EVALUATION OF MIG WELDING QUALITY OF Al-Mg 5454 ALLOY

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الخلاصة

يواجه أسلوب اللحام بالغاز الخامل المستمر(MIG) بعض الصعوبات عند استخدامه في وصل القطع أو الهياكل المعدنية، وذلك لصعوبة التوازن بين الوسائط المتعددة لعملية ألحام مع الحصول على الخواص الميكانيكية المطلوبة للوصلة تعتمد الطرق التقليدية المتبعة من قبل المهندسين والفنيين في اللحام على أسلوب المحاولة والخطأ لاختيار أفضل التوازنات بين الوسائط المتعددة فقد تعطى هذه الطريقة نتائج مرضية في بعض الأحيان ولكنها لا تحتمل أدنى تغير ولو بسيطا في أحد المتغيرات مما يؤثر سلبيا على جودة اللحام. تطبق طريقة تصميم التجربة لاستمثال أسلوب اللحام بالغاز الخامل المستمر (MIG) بدلا من أسلوب المحاولة والخطأ. حيث أنه استخدم في هذه الدراسة طريقة تصميم التجربة لوصل صفائح من سبيكة الألومونيوم Al-Mg 5454 وذلك بتبني أسلوب تاقوتشى (Taguchi) لإشارة جودة التميز و كذلك بأفضلية القيمة العالية لمعدل التشويش للإشارة (Signal to noise Ratio). للتحقق من تأثير الوسائط الثلاثة لعملية اللحام و تحديدا سرعة الحركة سرعة التغذية والجهد الكهربائي. تم أخيار ثلاثة مستويات لتصميم تاقوتشى (A, B, &C) لعدد سبع وعشرين محاولة وتم أيضا أجاد تأثير هذه الوسائط الثلاثة على مقاومة الشد لوصلة اللحام على عينات شد ذات ثلمة بشكل حرف (V) من طرفيها بغرض تركيز الاجهاد على منطقة اللحام.

أستخدم برنامج الحاسوب (MINITAB 15.0) في التصميم و تجميع النتائج وتحليلها. أشارة النتائج على أن استخدام طريقة تصميم التجربة فعالة جدا لاستمثال مقاومة الشد لوصلة اللحام (σ_u)، وأن تزايد سرعة التغذية والجهد الكهربائي يرفع من فعالية الطريقة في تحديد أقصى مقاومة للشد لأفضل التوازنات بين الوسائط المتعددة. حيث كانت أقصى مقاومة للشد 203 ميقابسكال متحصل عليها عند سرعة حركة 40 سم/دقيقة و سرعة تغذية 8 مم/ دقيقة وجهد كهربائي 17.5 فولت.

ABSTRACT

When MIG welding is applied to a machine part, it faces the problems of determination and balancing of welding parameters as well as the desired mechanical properties required of the MIG welded joints. Traditionally welding engineers, technicians and operators are not taught a systematic strategy to select the best condition for welding parameters. Both experience , trial and error approach are most widely used until a satisfactory weld is achieved, while the resulting member may be workable, it may not be robust enough to accommodate small changes in welding variables. The present study applied the experimental design for optimizing the process of continuous drive MIG welding Al-Mg5454 with a signal quality characteristic through the use of Taguchi and higher the better signal to noise ratio.

Three levels Taguchi design with twenty seven trials was selected to investigate the effect of three operating parameters including the travel speed, wire feed speed and voltage on the tensile strength of MIG welded joint. The selected design, data calculation and analysis were carried out by using Minitab software release 15.00 the results indicated that the use of experimental design is found to be very efficient for optimizing the tensile strength. The wire feed speed and voltage will increase the tensile strength performance , while decreasing the travel speed from source will increase the tensile strength performance and therefore efficiency of the tensile strength procedure is improved. The optimum (maximum) tensile strength of 202.9 MPa can be obtained when the travel speed, wire feed speed, and voltage equals to the values (40 cm/min, 8 mm/min, & 17.5V) respectively.

KEYWORDS: MIG Welding; Al-Mg 5454 Alloy; Tensile test; X-ray radiography; Welding parameters; MINITAB; (S/N) ratio; Design of experiment.

INTRODUCTION

Welding is one of the most important and versatile means of fabrication available to industry. Welding is used to join hundreds of different commercial alloys in many different shapes. Actually, many products could not even be made without the use of welding, for instance, guided missiles, nuclear power plants, jet aircraft, pressure vessels, chemical processing equipment, transportation vehicle and literally thousands of others [1,2].

Many of the problems that are inherent to welding can be avoided by proper consideration of the particular characteristics and requirements of the process. Proper design of the joint is critical. Selection of the specific process requires an understanding of the large number of available options, the variety of possible joint configurations, and the numerous variables that must be specified for each operation.

