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Experimental Investigation of MIG welding for AISI 1020 low carbon steel by using Taguchi method

"The Effect of Metal inert gas (MIG) processes on different welding parameters"

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***Abstract* – In this study Metal inert gas (MIG) welding also known as Gas Metal Arc Welding (GMAW) process consists of heating, melting and solidification of parent metals and a filler material in localized fusion zone by a transient heat source to form a joint between the parent metals. A consumable electrode is used which also plays the role of conductor. MIG welding gives little loss of material and can be operated as semi as well as fully automated. We have used AISI 1020 Low carbon steel, 10mm plate thickness and single V-groove joint is used. In which input parameters for MIG welding are welding speed, voltage, gas flow rate and wire feed rate. And the output parameters are tensile strength and heat affected zone (HAZ) for quality target. I have studied design of experiment method (orthogonal array) for this work and by use of the experimental data have optimized by Taguchi method. The aim of this study is to investigate the optimization process parameters for Metal inert gas welding (MIG).**

***Index Terms* - MIG Welding, Low Carbon Welded Steel, Tensile Strength, Heat Affected Zone, Taguchi Method**

1. INTRODUCTION

MIG is an arc welding process where in coalescence is obtained by heating the job with an electric arc produced between work piece and metal electrode feed continuously. A metal inert gas (MIG) welding process consists of heating, melting and solidification of parent metals and a filler material in localized fusion zone by a transient heat source to form a joint between the parent metals. The arc and molten weld are shielded by an inert gas like argon, helium, carbon dioxide or gas mixture hence flux is not used or required in this MIG welding process/ MIG also called Gas metal Arc welding (GMAW).Gas metal arc welding is a gas shielded process that can be effectively used in all positions[15].

Metal Inert Gas welding as the name suggests, is a process in which the source of heat is an arc formed between a consumable metal electrode and the work piece, and the arc and the molten puddle are protected from contamination by the atmosphere (i.e. oxygen and nitrogen) with an externally supplied gaseous shield of inert gas such as argon, helium or an argon-helium mixture. No external filler metal is necessary, because the metallic electrode provides the arc as well as the filler metal. It is often referred to in abbreviated form as MIG welding.

MIG welding was primarily developed as a high current-density, smaller-diameter metal- electrode process with argon shielding for welding aluminium. Hence the term MIG was appropriate and the process was equally applicable to deoxidized copper and silicon bronze. But when it was extended to the welding of ferrite and austenitic steels, addition of 1-2% oxygen to argon was found necessary to get smooth metal transfer. Later it was established that mild steel could be welded using 100% carbon dioxide (Co2) or argon- CO2mixture as a shielding gas. Since these gases are not inert, the process came to be termed as MIG/MAG welding process. MAG is an abbreviation of metal active gas in which active gas refers to argon- oxygen, carbon dioxide and argon-CO2 mixture, which are chemically reactive and not inert. The American Welding Society refers to the process as Gas Metal Arc Welding and has given it the letter designation GMAW. This term appears simpler because it to covers inert as well as active shielding gases.

MIG welding process overcome the restriction of using small lengths o electrodes as in manual metal arc welding and overcomes the inability of the submerged arc process to weld in various positions. It is not surprising, therefore, that the 50/50 level of the relative weights of weld metal deposited by manual metal- arc and MIG processes was reached in 1973 in the USA and in 1978 in Europe.[14]

2. WORKPIECE MATERIAL AND FILLER WIRE MATERIAL

We have selected AISI 1020 low carbon steel. The thickness of material is 10 mm. Single V-groove welds joint design is selected in which groove angle is 60° and root gap and root face is 1.5mm [21]

Table 1 Chemical composition AISI 1020

Material	Carbon	Manganese	Sulfur	Phosphorous	Iron, Fe

AISI 1020	0.209	0.558	0.048	0.038	Balance

Before the welding process preparation of work material is required for better quality of welding. In which first grind the surface with a grinder to remove the dust from the surface which is to be welded by gas metal arc welding. After grinding process it essential to maintain a flat surface of plate on top and bottom side and set the proper level during the welding process. Work material used in these experiments is AISI 1045 medium carbon steel, cut the work material in the dimensions (200mm x 150 mm x 6mm) after that prepare the groove angle 650 and root gap and root face 1.5 mm for better strength of welding joint.

