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STUDY ON THE EFFECT OFSHIELDING GAS AND FILLER MATERIALON TENSILE STRENGTH AND IMPACT STRENGTH OF MAG WELDED SS409M

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Keywords:MAG Welding, Shielding gases, Filler metals, SS409M, Tensile strength, Impact strength

Abstract.SS409M has been widely used in diversified fields of engineering including automobile and chemical industries. The present work analyses the effect of varying shielding gases (argon and argon with 5%nitrogen) and filler material (308L and 309L) during MAG welding of SS 409. The tensile strength and impact strength of weld depends onthe heat input during welding. The experimental work displayed better properties of joint when welded with low heat input, 309L filler material and shielding gas argon with addition of nitrogen. The resultant weld displayed minor difference in impact strength with filler material, shielding gas and heat input variations.

Introduction

Welding is one of the most prefer joining process used out of other different fabrication processes used for joining different metals, such as riveting and bolting [1]. Metal Inert Gas (MIG) and Metal Active Gas (MAG) welding is used for mechanical assembly [2]. The majority of research have focused on analysing mechanical properties and metallurgical characteristics of the MAG welded joints as a result of variation of process variables like welding current, welding speed, torch angle, arc length, gas flow rate, electrode diameter and arc voltage [2–5]. Researchers have worked with Pure Argon and Argon + CO_2 shielding gas for analysing welding output [6]. Different shielding gas like argon (Ar), helium (He) and carbon dioxide (CO_2) were used either alone, or in combinations or mixed to limit the issue associated with weld contamination and attain defect free weld [4][6, 7]. Addition of small amounts of other gas like oxygen (O_2), nitrogen (N_2) and hydrogen (H_2) have shown better joint quality [8]. The oxidizing characteristics of other gasses except inert gas like argon and helium are compromised with formulation of special wire electrode [6]. For obtaining spray transfer at low current, pulsed arc technique is used. Natural spray transfer during welding can be obtained by choosing proper combination of electrode and shielding gas. Mild Steel (MS) electrode with argon shielding produces spray transfer while if CO_2 as shielding will not produce spray transfer. Commercially pure argon of 99.95% is used for aluminum welding but same is not used for welding steel due to poor stability of the arc. Constrictive arc is generated with argon and O_2 gas that result in spray or pulsed metal transfer during welding [9, 10]. Better weld bead profile can be obtained with CO_2 addition producing less constricted arc as compared to that of O_2. For welding material of thickness less than 6 mm, argon with 5% CO_2, 2% O_2 results in nominal spatter while for thicker material, high CO_2 addition is preferred

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since it decreases chance of unfused sidewall but increases spatter. Ar + 15% CO_2 +2% O_2 produce better weld bead penetration and lower spattering. 99% Ar + 1% O_2 is preferred for high alloy ferrous materials. The addition of O_2 result in weld pool wetting with nominal loss of the higher reactive elements. 95% Ar + 5% CO_2 is used for low alloy ferrous materials. The addition of 5% CO_2 result in better wetting, minimal spatter, and prevent gas porosity in weld with better bead appearance [9, 11]. Lack of root or side wall fusion can occur as a result of faulty welding current, poor cleaning, fast arc travel speed, oxides or scale presence, etc. Choice of proper welding parameter ensuring optimum heat input without contamination of the shielding gas result in defect free weld. Low heat input result in incomplete weld melting while higher heat input produce large size weld pool [3, 4].

Ghosh et al [7] welded 409 to 316L using GMAW with 308 filler wire and Ar shielding gas as per L9 orthogonal array of Taguchi method. The effects of different welding parameters such as welding current, flow rate of shielding gas and nozzle to plate distance were analysed for tensile strength and yield strength of the weld. The parameters were optimized based on experiments and followed with confirmatory test attaining highest tensile strength of 422MPa. Kamble and Rao [12] GMAW welded 321 of 10 mm thick using 308 filler and studied the effects of voltage, speed, filler feed rate and gas flow rate and proposed mathematical model for geometry of weld bead, hardness and microstructure. Gupta et al. [13] studied effect of variation of heat-input on GMAW SS409 weld quality prepared with ER304 and ER308 filler wire. It was reported that weld prepared with ER304 and ER308 attained average tensile strength of approximately 550 and 470 MPa respectively. Mukherjee et al. [14] examined the effect of heat input on joint quality for GMAW weld of 409M using Ar+5%CO_2 shielding gas and 308L and 316L filler wires. The weld exhibited better impact strength at higher heat input due to higher amount of martensite formation. The weld prepared with 308L demonstrated higher impact strength compared to 316L filler. Shojaati and Beidokhti[15]analyzed the mechanical properties and microstructure of dissimilar 304 and 409 GMAW weld obtained with 310, 316L, 2209 and 80/20 Ni-base filler wires. The weld demonstrated comparable tensile strength with 316L and 2209 filler that was higher than 310 filler. The microhardness profile across the weld showed decreasing trend in sequence to 2209, 316L, 80/20 Ni-base and 310 filler wires. Considering cost factor the researcher accepted weld with 316L having better quality. Lakshminarayanan et al. [5] compared GMAW welded SS409 with filler wire of 308L, 430 and 2209. The weld with 2209 resulted in better fatigue property that was attributed to higher yield strength and toughness. Rajasekar et al. [16] welded SS409 using copper coated mild steel filler wire and optimized parameters using Taguchi method for quality joint. The experimental highest tensile strength of 486 MPa was reported. Table 1 briefly summaries outcome of different research work carried out with GMAW process. This research paper is aimed at comparing tensile strength and impact strength as a result of variation of filler wire and shielding gas composition.

