small circle to create a welding pool, the size of which depends on the size of the electrode and the amount of current. While maintaining a constant separation between the electrode and the workpiece, the operator then moves the torch back slightly and tilts it backward about 10–15 degrees from vertical. Filler metal is added manually to the front end of the weld pool as it is needed.

2.2.1.1 Tig welding equipment

The equipment required for the gas tungsten arc welding operation includes a welding torch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

- **Welding torch**
  GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. The automatic and manual torches are similar in construction, but the manual torch has a handle while the automatic torch normally comes with a mounting rack. The angle between the centerline of the handle and the centerline of the tungsten electrode, known as the head angle, can be varied on some manual torches according to the preference of the operator. Air cooling systems are

most often used for low-current operations (up to about 200 A), while water cooling is required for high-current welding (up to about 600 A).

- **Power supply**

  Gas tungsten arc welding uses a constant current power source, meaning that the current (and thus the heat) remains relatively constant, even if the arc distance and voltage change. This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch. Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult.

  The preferred polarity of the GTAW system depends largely on the type of metal being welded. Direct current with a negatively charged electrode (DCEN) is often employed when welding steels, nickel, titanium, and other metals. It can also be used in automatic GTAW of aluminum or magnesium when helium is used as a shielding gas. The negatively charged electrode generates heat by emitting electrons, which travel across the arc, causing thermal ionization of the shielding gas and increasing the temperature of the base material. The ionized shielding gas flows toward the electrode, not the base material, and this can allow oxides to build on the surface of the weld. Direct current with a positively charged electrode (DCEP) is less common, and is used primarily for shallow welds since less heat is generated in the base material. Instead of flowing from the electrode to the base material, as in DCEN, electrons go the other direction, causing the electrode to reach very high temperatures. To help it maintain its shape and prevent softening, a larger electrode is often used. As the electrons flow toward the electrode, ionized shielding gas flows back toward the base material, cleaning the weld by removing oxides and other impurities and thereby improving its quality and appearance.

- **Electrode**

  The electrode used in GTAW is made of tungsten or a tungsten alloy, because tungsten has the highest melting temperature among pure metals, at 3,422 °C (6,192 °F). As a result, the electrode is not consumed during welding, though some erosion (called burn-off) can occur. Electrodes can have either a clean finish or a ground finish—clean finish electrodes have been chemically cleaned, while ground finish electrodes have been ground to a uniform size and have a polished surface, making them optimal for heat conduction. The diameter of the electrode can vary between 0.5 and 6.4 millimetres (0.02 and 0.25 in), and their length can range from 75 to 610 millimetres (3.0 to 24.0 in).

- **Shielding gas**

  As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc.. Argon is the most commonly used shielding gas for GTAW, since it helps prevent defects due to a varying arc length. When used with alternating current, argon shielding results in high weld quality and good appearance. Another common shielding gas, helium, is most often used to increase the weld penetration in a joint, to increase the welding speed, and to weld metals with high heat conductivity, such as copper and aluminum.

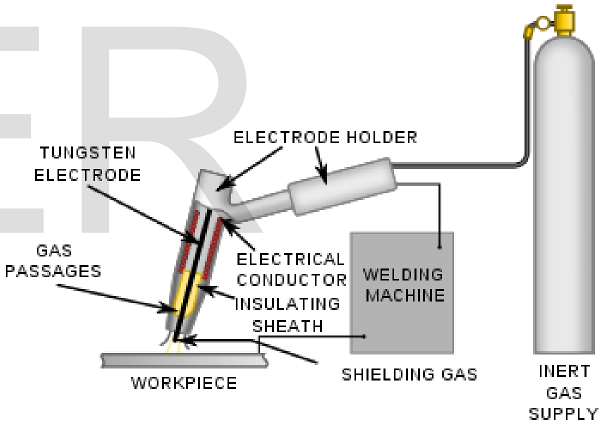

Fig 2.1TIG Welding Equipment

2.2.1.2 Materials

Gas tungsten arc welding is most commonly used to weld stainless steel and nonferrous materials, such as aluminum and magnesium, but it can be applied to nearly all metals, with a notable exception being zinc and its alloys. Its applications involving carbon steels are limited not because of process restrictions, but because of the existence of more economical steel welding techniques, such as gas metal arc welding and shielded metal arc welding. Furthermore, GTAW can be performed in a variety of other-than-flat positions, depending on the skill of the welder and the materials being welded.

