Study on Gas Metal Arc Welding in S235 Steel

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Abstract - *For the assembly of vehicle body sections made of high-strength S235 steel, one of the most popular techniques in the automotive industry is Gas Metal Arc Welding (GMAW) with Cold Metal Transfer (CMT), which is lauded for its affordability, weld quality, and welding speed. High-strength steel retains flexibility and malleability despite having increased strength thanks to the mix of metal alloys it contains, including silicon, chromium, manganese, and molybdenum. The welding process parameters in the gas metal arc welding process can significantly affect the quality of the welded connection. In this investigation, gas metal arc welding was used to join samples of S235 high strength steel. Butt joints were created using plates that were 6 mm thick. Each joint sample was produced using a unique set of parameters, including input current, voltage, weld speed, and wire supply. The percentage of elongation, yield strength, ultimate strength, and Rockwell Hardness of the welded samples were all used to assess the weld quality. Gas metal arc welding was the subject of a micro structural analysis for a variety of welded joint qualities.*

Key Words: Gas metal arc welding, cold metal transfer, High strength steel, tensile strength, Yield strength, Hardness, Microstructure.

1. INTRODUCTION

One of the best methods for manufacturing vehicle body parts out of high-strength S235 steels in the automotive industry is Gas Metal Arc Welding (GMAW) with Cold Metal Transfer (CMT). The metal pieces are warmed during the GMAW process by an electric arc that forms between the metal and a wire electrode. GMAW works in a number of industries, including as manufacturing, construction, auto racing, and car building. GMAW is also known as metal inert gas (MIG) welding. In the MIG and GMAW processes, a continuous solid wire electrode passes through the welding gun with a shielding gas those guards against airborne contaminants. Aluminium and other nonferrous metals, as well as thick and thin metal sheets, may all be joined together using this welding process. In comparison to carbon steel, high-strength steels are alloy steels with better mechanical properties and corrosion resistance. They're used by anything from vehicles to cranes to bridges [1].
Gas metal arc welding allows for the joining of a wide variety of materials, with carbon steel being the most common. Aluminium, stainless steel, titanium, and tool steel are a few examples of other materials [2].

1.1 Experimental method

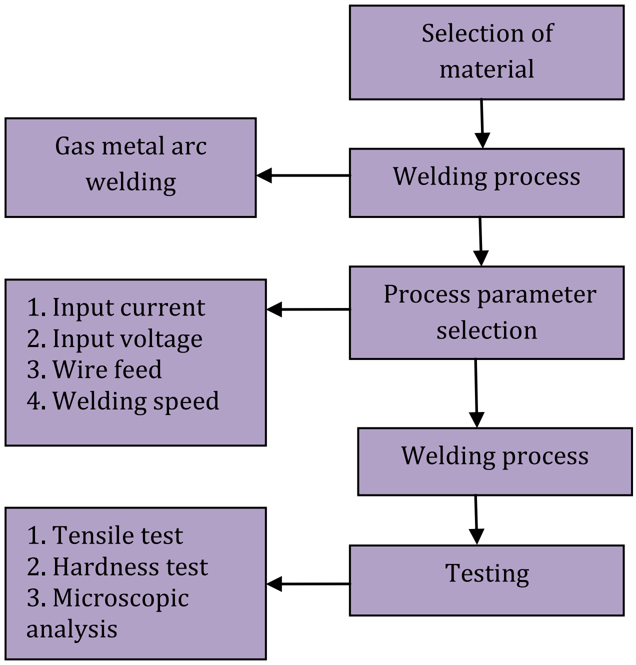

Fig – 1: Experimental flow chart

1.2 Materials

In comparison to carbon steel, high-strength steel (HSS) is an alloy steel with better mechanical properties and a greater level of corrosion resistance. In contrast to traditional steels, HSS steels are created to meet specific mechanical requirements rather than having a particular chemical composition [3]. They have a 0.05 to 0.25 percent carbon content to keep their formability and weld ability. High school (HSS) has received a lot of attention lately. Because HSS has a smaller cross-sectional area, its structures are lighter (and hence have a greater strength-to-weight ratio), have higher clearance heights, and are simpler to make and check [4]. These elements contribute to the widespread usage of HSS in high-rise and bridge construction. HSS has also just recently been used in civil engineering applications due to its high tensile strength and energy absorption, despite being widely used in the automotive industry. High-strength steel is defined as having yield strength of 550 MPa and a tensile strength of 700 MPa.

Table -1: Chemical compositions of S235 steel

Composition	Manganese (Mn) max	Silicon (Si) max	Carbon (C) max	Phosphorus (P) max	Sulfur (S) max
%	**1.6**	**0.05**	**0.22**	**0.05**	**0.05**

2. Experimental procedure

Gas metal arc welding is a consumable welding process that creates an arc between the work piece and the electrode. The base metal and wire electrode are melted by the heat of the arc, enabling the connection of the weld piece. These tests were conducted in the Government College of Technology's Coimbatore workshop. Figure 2 displays the experimental setup for gas metal arc welding with cold metal transfer (CMT).