Table 1 Brief summary of 409 GMAW welded steel

Reference	Base Material	Filler	Shielding Gas	Heat input	Output
[7]	409 & 316L Thickness = 3 mm	308	Argon	Not Mentioned	Obtained highest TS of 422MPa with optimized parameters

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[13]	SS409 Thickness = 3 mm	ER304 & ER308 1.2 mm diameter	Pure Argon	0.3, 0.4 and 0.5 kJ/mm	Better quality joint with ER304 than ER308
[14]	409M Thickness = 4 mm	308L & 316L 1.2 mm diameter	Ar+5%CO_2	0.4, 0.5 and 0.6 kJ/mm	Claimed better quality joint with 308 than 316L
[15]	304 & 409 Thickness = 3 mm	310, 316L, 2209, 80/20 Nichrome	99.999 % Pure Argon	~ 0.6 kJ/mm	Out of 310, 316L, 2209 and 80/20 Ni-base filler wires weld 316L and 2209 weld were of better and comparable quality
[5]	SS409 Thickness = 4 mm	308L, 430, 2209 1.6 mm diameter	99.99 % Argon	720 J/mm	Fatigue resistance of weld with 2209 filler was better than that of 308L and 430
[16]	SS409	Cu coated MS filler wire 2 mm diameter	Not Mentioned	Not Mentioned	experimental highest tensile strength of 486 MPa was obtained

Methodology

MAG Welding Machine Set up. The experimental setup with shielding gas cylinder of Pure Argon and Argon + Nitrogen mixture welding arrangement are shown in Fig.1. In this work, semi-automatic LORCH make MAG welding machine was used, in which the voltage can be varied, welding current adjusted with voltage and welding speed can be measured. The experimental work was carried out at KEEPSAKE welding center, Ahmedabad.

Fig.1Welding Machine Set up

SS409M and Specimen Preparation. The SS409M plate of 200 mm x 150 mm x 4mm were cut. The cut workpiece was cleaned carefully and contamination such as rust, dust, oil, moisture etc. was removed. The workpieces were rigidly fixed by suitable clamps as shown in Fig.2 during welding. To ensure quality weld bead, welding was performed by strictly controlling the process parameters.

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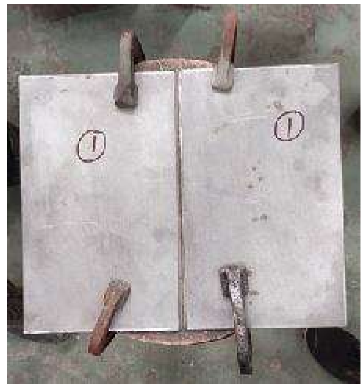

Fig.2Specimen Preparation for welding

The SS409M workpiece chemical composition was checked by Optical Emission Spectrometer (UMS-10) as per– IS 9879-98 RA: 2015 is shown in Table 2. The filler material chemical composition is shown in Table 3 and 4.

Table 2SS 409M base metal Chemical composition

Material	C	Mn	P	S	Si	Cr	Ni	Ti	N_2
AISI 409M	0.028	0.859	0.032	0.001	0.631	11.400	0.338	0.003	0.025

Table 3 308L electrode- chemical composition

Material	C	Mn	P	S	Si	Cr	Ni	Mo	Cu
AISI 308L	0.03max	1.0-2.5	0.03max	0.03max	0.30-.065	19.50-22.00	9.0-11.0	0.75max	0.75max

Table 4 309L electrode- chemical composition

Material	C	Mn	P	S	Si	Cr	Ni	Mo	Cu
AISI 309L	0.03max	1.0-2.5	0.03max	0.03max	0.30-.065	22.00-26.00	11.00-14.00	0.75max	0.75max

Selection of process parameters and Design of matrix. Arc voltage(21, 23 and 26) and welding speed (125, 165 and 225 mm/min) is considered as two variable welding parameters along with shielding gas of pure Ar and Ar(95%) and Ar(95%) + N_2(5%) and filler metals 308L and 309L of diameter 1.2 mm make Raajratna Electrodes (p) Ltd of in SS409M welding.