Aluminum and magnesium are most often welded using alternating current, but the use of direct current is also possible, depending on the properties desired. Before welding, the work area should be cleaned and may be preheated to 175 to 200 °C (347 to 392 °F) for aluminum or to a maximum of 150 °C (302 °F) for thick magnesium work pieces to improve penetration and increase travel speed.[35] AC current can provide a self-cleaning effect, removing the thin, refractory aluminum oxide (sapphire) layer that forms on aluminum metal within minutes of exposure to air. This oxide layer must be removed for welding to occur.[35] When alternating current is used, pure tungsten electrodes or zirconiated tungsten electrodes are preferred over thoriated electrodes, as the latter are more likely to "spit" electrode particles across the welding arc into the weld. Blunt electrode tips are preferred, and pure argon shielding gas should be employed for thin work pieces. Introducing helium allows for greater penetration in thicker work pieces, but can make arc starting difficult.

Direct current of either polarity, positive or negative, can be used to weld aluminum and magnesium as well. Direct current with a negatively charged electrode (DCEN) allows for high penetration. Argon is commonly used as a shielding gas for DCEN welding of aluminum. Shielding gases with high helium contents are often used for higher penetration in thicker materials. Thoriated electrodes are suitable for use in DCEN welding of aluminum. Direct current with a positively charged electrode (DCEP) is used primarily for shallow welds, especially those with a joint thickness of less than 1.6 mm (0.063 in). A thoriated tungsten electrode is commonly used, along with a pure argon shielding gas.For GTAW of carbon and stainless steels and alloy steels, the selection of a filler material is important to prevent excessive porosity. Oxides on the filler material and workpieces must be removed before welding to prevent contamination, and immediately prior to welding, alcohol or acetone should be used to clean the surface.[36] Preheating is generally not necessary for mild steels less than one inch thick, but low alloy steels may require preheating to slow the cooling process and prevent the formation of martensite in the heat-affected zone. Tool steels should also be preheated to prevent cracking in the heat-affected zone. Austenitic stainless steels do not require preheating, but martensitic and ferritic chromium stainless steels do. A DCEN power source is normally used, and thoriated electrodes, tapered to a sharp point, are recommended. Pure argon is used for thin workpieces, but helium can be introduced as thickness increases.Welding dissimilar metals often introduces new difficulties to GTAW welding, because most materials do not easily fuse to form a strong bond. However, welds of dissimilar materials have numerous applications in manufacturing, repair work, and the prevention of corrosion and oxidation. In some joints, a compatible filler metal is chosen to help form the bond, and this filler metal can be the same as one of the base materials (for example, using a stainless steel filler metal with stainless steel and carbon steel as base materials), or a different metal (such as the use of a nickel filler metal for joining steel and cast iron). Very different materials may be coated or "buttered" with a material compatible with a particular filler metal, and then welded. In addition, GTAW can be used in cladding or overlaying dissimilar materials.When welding dissimilar metals, the joint must have an accurate fit, with proper gap dimensions and bevel angles. Care should be taken to avoid melting excessive base material. Pulsed current is particularly useful for these applications, as it helps limit the heat input. The filler metal should be added quickly, and a large weld pool should be avoided to prevent dilution of the base materials.