Fig – 2: Gas Metal Arc Welding Setup

High-strength steel S235 with a butt joint was a possibility. for testing each sample's weld ability, including microscopic scrutiny, tensile strength, and hardness. High-strength steel S235 was used for the experimental work. The source metal is 6mm thick and was cut to the necessary measurements (75*50*6).

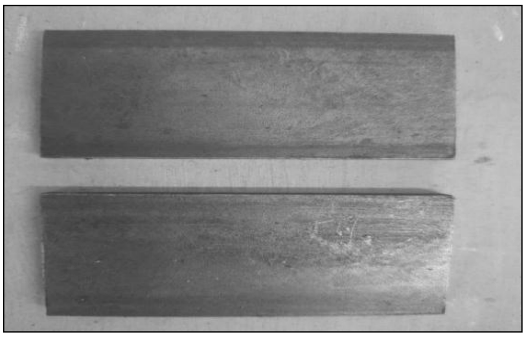

Fig – 3: S235 metal plates

Table -2: Welding parameters

S. NO	**VOLTAGE v**	**CURRENT Amps**	**WELDING SPEED mm/min**	**WIRE FEED m/min**	**GAS PRESSURE l/min**
1	23	190	80	6.2	5
2	22.5	180	75	5.8	5
3	21.9	170	70	5.4	5
4	21.4	160	65	5	5
5	21.3	150	60	4.7	5

3. Fabrication of joints

Gas metal arc welding is a consumable welding process that generates an arc between the work piece and the electrode. The base metal and wire electrode are melted by the heat of the arc, enabling the connection of the weld piece. Heat, current, voltage, shielding gas, wire feed, and welding speed are used to create the weld [5]. First, a high voltage current is transformed into a high current low voltage DC current supply. The welding electrode carries this current. A reusable wire is used as an electrode. The electrode is connected to the negative terminal, while the work piece is connected to the positive terminal. A fine, strong arc will emerge between the electrode and the work piece as a result of the power source [6]. The electrode and base metal were melted by the heat produced by this arc. The majority of electrodes are made of base metal to provide uniform junctions. This arc is well-protected by shielding gases [7]. These gases serve as a barrier between the weld and other reactive gases that can weaken the strength of the welding connection. This electrode must travel continuously across the welding surface for a good weld junction [8].

Fig – 4: Welded part

4. Universal tensile testing machine

Assess the tensile and yield strength of the joints; the welded samples were fabricated according to the American Society for Testing of Materials (ASTM EN8) standards [9]. The tensile strength of the welded object was determined using universal testing equipment. The tensile testing sample was cut using wire cut electrical discharge machining Wire electrical discharge machining (WEDM) uses a thin electrode wire to cut or shape a work item, generally conductive material, along a well-planned route.

Fig – 5: Tensile test sample

5. Rockwell hardness testing

Rockwell hardness testing is a technique for determining the bulk hardness of metals and polymers. For a number of structural alloys, including steel and aluminum, conversion tables from Rockwell hardness to tensile strength are available. Indentation testing is used to determine Rockwell hardness. A hard steel ball or a conical diamond serves as the indenter. Depending on the test scale, different indenter ball sizes between 1/16 and 1/2 are used.

6. Microscopic analysis

The process of measuring a material's bulk hardness is called Rockwell hardness testing for metals and polymers. There are charts that convert different structural alloys, including steel and aluminum, from Rockwell hardness to tensile strength. Through indentation testing, Rockwell hardness is identified. The indenter is either a hard steel ball or a conical diamond. Depending on the test scale, a range of indenter ball sizes from 1/16 to 1/2 are used.

7. Result and discussions

7.1. Tensile strength result

Tensile strength describes a material's capacity to endure a pulling (tensile) force, and it describes a material's breaking strength when a force that may simultaneously break several strands of the material is applied at a constant rate of extension/load. Psi, or pounds per square inch of cross-sectional area, is the usual unit of measurement. The findings of measuring the tensile and yield strengths of the welded samples are shown in table 3.

Table -3: Tensile strength of welded samples

S.NO	VOLTAGE (V)	CURRENT (A)	WELDING SPEED mm/min	WIRE FEED m/min	Tensile strength MPa	Yield strength MPa
Sample 1	23	190	80	6.2	532.893	475.08
Sample 2	22.5	180	75	5.8	553.000	486.92
Sample 3	21.9	170	70	5.4	560.613	488.213
Sample 4	21.4	160	65	5	518.027	316.307
Sample 5	21.3	150	60	4.7	487.880	439.8

Using a predetermined experiment, the maximum tensile strength (560 MPa) and yield strength (488 MPa) for sample 3 were found for the parameters of voltage 21.9v, current 170 Amps, welding speed 70 mm/min, and wire feed 5.4 m/min. With an average current input, sample 3's welding strength has risen.