With the L9 approach, three parameters welding speed, voltage, filler metals and % of shielding gases will be considered as variables at three levels. Table 5 mentions experimental conditions.

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Table 5 Design of Experiment

Run	Voltage (volts)	Welding Speed (mm/min)	Gas type	Filler rod
1	21	225 mm / min	Ar	308L
2	23	225 mm / min	Ar	308L
3	26	225 mm / min	Ar	308L
4	21	165 mm / min	Ar	308L
5	23	165 mm / min	Ar	308L
6	26	165 mm / min	Ar	308L
7	21	125 mm / min	Ar	308L
8	23	125 mm / min	Ar	308L
9	26	125 mm / min	Ar	308L
10	21	225 mm / min	Ar + N_2(5%)	308L
11	23	225 mm / min	Ar + N_2(5%)	308L
12	26	225 mm / min	Ar + N_2(5%)	308L
13	21	165 mm / min	Ar + N_2(5%)	308L
14	23	165 mm / min	Ar + N_2(5%)	308L
15	26	165 mm / min	Ar + N_2(5%)	308L
16	21	125 mm / min	Ar + N_2(5%)	308L
17	23	125 mm / min	Ar + N_2(5%)	308L
18	26	125 mm / min	Ar + N_2(5%)	308L
19	21	225 mm / min	Ar	309L
20	23	225 mm / min	Ar	309L
21	26	225 mm / min	Ar	309L
22	21	165 mm / min	Ar	309L
23	23	165 mm / min	Ar	309L
24	26	165 mm / min	Ar	309L
25	21	125 mm / min	Ar	309L
26	23	125 mm / min	Ar	309L
27	26	125 mm / min	Ar	309L
28	21	225 mm / min	Ar + N_2(5%)	309L
29	23	225 mm / min	Ar + N_2(5%)	309L
30	26	225 mm / min	Ar + N_2(5%)	309L
31	21	165 mm / min	Ar + N_2(5%)	309L
32	23	165 mm / min	Ar + N_2(5%)	309L
33	26	165 mm / min	Ar + N_2(5%)	309L
34	21	125 mm / min	Ar + N_2(5%)	309L
35	23	125 mm / min	Ar + N_2(5%)	309L
36	26	125 mm / min	Ar + N_2(5%)	309L

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Calculation of heat input and sample selection for experiments. The weld properties are affected by the heat input. Experiments are categorized based on the heat input into low, medium and high heat input. Of each category three samples are selected for weld evaluation in terms of tensile and impact tests. Heat input was calculated as the ratio of the power to the velocity of the heat source as given below [17]. Fig.3 displays selected GMAW welded samples as per Table 5. The sample welded are grouped according to heat input as less than 400 J/mm, 400-600 J/mm and more than 600 J/mm and are termed as low, medium and high heat input welds.

Heat Input (HI) = 60 I V η / 1000 S (kJ/mm)

where, I = Welding current (A)   V = Arc voltage (V)   S = Welding speed (mm/min)
η = Arc efficiency accounting for heat dissipation to the surrounding as a result of convection and radiation (0.85)