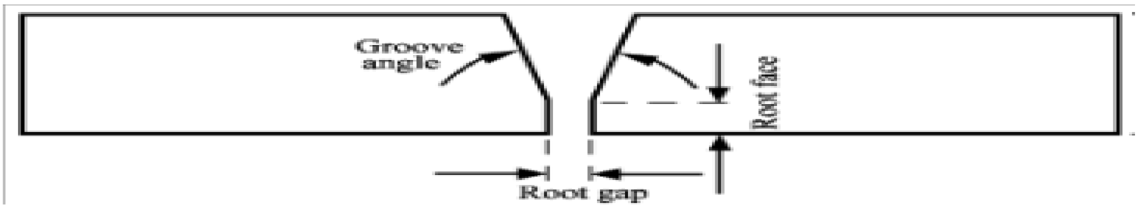

Fig.1 work material edge profile of the V-groove

We have selected Standard Wire: ER 70 S-6 Mild steel copper coated.

Table 2 Chemical composition of filler wire

Material	**Carbon**	**Manganese**	**Silicon**	**Sulfur**	**Phosphorous**	**Copper**
ER 70S-6	0.19%	1.63%	0.98%	0.025%	0.025%	0.025%

3. EXPERIMENTAL SETUP AND PROCEDURE

The experiments have been conducted on a PROSTAR MIG 350 welding Machine. In this machine the MIG welding torch moves over the work piece automatically with the help of guiding the way. By the controlling the motion of welding torch can control the some process parameters like welding speed, nozzle to tip distance. This welding machine, operating system, servo motor based, so the parameter is directly input through the computer in numerical form and welding machine perform the welding operation in giving input range. Heavy duty enclosed wire feeder with four roll drive ensures dust free & smooth wire feeding inbuilt cylinder trolley for ease of handling. In which input parameters for MIG welding are welding speed, voltage, gas flow rate and wire feed rate. And the output parameters are tensile strength and heat affected zone (HAZ) for quality target.

Fig. 2 Power unit of PROSTAR MIG- 3502

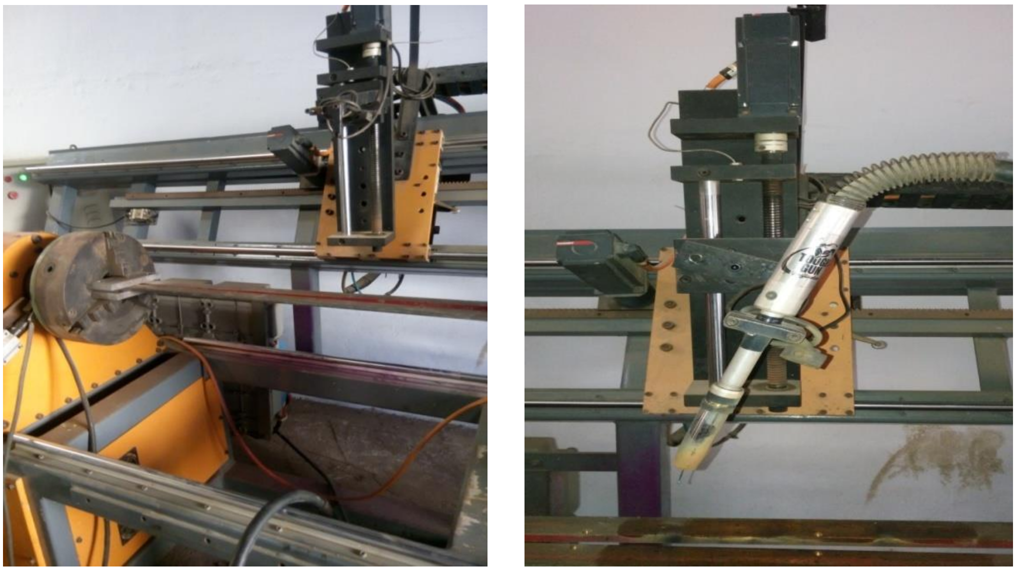

Fig.3 Experimental setup

The welding gun and welding electrode level is checked and set properly for experimentation on a level surface. After preparing the work material as mentioned above work material which is to be weld place over the platform and clamp both sides to avoid sleep during the operation. The laptop connects with DCIS (Digital Communication Interface system) This enables us to impart the values of process variables and carry out a control over the fully automatic welding cycle. These DCIS systems able to control x, y and z axes movement by the help of servo motor. Input variables, direct input through the laptop to the welding m/c. In this experiment welding speed is controlled by servo motor which monitoring of the DCIS system through the laptop. Set the desire current, voltage and gas flow rate on welding m/c to run 9 experiments. Now, after setting the work material on base support properly and after adjusting the distance of work material and electrode tip start the welding. after start the welding move over the work piece in linear motion with pre decided to weld speed. When the welding is complete on the work piece, it releases from the clamp.