2.2.1.3 Quality

Gas tungsten arc welding, because it affords greater control over the weld area than other welding processes, can produce high-quality welds when performed by skilled operators. Maximum weld quality is assured by maintaining cleanliness—all equipment and materials used must be free from oil, moisture, dirt and other impurities, as these cause weld porosity and consequently a decrease in weld strength and quality. To remove oil and grease, alcohol or similar commercial solvents may be used, while a stainless steel wire brush or chemical process can remove oxides from the surfaces of metals like aluminum. Rust on steels can be removed by first grit blasting the surface and then using a wire brush to remove any embedded grit. These steps are especially important when negative polarity direct current is used, because such a power supply provides no cleaning during the welding process, unlike positive polarity direct current or alternating current. To maintain a clean weld pool during welding, the shielding gas flow should be sufficient and consistent so that the gas covers the weld and blocks impurities in the atmosphere. GTAW in windy or drafty environments increases the amount of shielding gas necessary to protect the weld, increasing the cost and making the process unpopular outdoors.

2.2.1.4 Applications

While the aerospace industry is one of the primary users of gas tungsten arc welding, the process is used in a number of other areas. Many industries use GTAW for welding thin workpieces, especially nonferrous metals. It is used extensively in the manufacture of space vehicles, and is also frequently employed to weld small-diameter, thin-wall tubing such as those used in the bicycle industry. In addition, GTAW is often used to make root or first-pass welds for piping of various sizes. In maintenance and repair work, the process is commonly used to repair tools and dies, especially components made of aluminum and magnesium.Two SAE 4130 chromoly plates of dimension 200x100x3mm were cut, polished with emery paper and cleaned in acetone. The type of welding adopted was butt welding. For this, the edges of the plates were ground and placed together to form 60° notch angle. The plates were clamped using C clamps after providing a clearance of 1.5 mm between notches.The welding generator used was of constant current type (MAKE: MOSTIG, MODEL: 200S) TIG welding machine with DC electrode negative configuration. The filler used was ER 70S-2, whose chemical composition is shown in the Table .Table 2.2. Under a constant welding current of 55 A, multi pass weld was laid over the notch by an experienced welder. The shielding gas used was Argon IS 20162 Mild steel plates of the same dimension were welded under the same parameters as that of the chromoly plates for comparison.

2.3 Tensile Test

The basic test for determination of material behavior is the tensile test. Generally, it is carried out using a round specimen. When determining the strength of a welded joint, also standardized flat specimens are used.Here, we make use of Ultimate Testing Machine *(MAKE : KRYSTAL ELMEC MODEL:…….)* for obtaining the Yield stress and Ultimate tensile strength of the welded Chromoly plates.

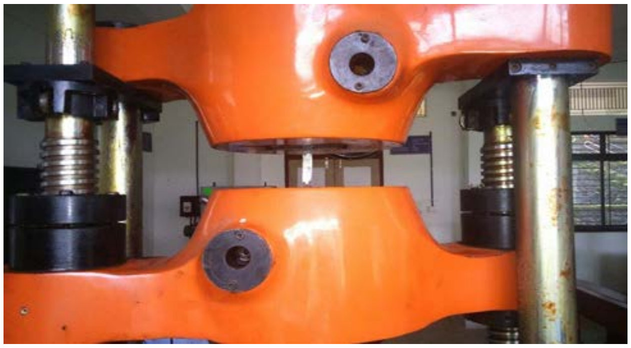

Fig 2.2 Ultimate Testing Machine (UTM)

2.3.1 Tensile Test Specimen Preparation

The specimen is prepared according to ASTM e8 standard. An I section of the required dimension is cut from the welded plate by wire cut electron discharge machining (EDM) method. Fig2.3 shows the specimen drawing and the Table 2.2 shows the dimensions of the specimen.