If the potential benefits of welding are to be obtained and harmful side effects are to be avoided, proper consideration has to be given to the selection of the process and the design of the joint. The increasing need for light structure, especially for transportation vehicles has a higher interest in using Al alloys. In many cases are joined with MIG welding [3]. Two of the most prevalent quality problems in MIG welding are dross and porosity. If not controlled, they can lead to weaker, less ductile welds. Dross is an especially common problem in aluminum MIG welds, normally coming from particles of aluminum oxide or aluminum nitride present in the electrode or base materials. Any oxygen in contact with the weld pool, whether from the atmosphere or the shielding gas, causes dross too. As a result, sufficient flow of inert shielding gases is necessary, and welding in volatile air should be avoided [4]. Robust design method is a term that is often used to describe the Taguchi method. The method or approach focuses on improving the fundamental function of the product or process. It is indeed the most powerful method to reduce product cost, improve quality, and simultaneously reduce development interval. G. Taguchi demonstrates the applicability of his method in the earliest phases of the design process. It is important to build quality technologies which imply a sequence of activities including identification of potential noise factors, controllable factors, and appropriate performance criteria. This criterion can be used to maximize the "functionality" of the new or traditional technology. This will allow development of high – quality, low–cost product in a timely fashion. Taguchi off-line quality control is very efficient tool for developing high quality products at a low cost [5].

This paper aims at optimizing the travel speed, wire feed speed, and voltage MIG welding parameters of 3 mm Al-Mg 5454 alloy sheet and estimating high quality of this alloy by determine the best high strength of the weld pool parameters.

EXPERIMENTAL WORK

Raw material

The raw material used in MIG welded were selected pieces of aluminium magnesium sheets with 3 mm thickness, and EWS; ER5554; wire electrode of AL Mg having a diameter of 1.6 mm as a filler metal . The chemical compositions of the base metal (analyzed by spectral emission method) are given in Table (1). This study work involved a butt welding to specimens in form of a sheet with dimensions 320 x 250mm received as two pieces with 3 mm thick.

Table 1: chemical composition of base metal

Material	Chemical composition wt%								
Al-Mg 5454	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
wt %	0.25	0.4	0.1	2.7	0.13	0.15	0.15	0.12	balance

PROCEDURE

Welding process was done automatically using gas metal arc welding technique of different controlled parameters. As it has been mentioned earlier the purpose of the project was to fined suitable welding parameters (wire feed speed, welding speed, voltage) that produce least weld problem for welding seam line 3 mm width. Table (2) summarizes the 27 welding runs done along with wire feed speed, welding speed, voltage and calculated heat input (IxV)/S for each run .

Where:

I = welding current (Amp), V = arc voltage (Volt),S = welding speed (cm/min),

Heat input = I x V (watt/sec)

Table 2: Summary welding runs performed

Run no	A	B	C	Travel speed (cm/min)	Wire feed speed (mm/min)	Voltage(V)
1	1	1	1	40	7.5	17
2	1	1	2	40	7.5	17.5
3	1	1	3	40	7.5	18
4	1	2	1	40	8	17
5	1	2	2	40	8	17.5
6	1	2	3	40	8	18
7	1	3	1	40	8.5	17
8	1	3	2	40	8.5	17.5
9	1	3	3	40	8.5	18
10	2	1	1	45	7.5	17
11	2	1	2	45	7.5	17.5
12	2	1	3	45	7.5	18
13	2	2	1	45	8	17
14	2	2	2	45	8	17.5
15	2	2	3	45	8	18
16	2	3	1	45	8.5	17
17	2	3	2	45	8.5	17.5
18	2	3	3	45	8.5	18
19	3	1	1	50	7.5	17
20	3	1	2	50	7.5	17.5
21	3	1	3	50	7.5	18
22	3	2	1	50	8	17
23	3	2	2	50	8	17.5
24	3	2	3	50	8	18
25	3	3	1	50	8.5	17
26	3	3	2	50	8.5	17.5
27	3	3	3	50	8.5	18

A, B, and C = parameters level

X-ray test

X-ray radiography was used to examine the deposited weld metal for any possible defects. Radiography voltage, exposure time and current used were 115 Kv ,36 seconds and 5 mA respectively , the film type and size = D7 (24 X10cm) and this was according to know standards as published in the technique chart of aluminum .

Tensile Test

Tensile tests provide information on the strength and ductility of materials under uniaxial tensile loading. The pertinent data obtained from a tension test are ultimate tensile strength, yield strength, Young's modulus, percent elongation, percent reduction of cross-sectional area, and the stress-strain relationship. Transverse tensile tests are generally used to determine weld quality during the weld qualification process. The base metal and weld metal tests are performed on a tensile testing machine in accordance with the requirements of ASTM E338. The result of the tensile test is the average of the results of the specimens. A consummate preparation by two different methods V-notch in welding joint as in Figure (1) and smooth edges weld joint as in Figure (2).

Figure 1: V notch at joint welding.

Figure 2: smooth edges weld joint.

