International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Optimization of Resistance Spot Welding (RSW) Parameters by using Taguchi Method

Nor Atirah Mat Yasin, Anizahyati Alisibramulisi, Zuraidah Salleh, Farizah Adliza Ghazali , Anuar Pawan

Abstract: ***This study was intended to optimize the resistance Spot Welding Parameters (RSW) of sheet metals joints. The variation parameters selected were electrode force, welding current and welding time of 1.2 mm thickness low carbon steel. The settings of process parameters were conducted according to the L9 Taguchi orthogonal array in randomized way. The optimum process parameter was then obtained by using signal to noise ratio and analyzed further on the significant level by using Analysis of Variance (ANOVA). The developed response has been found well fitted and can be effectively used for tensile shear strength prediction. The optimum parameters achieved were electrode force (2.3 kN), welding time (10 cycles) and welding current (8 kA). Based on the ANOVA, it was found that the electrode force is a vital parameter in controlling the tensile shear strength as compared to welding time and welding current.***

Keywords: ***Optimization, Resistance Spot Welding (RSW), Taguchi Method, ANOVA.***

I. INTRODUCTION

The advantages of spot welding are its high speed and adaptability for automation in high rate or high volume engenderment. Despite these advantages, resistance spot welding (RSW) also has issues of quality inconsistencies from weld to weld [1]. It was found that the shear strength of joints was strongly depend on the welding current, type of filler and welding time. The joint strength decreases with an increasing level of current and weld nugget size. It was also found that welding time and welding currents are two important factors that brings good weldability of metals [2]. Thus, welding time, welding current and electrode force were chosen to be the varying parameters in this study.

In order to identify parameter levels that provide the best performance,

Revised Manuscript Received on January 30, 2020.

* Correspondence Author

Nor Atirah Mat Yasin, Malaysia Rail Link Sdn Bhd, Kuala Lumpur, Wilayah Persekutuan, Malaysia.

Anizahyati Alisibramulisi*, Faculty of Civil Engineering and Institute for Infrastructure Engineering and Sustainable Management (IIESM), Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia.

Zuraidah Salleh, Fakulti Kejuruteraan Mekanikal, Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia.

Farizah Adliza Ghazali, Fabrication & Joining Section, Universiti Kuala Lumpur Kampus Cawangan Malaysia France Institute (MFI), Bandar Baru Bangi, Selangor, Malaysia.

Anuar Pawan, Jabatan Kerja Raya (JKR), Malaysia.

Taguchi method system was adopted. The optimum condition is selected so that the influence of uncontrollable factors can minimize variation to the system performance [3]. The chosen three parameters will be used further to evaluate the tensile shear strength of the welded specimen.

The control of the welding parameters plays a major role i n the weld quality. [4]. Thus, a study on the optimization of these parameters by using Taguchi Method, is deemed necessary.

II. METHODOLOGY

A. Specimen preparation

Low carbon steel is used as the type of specimen that is used in this study. This material is widely used to draw motorcycle parts, car bodies and other domestic applications [4]. The samples are prepared by cutting the material of the workpiece into correct dimensions of 1.2mm thickness, 45mm width, 105mm length and 35mm contacting overlap. The specimens were prepared for nine trials with different rate of welding time, welding current and electrode force, see Table I. Each trial has three to four numbers of specimens. The reason of why each trial has a different number of specimens is because, while cutting the specimens with the same dimension, there are three specimens that are left, so the remaining specimens were used in the fifth, eighth and ninth trial. The minimum number of specimens for each trial is three and for the trial that has four number of specimens, it will help to give a better result to obtain the optimum value of parameters.

Table I: Number of specimens with the details for each parameter

Trial	Number of specimens	Electrode force (kN)	Welding current (kA)	Welding time (cycles)
1	3	2.3	8	10
2	3	2.3	10	15
3	3	2.3	12	20
4	3	2.7	8	10
5	4	2.7	10	15
6	3	2.7	12	20
7	3	3.1	8	10
8	4	3.1	10	15
9	4	3.1	12	20

Material checking was conducted by using Arc Spark Optical Spectrometer machine with pure Argon 99.9% and its software of Spark Analyzer MX. Size of the sample needed for the checking of the composition of the specimen is 40mm x 40mm and the thickness of the specimen used for this checking must not be less than 1 mm.

Three readings were taken from three different spots on the sample. From the test, the composition of the sample can be identified.