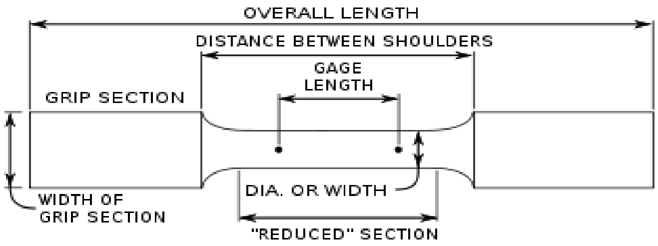

Fig 2.3 Tensile Test Specimen

TABLE 2.2

Dimensions of the test specimen

Parts	**dimensions (mm)**
Gauge length	51
Width	13
Thickness	3
Fillet radius (min.)	6.35
Overall length (min.)	205
Length of reduced section (min.)	57.17
Length of grip section (min.)	51
Width of grip section (approx.	20

Fig 2.3 & Fig 2.4 shows Chromoly 4130 and IS 2062 Mild Steel specimens for tension testing respectively.

Fig 2.3 Tensile test specimen (Chromoly steel)

Fig 2.4Tensile test specimen (Mild steel)

The specimen is held in the Ultimate Testing machine and a load is applied gradually until the specimen breaks. The yield point load and the ultimate load are noted down to calculate the Yiels stress and the Ultimate stress respectively.

2.4 Micro Hardness Test

The Micro Hardness of the Welded material is determined using Rockwell Hardness Tester (*MAKE: KRYSTAL ELMEC, MODEL: KAS*). Fig 2.5 shows the image of the Rockwell hardness tester.

Fig 2.5 Rockwell hardness testing machine

Hardness is defined as resistance to indentation and is commonly used as a measure of resistance to abrasion or scratching. For the formation of a scratch or causing abrasion, a relative movement is required between two bodies and out of two one body must penetrate/indent into other body. Indentation is the penetration of a pointed object (harder) into other object (softer) under the external load. Resistance to the penetration of pointed object (indenter) into the softer one depends on the hardness of the sample on which load is applied through the indenter. All methods of hardness testing are based on the principle of applying the standard load through the indenter (a pointed object) and measuring the penetration in terms of diameter/diagonal/depth of indentation. High penetration of an indenter at a given standard load suggests low hardness.

In case of Rockwell hardness test, minor load (10 KN) is applied first before applying major load. Minor load is applied to ensure the firm metallic contact between the indenter and sample surface by breaking surface films and impurities if any present on the surface. Minor load does not cause indentation. Indentation is caused by major load only.

Then major load of 150kg is applied on the surface of the work-piece through the indenter and the same is decided by scale (A, B, C and D) to be used as per type of material to be tested. Minor load is not changed. Out of mainly scales, B and C scales are commonly used. Different indenter and major load are required for each scale. Steel ball and diamond cone are two types of indenters used in Rockwell testing.

For Hardness Testing of Chromoly weld is done on B scale which makes use of a steel ball indenter of diameter 1/16”. The welded Chromoly was tested for Rockwell hardness in the three zones:i) base metal ii) heat affected zone iii) weld zone. The pointer position on the dial directly gives the Rockwell Hardness Number of the Chromoly weld. The same procedure is carried out to obtain the hardness number of the Mild steel weld.

2.5 Microstructural Analysis

Microstructure is the small scale structure of a material, defined as the structure of a prepared surface of material as revealed by a microscope above 25× magnification. The microstructure of a material (such as metals, polymers, ceramics or composites) can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior or wear resistance. These properties in turn govern the application of these materials in industrial practice. Microstructure at scales smaller than can be viewed with optical microscopes is often called nanostructure, while the structure in which individual atoms are arranged is known as crystal structure.

When a polished flat sample reveals traces of its microstructure, it is normal to capture the image using macro photography. More sophisticated microstructure examination involves higher powered instruments: optical microscopy, electron microscopy, X-ray diffraction and so on, some involving preparation of the material sample (cutting, microtomy, polishing, etching, vapor-deposition etc.). The methods are known collectively as metallography as applied to metals and alloys, and can be used in modified form for any other material, such as ceramics, glasses, composites, and polymers.Two kinds of optical microscope are generally used to examine flat, polished and etched specimens: a reflection microscope and an inverted microscope. Recording the image is achieved using a digital camera working through the eyepiece.