MINITAB release 15.0 for windows

MINITAB software is used in this research for selecting the type of design to be used for running the experiments, to display all possible combination of controllable factor and analyzing data representing the main and interaction relationship between them. MINITAB 15.0 for windows is a powerful statistical software package that provides a wide range of basic and advance data analysis capabilities.

All experiments carried out with three operating parameters (travel speed A, wire feed speed B, and voltage C) each run is conducted three times indicated as R1, R2, and R3 all parameters level are identified in the machine data setting for each run separately. Samples are loaded after cleaning with acetone for each run. The noise factors cause some difference in the response from one run to another.

RESULT AND DISCUTION

X-rays test result

The results of x-ray radiography tests are shown in Table (3). The table indicates the defects found in radiographs of welded specimens. The main defect is undercut, intermittent lack of penetration and porosity.

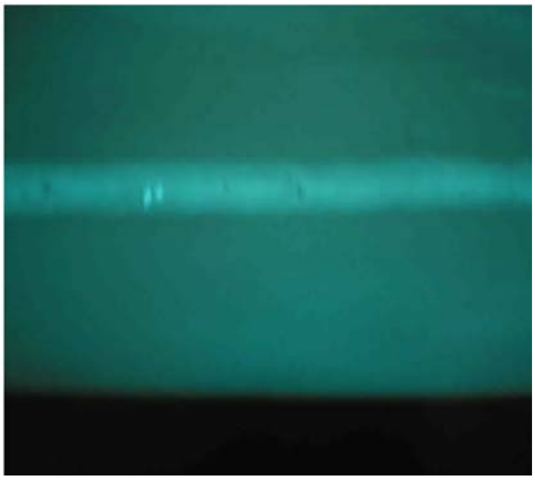
Table 3: defects observed in welded specimen by x-ray radiography

Specimen No	Defect
1,2,3,4,5,6,7,8,9,11,14,16,17,20,22,23,24,25,&27	No defects
10	Lack of penetration and porosity
12	undercut
13	undercut
15	undercut
18	undercut
19	Lack of penetration & undercut
21	undercut
26	undercut

From Table (3) undercut is found in six specimens out of eight, this type of defect is most commonly caused by improper welding parameters, particularly the travel speed and arc voltage. When the travel speed is too high, the weld bead will be very peaked because of its extremely fast solidification. The forces of surface tension have drawn the molten metal along the edges of the weld bead and piled it up along the center. Melted portions of the base plate are affected in the same way. However as the arc voltage is raised to excessive levels, undercutting may again appear. This is particularly true in spray arc welding as stated by [6, 7]. When the arc becomes longer, and also wider as a result of an increased amount of base material being melted. The heat transfer along arc is relatively poor, so that the arc is supplying no more enough heat to the weld zone. The outermost areas are very quickly cooled and again proper wetting is prevented. Excessive welding current can also cause undercutting. The arc force, arc heat and penetration are so great that the base plate under the arc is actually "blown" away [7].

Table (3) shows that sample number ten has lack of penetration and porosity defects. Lack of penetration is usually caused by the use of too low welding current and can be eliminated by simply increasing the amperage [7, 8]. Other causes can be the use of too slow travel speed and an incorrect torch angle. Both will allow the molten weld metal to roll in front of the arc, acting as a cushion to prevent penetration. The arc usually kept on the leading edge of the weld puddle. But the most common causes of porosity are atmosphere contamination, excessively oxidizes work piece surfaces, inadequate deoxidizing alloys in the wire and the presence of foreign matter [8]. Foreign matter can be a source of porosity. The hydrocarbons are sources of hydrogen which is particularly harmful for aluminum.

In the present study the undercut is believed to be related to the higher voltage for sample 18 and to high travel speed for samples 21, and 26. The lack of penetration could be caused by low current for samples 10, and 19. But porosity in sample 10 related to high travel speed and low current.

Figures 3: Under-cut, lack of penetration, and porosity defects in the welded joint

Figure 4: NO defects observed in the welded joint.

Tensile test results

From tensile test results the samples with V notch in welding joint , the fracture took place due to the effect of stress concentration at the notch tip of the V shape, where the concentration of stresses produced by the introduction of a notch have important consequences in the fracture process. The presence of a notch will increase appreciably the ductile – brittle transition behavior of the alloy and a local stress peak is developed. Plastic flow begins at the notch root when this local stress reaches the yield strength of the material. The plastic flow relieves the high elastic stress and limits the peak stress to the yield stress of such material [9]. The chef effect of the notch is increase ability to analyze the achieved results by using MINITAB software because the main objective of this study is to obtain the optimum parameters of MIG welding that givens variation in tensile strength of the weld joints. For all smooth edges specimens the obtained results were excluded because the fracture occurred away from the weld joint.