Table 3 Factors and their level

Factors	**Level 1**	**Level 2**	**Level 3**
Welding speed(mm/min)	200	225	250
Voltage(V)	23	24	25
Gas flow rate (lit/min)	20	23	26
Wire feed rate(cm/min)	350	400	450

Experiments were planning according to Taguchi’s L9 Orthogonal Array, which has 9 rows corresponding to the number of testes (24 degree of freedom) with 4 factors and three levels as shown in TABLE III.

Worksheet 2 ***

↓	C1	C2	C3	C4
	Welding speed(mm/min)	Voltage(v)	Gas flow rate(lit/min)	Wire feed rate(cm/min)
1	200	23	20	350
2	200	24	23	400
3	200	25	26	450
4	225	23	23	450
5	225	24	26	350
6	225	25	20	400
7	250	23	26	400
8	250	24	20	450
9	250	25	23	350

Fig.4 Orthogonal array l9 of Taguchi method using minitab-16 software

The first column of Fig.5 was assigned to Welding speed (mm/min) and second, third and fourth column assign to voltage (v), Gas flow rate (lit/min) and Wire feed rate (mm/min) respectively. This orthogonal array is chosen due to its capability to check the interactions among factors.

Fig.5. Work pieces after MIG Welding

Table 4 Experimental result table

Sr.no	Welding speed (mm/min)	Voltage (v)	Gas flow rate (lit/min)	Wire feed rate (cm/min)	UTS MPa	HAZ (mm)
1	200	23	20	350	551.220	11.15
2	200	24	23	400	559.996	7.12
3	200	25	26	450	551.272	10.77
4	225	23	23	450	563.140	9.82
5	225	24	26	350	552.710	9.91
6	225	25	20	400	440.439	11.24
7	250	23	26	400	556.562	10.12
8	250	24	20	450	570.498	9.47
9	250	25	23	350	559.211	11.15

4. ANALYSIS AND RESULTS

Minitab version 17 software was used to analyze the result obtained by the experiments. The S/N ratio for Maximum UTS coming under Larger- is-better characteristic

The larger is the better characteristic:

S/N = -10 Log10 [mean of sum of squares of the reciprocal of measured data]

The optimal setting is the parameter combination, which has the largest positive S/N ratio.

Worksheet 2 ***

↓	C1	C2	C3	C4	C5	C6	C7
	Welding speed(mm/min)	Voltage(v)	Gas flow rate(lit/min)	Wire feed rate(cm/min)	UTS(MPa)	SNRA1	MEAN1
1	200	23	20	350	551.220	54.8265	551.220
2	200	24	23	400	559.996	54.9637	559.996
3	200	25	26	450	551.272	54.8273	551.272
4	225	23	23	450	563.140	55.0123	563.140
5	225	24	26	350	552.710	54.8499	552.710
6	225	25	20	400	440.439	52.8777	440.439
7	250	23	26	400	556.562	54.9103	556.562
8	250	24	20	450	570.498	55.1251	570.498
9	250	25	23	350	559.211	54.9515	559.211

Fig.6 Experiment result in Minitab for UTS

Table 5 Response table for means for UTS

Level	Welding speed (mm/min)	Voltage (v)	Gas flow rate (lit/min)	Wire feed rate (cm/min)
1	554.2	557.0	520.7	554.4
2	518.8	561.1	560.8	519.0
3	562.1	517.0	553.5	561.6
Delta	43.3	44.1	40.1	42.6
Rank	2	1	4	3