2.5.1 Optical microscope

The optical microscope, often referred to as light microscope, is a type of microscope which uses visible light and a system of lenses to magnify images of small samples. Optical microscopes are the oldest design of microscope and were possibly invented in their present compound form in the 17th century. Basic optical microscopes can be very simple, although there are many complex designs which aim to improve resolution and sample contrast.

The microstructure analysis of materials can be done using an optical microscope. In this project, we make use of an Optical microscope *(MAKE: OLYMPUS, MODEL: BX61)* to obtain the grain structure ofTIG generatedChromoly weld.

Fig 2.6 Optical Microscope

The image from an optical microscope can be captured by normal light-sensitive cameras to generate a micrograph. The micrograph allows us to view the grain structure and grain alignment at various magnifications.

2.5.2 Specimen preparation for microstructure analysis

2.5.2.1 Sectioning and Cutting

Following proper documentation, most metallographic samples need to be sectioned to the area of interest and for easier handling. Depending upon the material, the sectioning operation can be obtained by abrasive cutting (metals and metal matrix composites), diamond wafer cutting (ceramics, electronics, biomaterials, minerals), or thin sectioning with a microtome (plastics).Proper sectioning is required to minimize damage, which may alter the microstructure and produce false metallographic characterization. Proper cutting requires the correct selection of abrasive type, bonding, and size; as well as proper cutting speed, load and coolant.

2.5.2.2 Mounting

The mounting operation accomplishes three important functions (1) it protects the specimen edge and maintains the integrity of a materials surface feature (2) fills voids in porous materials and (3) improves handling of irregular shaped samples, especially for automated specimen preparation. The majority of metallographic specimen mounting is done by encapsulating the specimen into a compression mounting compound (thermosets - phenolics, epoxies, diallyl phthalates or thermoplastics - acrylics), casting into ambient castable mounting resins (acrylic resins, epoxy resins, and polyester resins), and gluing with a thermoplastic glues.

2.5.2.3 Coarse grinding

In view of the perfection required in an ideally prepared metallographic sample, it is essential that each preparation stage be carefully performed. The specimen must:

1. Be free from scratches, stains and others imperfections which tend to mark the surface.

2. Retain non-metallic inclusions.

3. Reveal no evidence of chipping due to brittle intermetallic compounds and phases.

4. Be free from all traces of disturbed metal.

The purpose of the coarse grinding stage is to generate the initial flat surface necessary for the subsequent grinding and polishing steps. As a result of sectioning and grinding, the material may get cold worked to a considerable depth with a resultant transition zone of deformed material between the surface and the undistorted metal. Coarse grinding can be accomplished either wet or dry using 80 to 180 grit electrically powered disks or belts, but care must be taken to avoid significant heating of the sample. The final objective is to obtain a flat surface free from all previous tool marks and cold working due to specimen cutting.

After this the specimen surface is ground using emery paper of various grades. Initially emery paper of grade 1/0 is used to remove the remaining scratches after vrough grinding. The specimen is moved rubbed on the paper in one direction until we obtain unidirectional scratches on the surface. After this grade 2/0, 3/0/ and 4/0 are used and the direction of grinding must be perpendicular to the preceding direction of grinding.

2.5.2.4 Mechanical polishing

Polishing involves the use of abrasives, suspended in a water solution, on a cloth-covered electrically powered wheel. Diamond abrasives provide the best, and most expensive, compounds utilized in polishing; standard sized aluminum oxide powders are applied for general use purposes. Following the final 600 grit fine-grinding stage, the sample must be washed and carefully dried before proceeding to the first polishing stage.

Beginning with 25-micron suspended aluminum oxide particles (suspended in water) on a Nylon-cloth, the final fine grinding surface layer resulting from the previous grinding procedure should be completely removed with a rotation rate of 150-200 rpm. The specimen is initially held at one position on the wheel, without rotation, until most of the previous grinding marks are removed. It can be rotated slowly, counter to the wheel rotation, until only scratches from the 25-micron aluminum oxide are visible.