Totally 27 experiments with different welding speed , voltage and wire feed speed (current) combinations were performed and the tensile strength of joint was measured for all cases and used for further analysis

The effect of three welding parameters on strength

The wire feed speed was fixed as 7.5 mm/min and the change in strength of joint is related to the increasing welding speed at 17 Volts. The highest strength value was obtained is 193.4 MPa in 40cm/min welding speed, while the lowest figure is 165.9MPa in 50 cm/min welding speed. In all three conditions of wire speed (7.5, 8, and 8.5 mm/min), and voltages (17, 17.5, and 18V), the strength of joint decreases with increasing welding speed. When the travel speed is reduced, the filler metal deposition is expected to increase for each run of unit length. At very low speed the welding arc impinges on the molten weld pool rather than the base metal, thereby reducing the effective penetration, and a wide weld bead is also results [10]. As the travel speed increased, the thermal energy per unit length transmitted to the base metal from the arc is at first slightly higher, because the arc acts more directly on the base metal. Therefore, melting of base metal at the beginning increases and then decreases with increasing travel speed. For higher heat input, the depth of penetration is deeper. Where the depth of penetration of the weld bead is of high importance in such applications because it has a direct influence on weld strength [7].

In general trial runs are necessary to adjust the arc voltage to produce the most favorable arc characteristics and weld bead appearance, where the optimum arc voltage is dependent upon a variety of factors, including the type of joint, welding position, shielding gas composition, and type of weld. The effect of voltage on strength was commented to the obtained results. The strength measured at different voltage values (17, 17.5, and 18 V) and constants values of welding speed and wire feed speed shows an optimum strength of joint obtained at17.5 V. In such conditions a gradient increase in voltage (voltage range of 17 V to 18 V) results as more amount of heat input and hence increases the depth of bead penetration, and may lead to spatter and under cut defects [11, 12].

The effect of wire feed speed on strength is appeared as the strength increases with faster wire feed speed at a constant welding speed and voltage. For a constant 40cm/min travel speed and a constant voltage of 17 V, and variant values of wire feed speed (7.5, 8, and 8.5mm/min) the strength was found to be (171.7, 177.3 and 163.6 MPa) respectively. This effect is strongly related to the direct relationship between the electrode feed speed and welding current [10]. With all other variables held constant, an increase in welding current (electrode feed speed) will results in a deeper and wider penetration, a faster deposition rate. Welding current intensity has the strongest effect on melting capacity and depth of penetration, especially for thin parts, the welding current factor is importance; in this case to improve strength but excessive welding current can also cause undercutting.

Analysis using signal -to- noise (S/N) ratios

In this study each welding run was repeated three times, that to ensure the reproducibility of the data and to determine the error associated with each run, also limiting the number of trials to three run saved time, and all results obtained are used for current analysis. In addition to the design of experimental (DOE), another requirement of the robust design in the single- to- noise ratio, this is abbreviated as (SNR), which will give the best combination (optimum setting) in terms of both the mean and standard deviation simultaneously .S/R aims to identify variables that can be controlled to reduce variation and to improve the performance. To maximize the number of MIG welding, and reaching the detector with minimum variation is the main target. So that, the higher the SNR, the better process performance will be. For (S/R) the larger – the- better quality characteristic is given by the following equation:

$$LTB = -10\ell og_{10}[1/n]\sum 1/R_i^2$$

Where R_i represent each individual quality characteristic value and n is the number of repeated observed values per trial or run. the treatment shown in Table (4) is the best setting that gives highest tensile strength and the signal –to-noise ratio is 46.13 which indicates that the best factors levels as: the travel speed is 1 which is (40cm/min), the wire feed speed is 2 (8 mm/min) and voltage at level 2 which is (17.5 V) .these may also $A_1B_2C_2$.

Table 4: The best setting of welding parameters that gives highest strength and S/N ratio.

Run No	A	B	C	travel speed (cm/min)	wire feed speed (mm/min)	Voltage (V)	R1 (σ_m) MPa	R2 (σ_m) MPa	R3 (σ_m) MPa	S/N	STDE	MEAN
5	1	2	2	40	8.0	17.5	212.9	200. 9	194.9	46.13	9.16	202.88