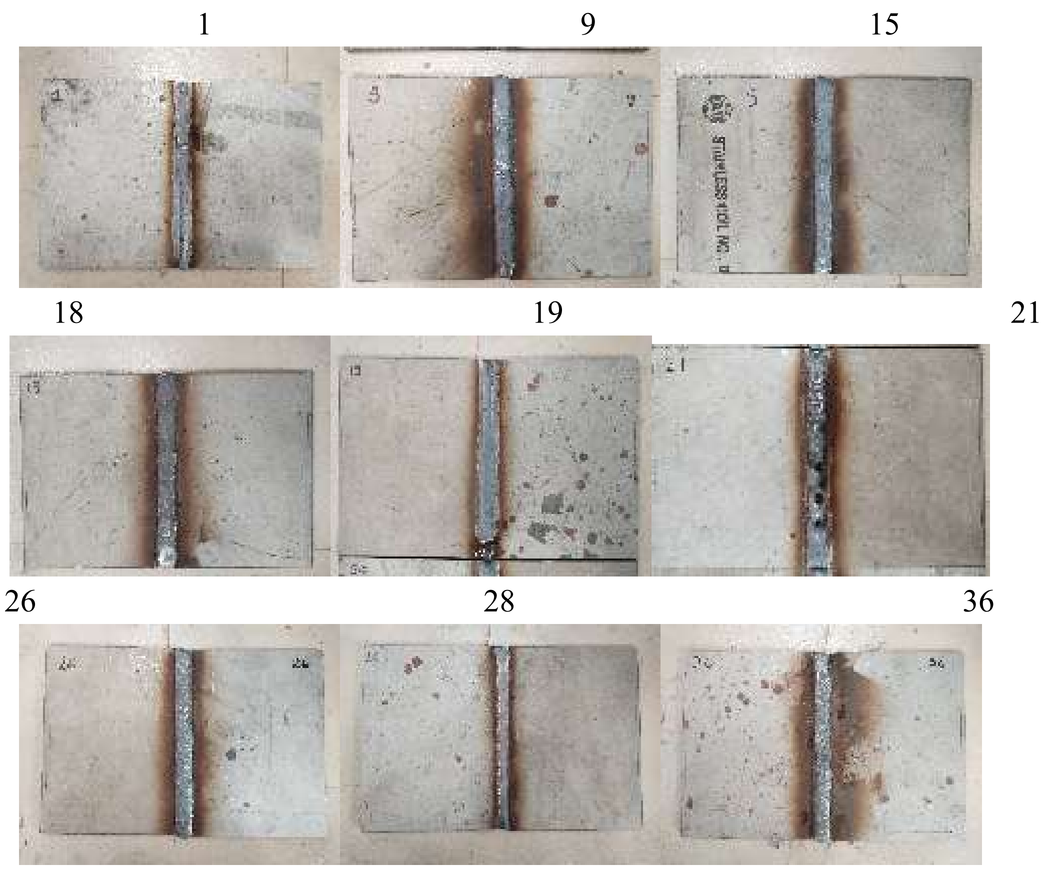

Fig.3MAG welded samples

Tensile test. The tensile strength of base metal and weld were tested under static loading condition. The transverse tensile test is accepted for qualification of the weld strength equalling the base metal tensile strength or some other specified minimum value [2, 3, 14]. The tensile test specimens were prepared as per ASTM A370M standard as shown in Fig.4. The tensile test specimens were prepared

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by cutting the welded joints across the welding direction with power hacksaw and automated milling machine. Fig.5 shows the tensile test specimens before the test.

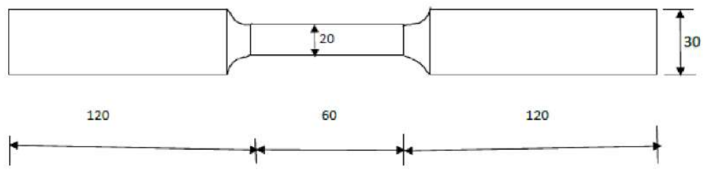

Fig.4Tensile Specimen prepared as per ASTM A370M standard

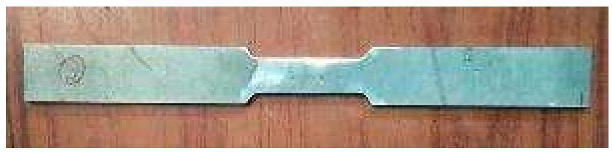

Fig.5 Tensile test specimen

Impact Test. Impact test was conducted to measure the ability of the material to resist loading. The impact strength determines the service life of a part, or the suitability of a designated material for a predetermined application. The impact strength of the material is also used to know the product liability and safety. Impact test measures the amount of energy absorbed during fracture of a specimen. Impact strength is measured for weld deposit & heat affected zones [2, 3, and 14]. The Impact test was conducted as per ASTM A 370-21 standard (Fig.6) for the higher, lower and medium heat input samples (Fig.7), using a computerized UTE-60.