Fig 2.7 Fine Polishing using Diamond Paste

Fig 2.8 Fine polishing with Alumina Powder

For precision work, extremely fine grades of diamond abrasives may often be used for the final polishing sequence. Cerium Oxide is especially excellent for the final polishing of aluminum and other soft metals and alloys. The best abrasive types and sizes for various metals and alloys are listed in the literature;

2.5.2.5 Etching

Microscopic examination of a properly polished, unetched specimen will reveal only a few structural features such as inclusions and cracks or other physical imperfections. Etching is used to highlight, and sometimes identify, microstructural features or phases present. Etchants are usually dilute acid or dilute alkalis in a water, alcohol or some other solvent. Etching occurs when the acid or base is placed on the specimen surface because of the difference in rate of attack of the various phases present and their orientation. The etching process is usually accomplished by merely applying the appropriate solution to the specimen surface for several seconds to several minutes.

Nital, a 2%Nitric Acid –98% Alcohol mixture, is the etchant commonly utilized with common irons and steels. Nital is dripped onto the specimen using an eye-dropper or cotton swab. Ten seconds to one minute is usually sufficient for proper etching depending on sample and nital concentration. The sample is immediately washed under running water, rinsed with alcohol and dried in an air blast. Do not touch, wipe or swab the specimen following etching; dry off the rinsing alcohol on the specimen with the air blast and then move on to the microscopic

2.5.2.6 Microscopic examination

Initial microscopic viewing should be done utilizing a stereomicroscope, which reveals a three-dimensional scanning of the specimen surface. The specimen is placed on the stage of the microscope so that its surface is perpendicular to the optical axis. Detailed viewing is done with a Metallurgical Microscope.

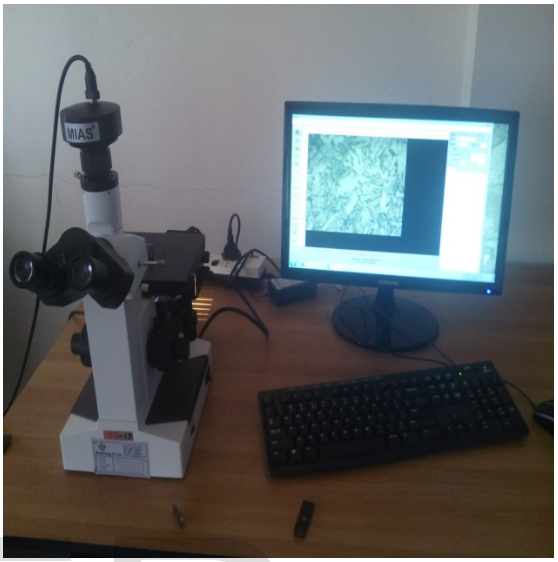

Fig 2.9 Microscopic Examination

3. RESULTS AND DISCUSSION

TIG welding was carried out successfully on Chromoly 4130 steel and Mild steel IS2062 and tests were conducted on them to determine the ultimate tensile strength and microhardness number of the welded.

3.1. Tension Test

The tension test was conducted on both the welded AISI 4130 Chromoly and IS 2062 Mild Steel plates and the results are shown in Table 3.1

TABLE 3.1

Tension test

Trial	**Yield Strength (MPa)**	
	AISI 4130 Chromoly	**IS 2062 Mild steel**
1		**307.69**
2		**289.54**
Average		
Trial	**Ultimate Tensile Strength (Mpa)**	
1	635.97	405.14

2	626.92	382.15
Average	631.445	393.64

The tension tests on base metals were also carried out and the results were obtained. It has been found that the yield strength and the ultimate tensile strength and of unweldedAISI 4130 Chromoly is 483MPa and 641MPa respectively and the values of yield strength and ultimate tensile strength for IS 2062Mild Steel is

3.2 Microhardness Test

Hardness number of TIG generated Chromoly 4130 weld and IS 2062 Mild Steel was found using Rockwell Hardness Tester. Table3.2 shows the results obtained.