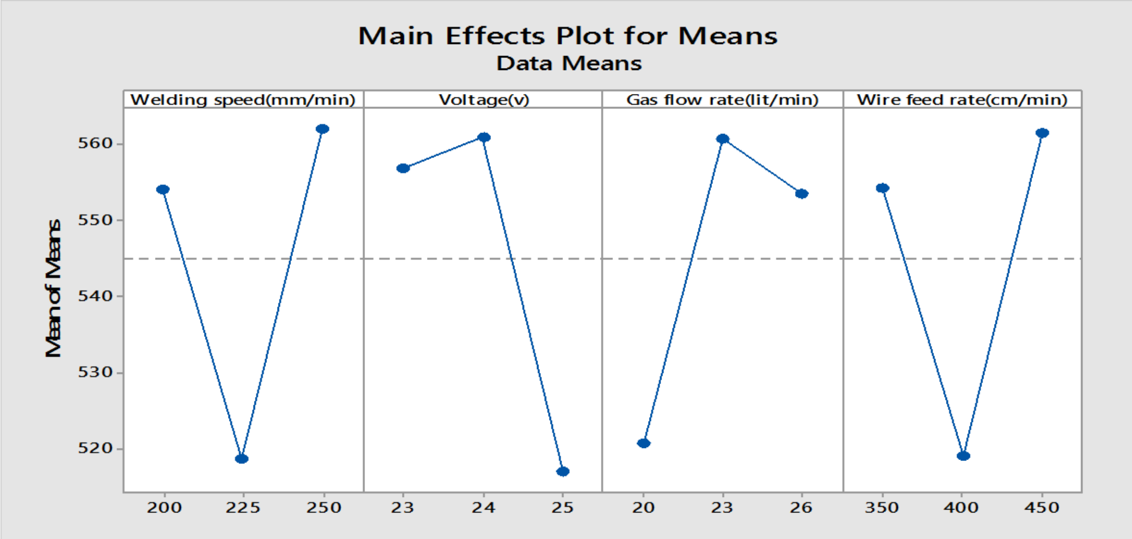

Fig.7 Main Effects Plot for Mean data (UTS)

Table 6 Response table for signal to noise ratio for UTS

Level	Welding speed (mm/min)	Voltage (v)	Gas flow rate (lit/min)	Wire feed rate (cm/min)
1	54.87	54.92	54.28	54.88
2	54.25	54.98	54.98	54.25
3	55.00	54.22	54.86	54.99
Delta	0.75	0.76	0.70	0.74
Rank	2	1	4	3

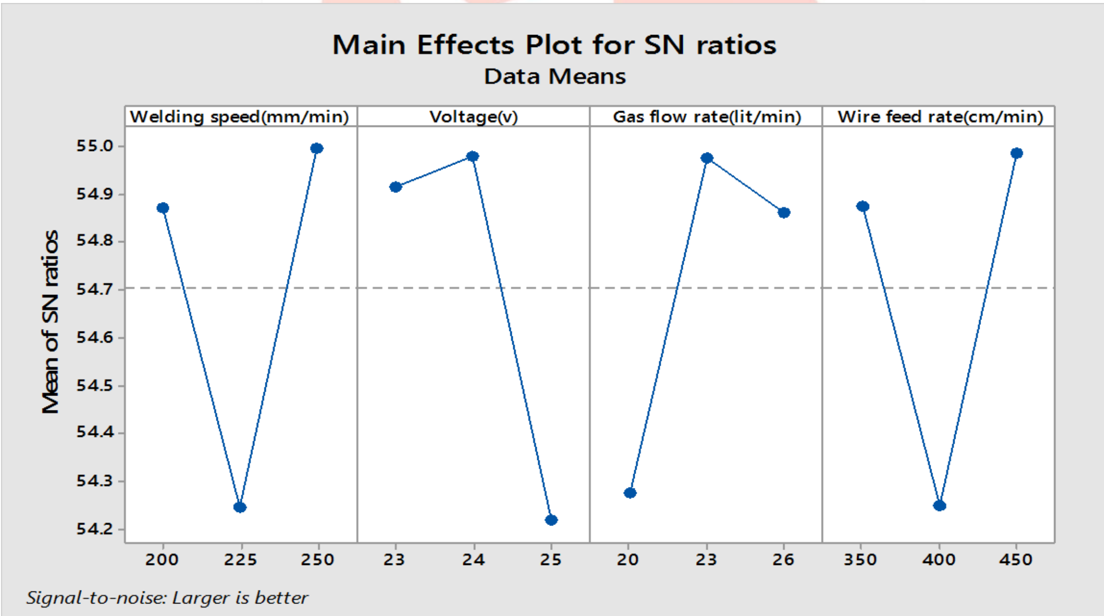

Fig.8 Main Effects Plot for S/N ratio data (UTS)

Minitab version 17 software was used to analyze the result obtained by the experiments. The S/N ratio for Minimum HAZ coming under smaller- is-better characteristic
The smaller is the better characteristic:
S/N = -10 Log10 [mean of sum of squares of measured data]
The optimal setting is the parameter combination, which has the smallest Non-negative with a target value of zero S/N ratios.