The tested material's chemical composition and mechanical properties are tabulated in Table II and Table III respectively.

Table II: The specimen's Chemical composition

Steel	%C	%Mn	%S	%P	%Ni
Low carbon steel	0.186	0.91	0.146	0.0033	0.032

Table III: The specimen's Mechanical properties

Steel	Yield strength (MPa)	Ultimate tensile strength (MPa)
Low carbon steel	144	209

B. Welding

The welding experiment involved of joining two layers of sheets using a portable Resistance Spot Welding (RSW) machine with 450V/50Hz primary weld voltage, 450kVA maximum power input, 150kVA rated capacity (one welding transformer) and maximum welding current of 12kA. The welding was done using a 6mm face diameter electrode with 450 truncated cone Class 2. The welding current were 8kA, 10kA and 12kA used to weld the specimens, whereas the electrode forces used were 2.3kN, 2.7kN and 3.1kN. Welding time for each welded specimen was in 10, 15 and 20 cycles. The mounting process was the next step after the specimens were welded, in which it was carried out to ease holding the samples. The molding type was hot mounted with a temperature of approximately about 150^0C using mounting press in a thermostatic plastic. The samples were then etched in 2% Nital etching reagent to reveal the features of the welded zone. Fig. 1 shows the welded specimen was cut at the middle of the weld spot, whereas Fig. 2 shows the specimen after the hot mounting.

Fig.2: Welded sheet steel after cutting

Fig.3: Specimens after hot mounting

At the beginning, the weld current must be kept as low as possible and it will gradually increase until the weld spatter occurs between the metal sheets. It means that the right welding current has been achieved. An ampere meter is used as a unit to measure the strength of the welding current. If the welding power is so high, the welding transformers can be damaged and the welding circuit switched off [5]. According to Kim et al [6], the residual stresses remaining in the welded component will also increase if the welding current and the tensile load are increased.

When welding a specimen with a thickness more than 2mm, it might be appropriate to divide the weld time into the number of impulses in order to avoid the increment of heat energy. This method will make a good-looking spot welding, but it might be poor in strength. Furthermore, when welding two specimens with a thickness of 1mm each, the appropriate weld time is 10 cycles where it is equal to 50Hz. According to Moshayedi and Sattari-far [7], comparing between welding time and welding current, it shows that welding current has a greater impact on weld dimensions in the early part of the welding cycles. It is also observed that as the welding time increases, it causes more heat to escape from the weld region [8] also in good agreement with [7] statement because in their study, it was proven that apart from temperature of welding process, the welding time also has a significant influence on the results. Kocabekir et al [9], by examining the tensile shear load, examined the effects of the welding time on the joint performance of the welded 316L stainless steel and found that the final mechanical properties were directly connected to the welded test parameters.

According to Zhao et al. [10], the electrode force has an obvious effect on the welded joint failure energy absorption and tensile shear load bearing capacity and there is also a limit of critical electrode force in which optimum values of welded joints mechanical properties will be reached. During the welding process, the contact surface size will also increase and thus will cause a problem. In order to keep the same conditions during the whole welding process, the electrode force needs to increase gradually. Usually average value is chosen because it is difficult to change the electrode force in the same rate as electrodes are sprouted.

C. Tensile Test

Tensile test was performed by using Universal Testing Machine (UTM). The specimen was clamped on each end and being pulled apart until it breaks. Tensile test measures how strong the specimen (tensile strength), how stretchy it is (elongation/ductility) and how stiff it is (tensile modulus). Fig.3 shows the specimens after the tensile test.

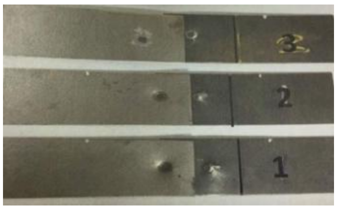


Fig.3: Tensile test specimens

To estimate the mechanical property of the joint by means of a tensile shear strength test, a single lap joint was chosen. According to Saeed [11], tensile shear load strength of welded materials was found to increase as the peak welding current increased. Xu et al [12] mentioned that the formability of the steel is represented by the yield strength and tensile strength ratio. The materials should have a lower yield ratio in order to have a good welding formability, particularly in flaring activity. The higher yield ratio material showed poor formability relative to the lower yield ratio material.

D. Optimization

In this study, three level process parameters; electrode force, welding time and welding current are considered. The value of the welding process parameters at different levels are tabulated in Table IV.