Trial	**AISI 4130 Chromoly**			**IS 2062 Mild Steel**		
	Base Metal (HRB)	*Heat Affected Zone*	*Weld zone*	*Base Metal*	*Heat Affected Zone*	*Weld zone*
1	95	92	96	65	69	75
2	92	98	94	71	53	69
3	89	96	88	69	58	72

Table 3.2

3.3. Microstructure

The micrographs of IS 2062 mild steel weld and SAE 4130 chromoly are shown in the Fig. 3.1.

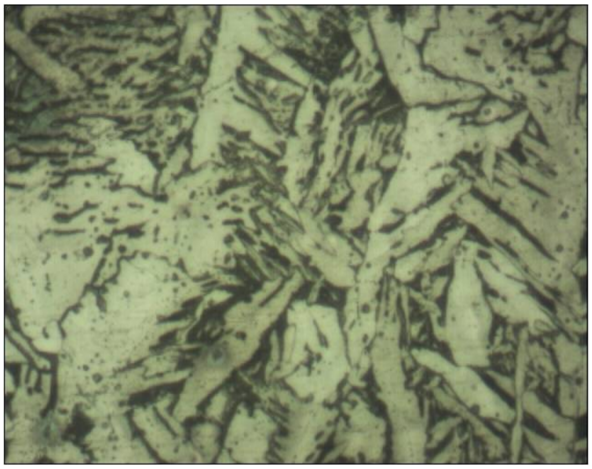

Fig 3.1 Microstructure of mild steel 1062 weld

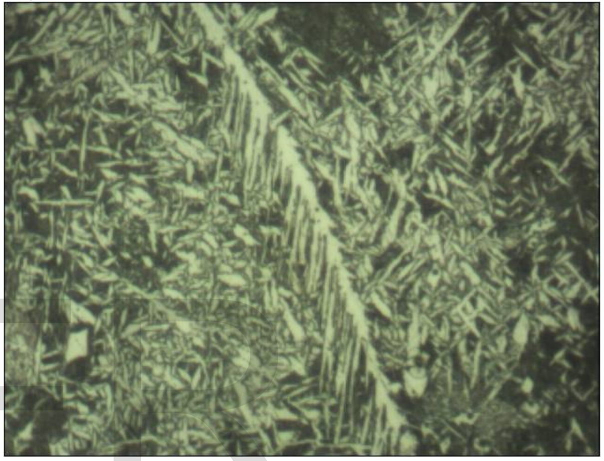

Fig 3.2 Microstructure of AISI 4130Chromoly Weld

Both weld microstructures consist of ferrite granules (light etched) with Pearlite in between (darkly etched). The microstructure of mild steel weld was found to contain large sized acicular ferrite and Widmanstatten ferrites (Fig. 3.1). The microstructure of Chromoly weld composed of Bainite and Widmanstatten ferrites. It was further noted that the grains were more refined compared to that of mild steel.To get a better estimate of grain refinement, the average grain size of the weld was found out feom the micrographs using the average line intercept method as per the ASTM E-1132 standard. Table 3Shows the average grain size of the mild steel and chromoly weld.

TABLE3.3

Grain Size of the Welds

Type of Weld	**Grain Size (μm)**
Mild steel weld	25.32

Chromoly weld	9.21

The values in the above table indicates that the chromoly weld have highly refined grains compared to mild steel which will be advantageous in terms of its ductility and strength.

4. CONCLUSIONS

It was found that when the metals were welded under same parameters, Chromoly seems to exhibit better tensile strength. Microhardness of Chromoly was greater than Mild steel.Also it has been inferred from the microstructure analysis that Chromoly has more refined grain structure compared to Mild steel which will be advantageous in terms of its ductility and strength.

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