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7
	Welding speed(mm/min)	Voltage(v)	Gas flow rate(lit/min)	Wire feed rate(cm/min)	HAZ(mm)	SNRA1	MEAN1
1	200	23	20	350	11.21	-20.9921	11.21
2	200	24	23	400	11.15	-20.9455	11.15
3	200	25	26	450	7.12	-17.0496	7.12
4	225	23	23	450	10.77	-20.6443	10.77
5	225	24	26	350	9.82	-19.8422	9.82
6	225	25	20	400	9.91	-19.9215	9.91
7	250	23	26	400	11.24	-21.0153	11.24
8	250	24	20	450	10.12	-20.1036	10.12
9	250	25	23	350	9.47	-19.5270	9.47

Fig.9 Experiment result in Minitab for HAZ

Table 7 Response table for means for HAZ

Level	Welding speed (mm/min)	Voltage (v)	Gas flow rate (lit/min)	Wire feed rate (cm/min)
1	9.827	11.073	10.413	10.167
2	10.167	10.363	10.463	10.767
3	10.277	8.833	9.393	9.337
Delta	0.450	2.240	1.070	1.430
Rank	4	1	3	2

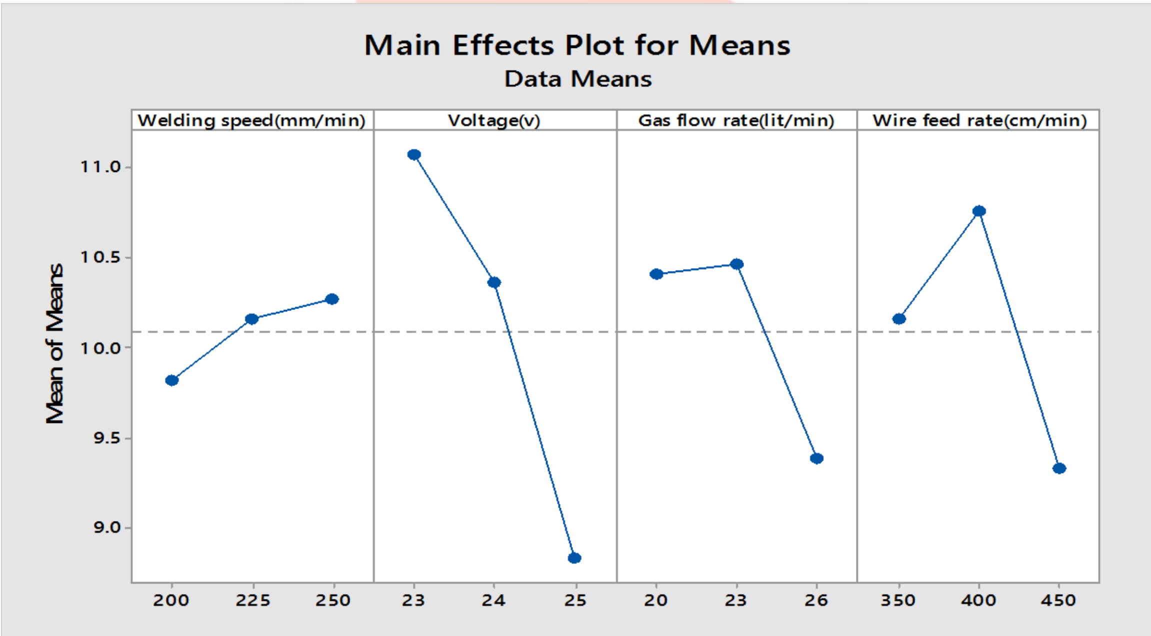

Fig.10 Main Effects Plot for Mean data for HAZ

Table 8 Response table for signal to noise ratio for HAZ

Level	Welding speed (mm/min)	Voltage (v)	Gas flow rate (lit/min)	Wire feed rate (cm/min)
1	-19.66	-20.88	-20.34	-20.12
2	-20.14	-20.30	-20.37	-20.63
3	-20.22	-18.83	-19.30	-19.27
Delta	0.55	2.05	1.07	1.36
Rank	4	1	3	2