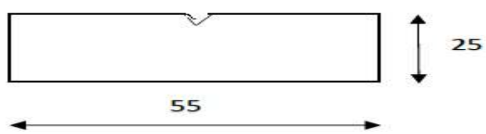

Fig.6Impact Specimen prepared as per ASTM A 370-21 standard

Fig.7Impact test specimen

Result and Discussion

Table ***6*** displays the average results obtained for tensile test and impact test of GMAW welded SS409M. Fig.8 displays the tensile strength of different samples obtained experimentally. The results shows that the sample prepared with least heat input displays highest tensile strength than samples welded with medium or high heat input. Gupta et al. [13] demonstrated that at lower heat input of 0.4 kJ/mm the weld attained best mechanical properties. While Raol and Patel [4] argued that for better

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joint properties heat input should be optimum. The samples welded with 309L and 308L attained average tensile strength of 512 and 501 MPa respectively. Mukherjee et al. [14] claimed better properties of joint with 308L compared to 316L while Gupta et al. [13] reported better joint with 304L than 308L. The result indicated higher tensile strength values with 309L this can be attributed to higher amount of Cr and Ni than 308L. Nickel has austenite stabilizing tendency to form austenite contributes to high strength and improves corrosion resistance [3]. The samples welded with Ar+N_2 and Ar displayed average tensile strength of 513 and 502 MPa respectively. Liu et al. [8] noted that adding N_2 during welding improve weld performance. Impact strength results for weld and HAZ with respect to heat input, filler wire and shielding gas are in range of 23-27 Joules. There is little variation in impact strength. There is marginal decrease of impact strength with increasing heat input. It was claimed by other researcher that with higher heat input grain size increases which decreases the impact strength [14]. Based on experimental results it is noted that sample 19 made with current 103A, Speed 179 mm/min and voltage 21 V attained highest tensile strength value 533.7 MPa while sample 28 made with current 92 A, Speed 222 mm/min and voltage 21 V attained highest impact strength.

Table 6 Effect of heat input, filler and shielding gas on Tensile strength and impact strength

Heat Input	**Average TS in (MPa)**	**Average Impact (in Joules)**	
		Weld	**HAZ**
Low	518	25.56	27.11
Medium	496	23.78	21.11
High	507	23.56	24.00
Filler			
Filler	**Average TS in (MPa)**	**Average Impact (in Joules)**	
		Weld	**HAZ**
308L	501	24.17	23.67
309L	512	24.40	24.40
Shielding Gas			
Shielding Gas	**Average TS in (MPa)**	**Average Impact (in Joules)**	
		Weld	**HAZ**
Ar	502	24.80	23.20
Ar+N_2	513	23.67	25.17

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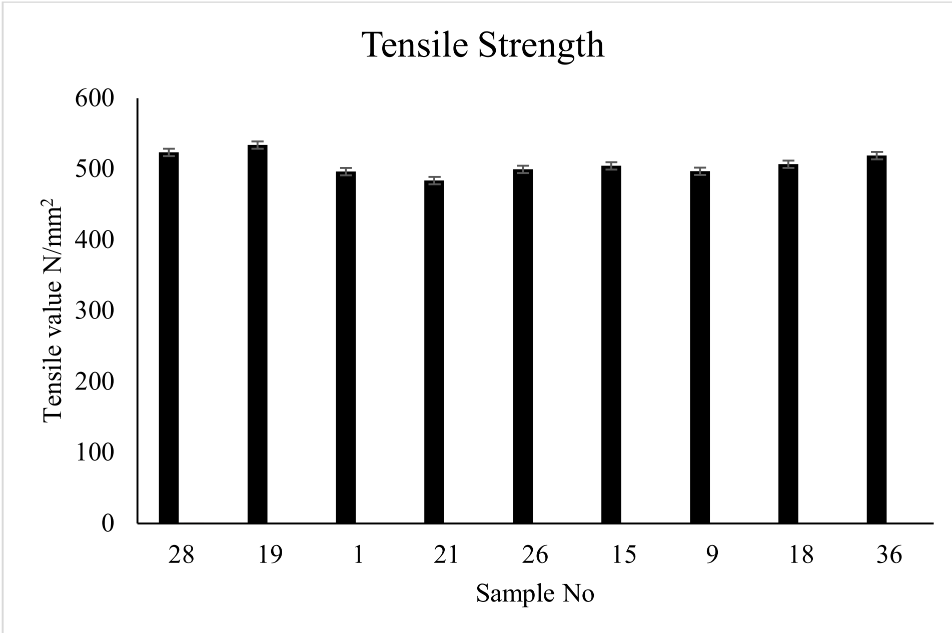

Fig.8 Tensile Strength of different samples

Conclusions

Following conclusions are drawn in respect of MAG Welding of SS409M with varying shielding gases types and varying filler metals:

The results shows that the sample prepared with least heat input displays highest tensile strength.

The samples welded with 309L attained higher average tensile strength of 512 MPa.

The samples welded with $Ar+N_2$ have average tensile strength of 513 MPa.

Impact strength results for weld and HAZ demonstrated little fluctuation with respect to heat input, filler wire and shielding gas.

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