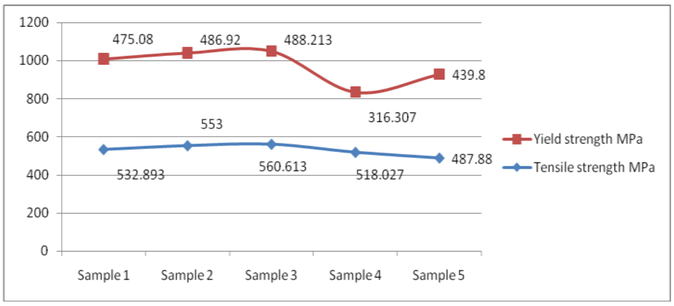

Chart -1: Tensile and Yield Strength of the Sample

7.2. Rockwell hardness result

A substance's capacity to withstand localized persistent deformation, such an indentation, is referred to as hardness. Hardness is a term that occasionally refers to a material's resistance to deformation caused by outside forces [10]. The results of the determination of the hardness of welded samples are shown in table 4.

Table -4: Rockwell hardness result

S.NO	VOLTAGE (v)	CURRENT (A)	WELDING SPEED mm/min	WIRE FEED m/min	ROCKWELL HARDNESS NUMBER(RHC)
Sample 1	23	190	80	6.2	73
Sample 2	22.5	180	75	5.8	64
Sample 3	21.9	170	70	5.4	67
Sample 4	21.4	160	65	5	77
Sample 5	21.3	150	60	4.7	87

According to a predetermined experiment, sample 3 exhibits the highest hardness (87) at the following conditions: voltage 21.3 volts, current 150 amps, welding speed 60 mm/min, and wire feed 4.7 m/min

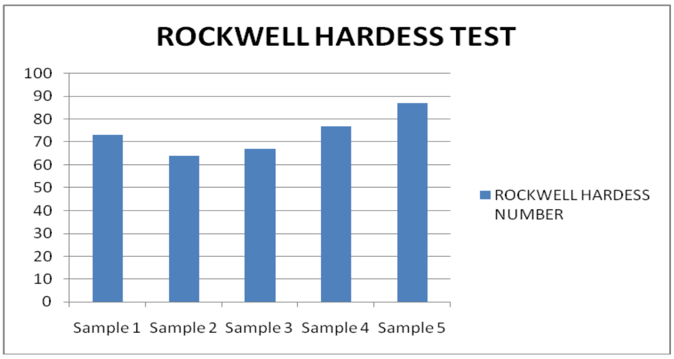

Chart -2: Rockwell Hardness Graph

7.3. Micro structural analysis

Several microscopy methods can be used to survey microstructure. Microstructure analysis requires a microscope. The visible characteristics are often measured in millimeters, micrometers, or even nanometers. When analyzed at various length scales, a material's micro structural characteristics may significantly change. As a result, it's crucial to consider the length scale (100X) of your observations when characterizing the microstructure of a material. Images show the findings of a study on the microscopic structure of welded samples. Figures 6 depict the microstructure examination of samples 3 and 5.

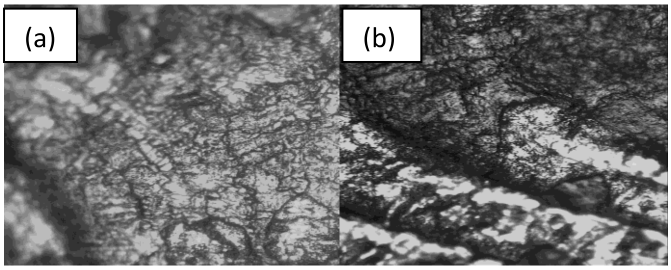

Fig – 6: Microstructure (a) Sample 3, (b) Sample 5

The study of the five samples was done using distinctively GMAW-welded sample areas, and the microstructure of the targeted area was discovered by looking at the samples' microstructure. Figure 10 displays the visual results of examples 3 and 5. Samples 3 and 5 had the best microstructure for grain structure. In the comparison, it is simple to examine the microstructure of sample 3's GMAW weld.

8. Conclusion

In this paper, the gas metal arc welding of S235 high-strength steel was examined. Each sample was prepared by varying the welding process parameters such as input current, input voltage, welding speed, and wire feed. The ratio of argon and carbon dioxide used as the shielding gas input during welding was 75% and 25%, respectively. The quality of the weld was evaluated by tensile strength, yield strength, Rockwell hardness, and microscopic inspection. The ideal tensile strength (560 MPa) and yield strength (488 MPa) of the weld were achieved in sample 3 with voltage input 21.9 v, current input 170 Amps, and welding speed 70 m/min. The best value of average hardness (93 HRC) was achieved in sample 5 with voltage input of 21.3 v, current input of 150 Amps, and welding speed of 60 m/min. Samples 3 and 5 had the best microstructure. The comparison indicates unequivocally that the microstructure of GMAW weld samples 3 and 5 contains more grains. The weld bead in sample 5 has a distinct structure compared with others.

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