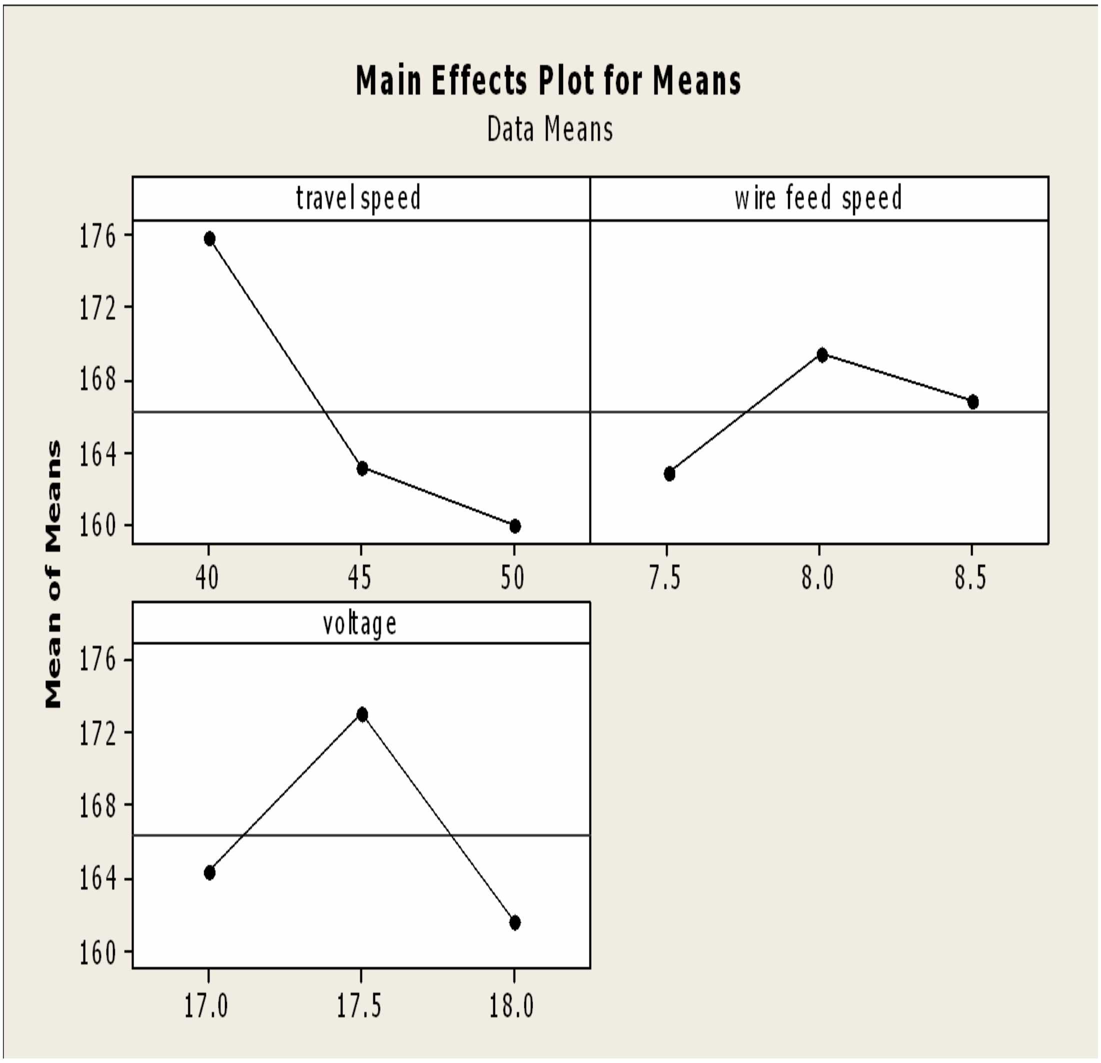


Figure 4: main effects plots for means

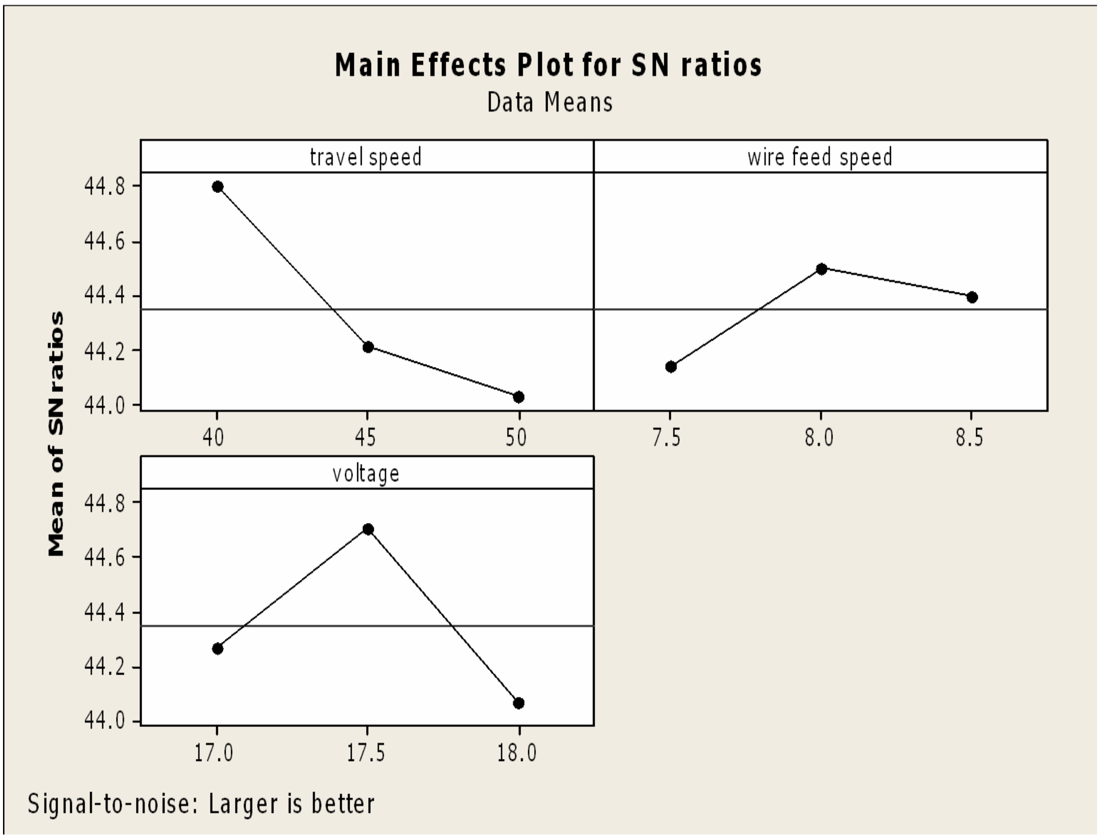


Figure 5: main effects plots for S/N ratios

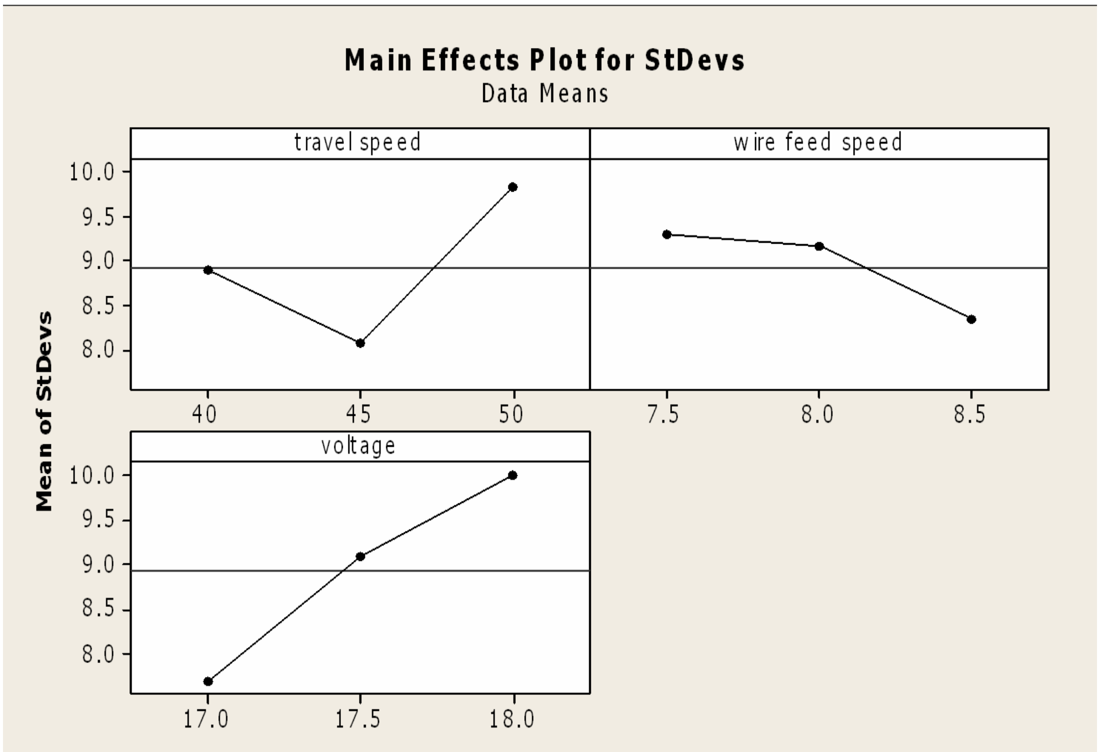


Figure 6: main effects plots for standard deviation

Interaction effect

Taguchi design traditionally focuses on main effects Figures (4, 5, &6), but it is important to test suspected interaction. Interaction plots can be used to determine whether the effect of one factor on response characteristic depends on the level of another factor.

In order to study which factor / interaction affects the signal-to-noise ratio the interaction between operating parameters and S/N ratio is explained in Figure (7) which shows.

- Travel speed

  There are strong interactions between travel speed and wire feed speed at three levels of travel speed and strong interaction between travel speed and voltage at three level of travel speed.

- Wire feed speed

  There are little interaction between wire feed speed and travel speed at the lower level of wire feed speed.

- Voltage

  There are simple interactions between voltage and travel speed at lower level voltage and there are strong interaction between voltage and wire feed speed at three level of the voltage.

Figures (8, 9) show interaction between parameters for means and Standard deviations respectively.