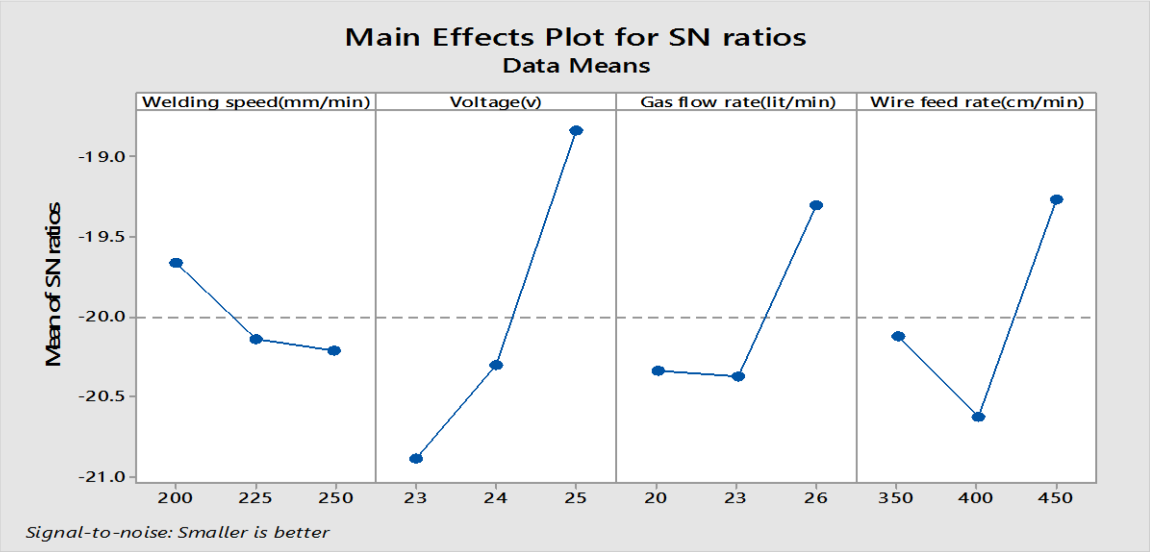

Fig.11 Main Effects Plot for S/N ratio data for HAZ

Table 9 Optimal combination set of input parameters for UTS

Welding speed (mm/min)	Voltage (v)	Gas flow rate (lit/min)	Wire feed rate (cm/min)
250	24	23	450

Table 10 Validation test result for UTS

Predicted welding strength UTS(MPa)	Experimental welding strength UTS(MPa)	% of Error
590.56	581.68	1.5%

5. CONCLUSION

Based on the experiments, the effect of selected input parameters on the output response like weld strength and heat affected zone is studied. In this research work L9 Orthogonal array with four input factors and three levels optimized using SNR. Larger-the-better quality characteristic has been used to predict the optimized run set for weld strength. And smaller-the-better quality characteristic has been used to predict the optimized run set for HAZ. From graphical representation and main effects plot for UTS the wire feed rate is the most significant parameter. Voltage and welding speed also has an effect on UTS. Minitab 16 software has used to optimize the combination set of parameters according to that UTS value is 590.56 MPa for an optimum run set welding speed 250 mm/min, Voltage 24 V, Gas flow rate 23 lit/min and wire feed rate 450 cm/min. This optimal combination set of input parameters uses for validation test. UTS value predicted by the Taguchi is close to the experimental result of UTS. Experimental validation test gives 581.68 MPa value of welding Strength and the error of percentage is 1.5. In a constant voltage system, the wire feed speed and welding current are controlled by the same knob. As the wire feed speed is increased the welding current also increases, resulting in increases in the wire melt-off rate and the rate of deposition. If the wire feed rate is too high, the size of the weld bead is large and the tensile strength is also large. If the voltage is increase, the tensile strength is increase. Excessive voltage causes the formation of excessive spatter and porosity. If the voltage is increase, the heat affected zone is decrease. If the wire feed rate is increase, the heat affected zone is increases.

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