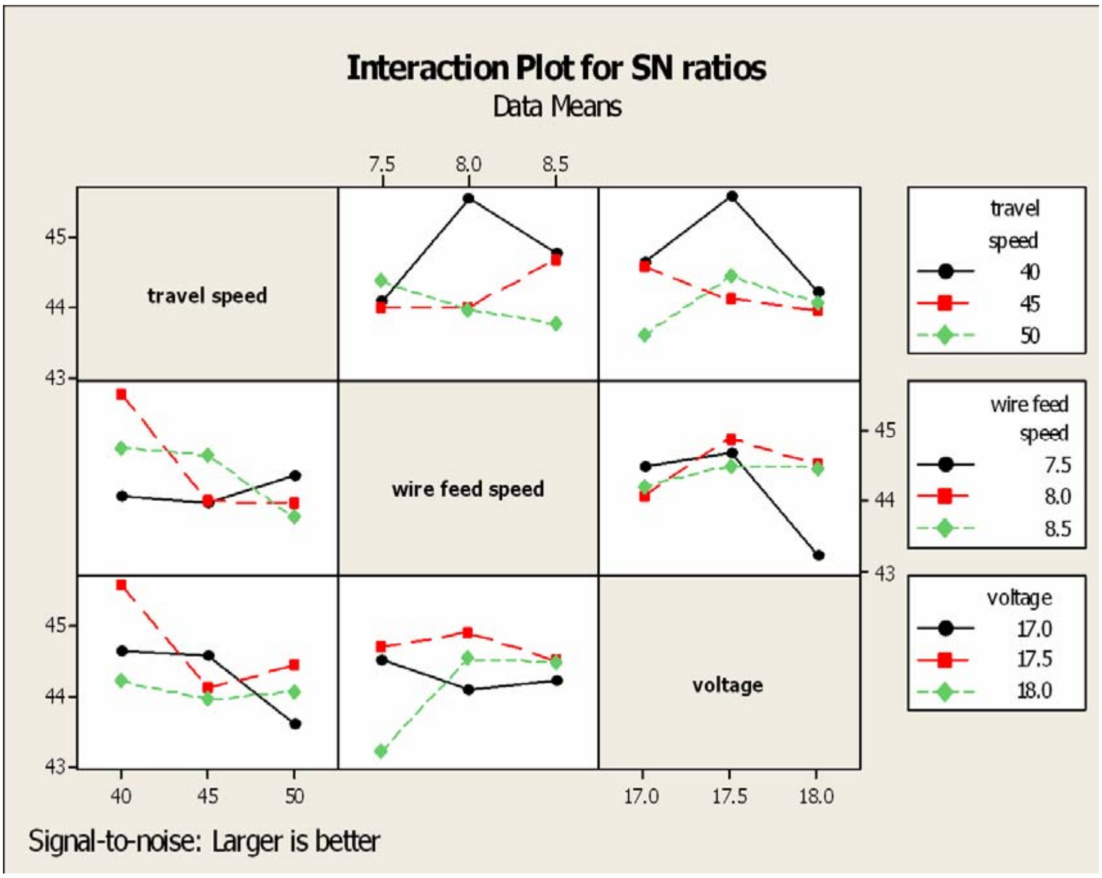


Figure 7: interaction plot for S/N ratios

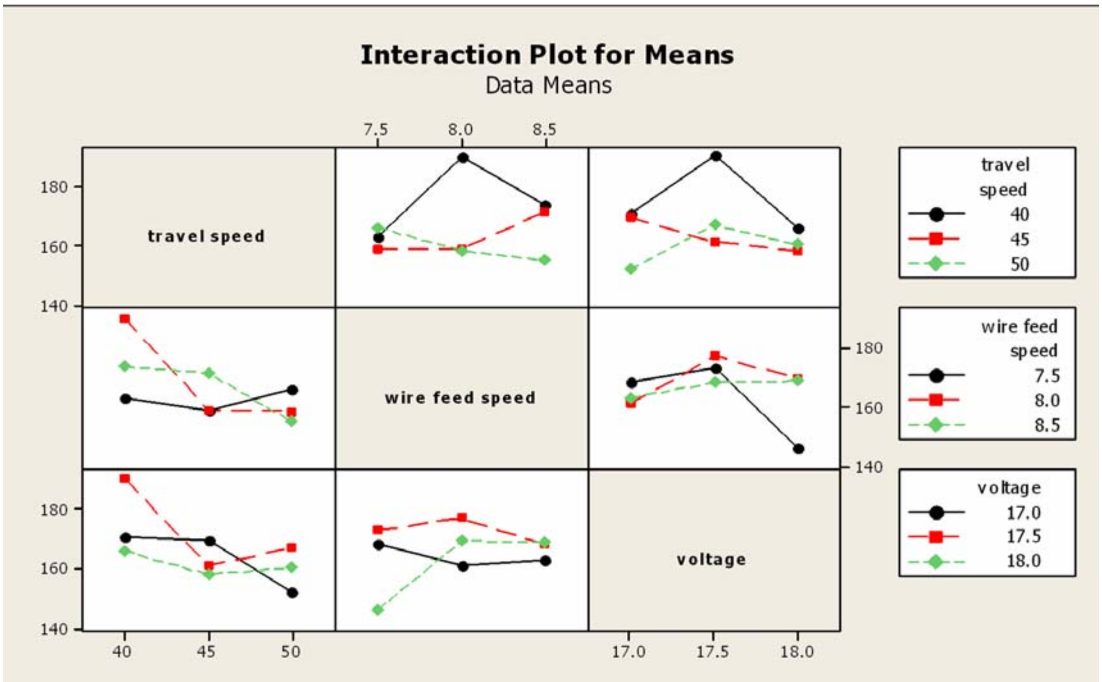


Figure 8: interaction plot for means

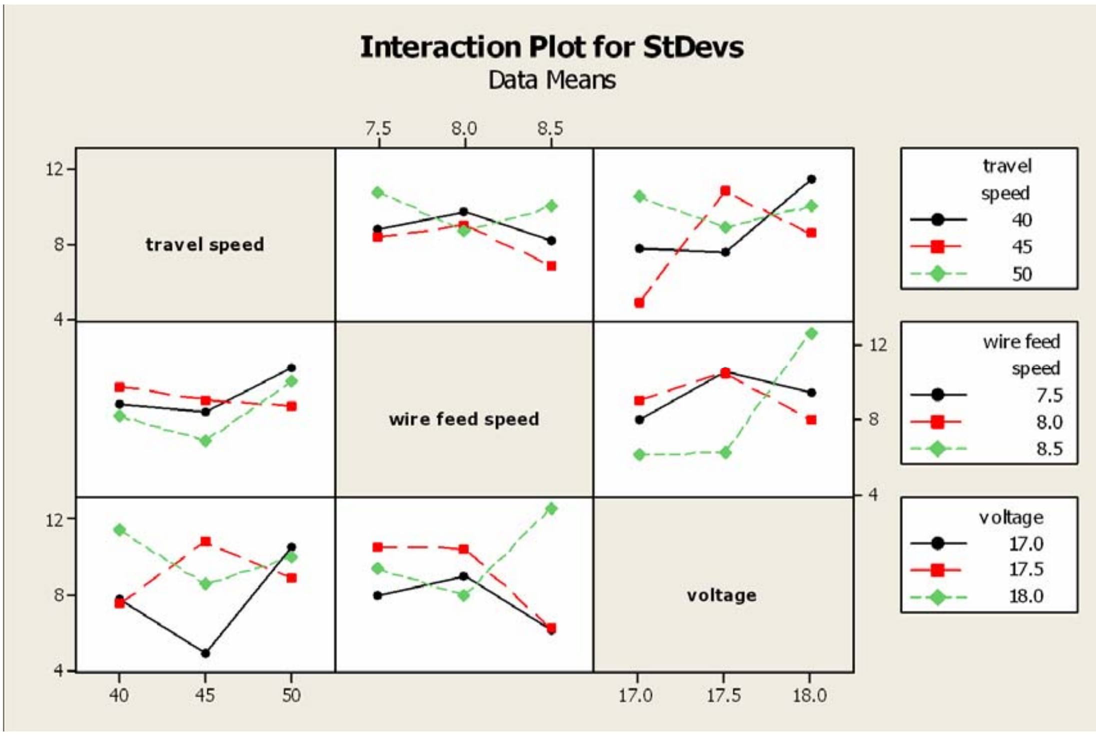


Figure 9: interaction plot for standard deviations

CONCLUTION

This study was undertaken with the objective of determining the effects of travel speed, wire travel speed and voltage on the tensile strength of the MIG butt welds. The Taguchi design and signal – to –noise ratio techniques were used and the following points are concluded:

- The three levels Taguchi design is found to be very contusing for optimizing the tensile strength.
- The travel speed as a factor (A), where the tensile strength of the welded joint is considered to increase as the travel speed gets slower, Wire feed speed as a factor (B), the tensile strength is greatly affected as the wire feed speed increased, and Voltage as a factor (C), the tensile strength is found to be with high value as voltage of MIG welding increased.
- Travel speed and wire feed speed interact to affect the weld strength to the higher value.
- As the currant presented in terms of wire feed speed, affects the amount of heat input, and the amount of deposited material also be affected which reflect that on joint strength.
- Interaction between travel speed and voltage has the large affects on the weld strength, while travel speed is the most significant parameter influencing the tensile strength.
- The optimum (maximum) tensile strength of 203 MPa can be obtained when the travel speed 40 cm/min, wire feed speed 8 mm/min and 17.5V voltage, and the best operating parameters setting are, travel speed (1), wire feed speed (2), and voltage (2).

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