Table IV: Process parameters and their levels

Process parameter	Unit	Level 1	Level 2	Level 3
Electrode force	kN	2.3	2.7	3.1
Welding time	cycles	10	15	20
Welding current	kA	8	10	12

The interaction effects of the process parameters are important in manufacturing systems and processes. The interaction effect of the welding parameters could not be taken into optimization phase as orthogonal arrays do not check all variables combination. Thus, Only the main effect of each welding parameter was taken on the tensile strength response. In this study, the L9 orthogonal array is used, nine experiments are required to study the entire welding parameter space. The orthogonal array layout of experiment for the welding process parameters using L_9 (3^3) is shown in Table V.

Table V: Experimental layout using an L_9 (3^3) orthogonal array

Experiment number	Process parameter level		
	Electrode force	*Welding time*	*Welding current*
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

In this study, for focusing on tensile shear strength, the Larger-is-better equation is chosen:

$$\textbf{Larger-is-better} = \text{MSD} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{yi2} \qquad (1)$$

Where;

MSD = Mean square deviation for the output characteristic also known as quality loss function

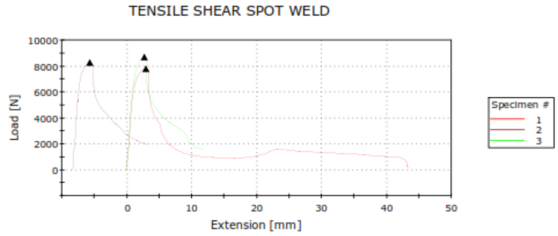
n = number of tests

y_i = value of responses

For tensile shear strength, if it gets a largest number it indicates that it is good in tensile shear strength.

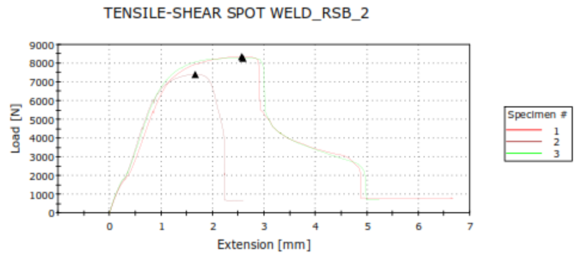
III. RESULTS AND DISCUSSIONS

Fig. 4, 5, 6, 7, 8, 9, 10, 11 and 12 shows the result from tensile test on nine trials of specimens. The maximum load and extension at maximum load were tabulated under the graph respectively. For the first trial, the graph plotted for the second specimen located at negative value for x-axis. This is due to not resetting the equipment before started. Nevertheless, the maximum strength data is still useable, in fact it has the same maximum strength as the other data. Thus, it is considered legitimate.



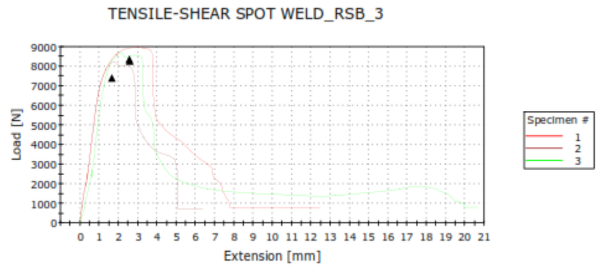
	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	7798.75586	2.95271
2	150.000	8264.76172	-5.66138
3	150.000	8699.38867	2.72603
Mean	150.000	8254.30208	0.00579
Median	150.000	8264.76172	2.72603
Std dev	0.000	450.408	4.909

Fig.4: Tensile shear for Trial 1



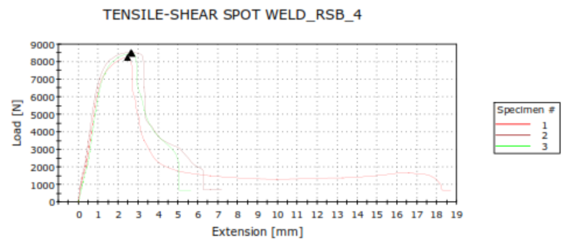
	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	8355.58301	2.56602
2	150.000	7408.12207	1.66268
3	150.000	8271.40527	2.58931
Mean	150.000	8011.70345	2.27267
Median	150.000	8271.40527	2.56602
Std dev	0.000	524.409	0.528

Fig.5: Tensile shear for Trial 2



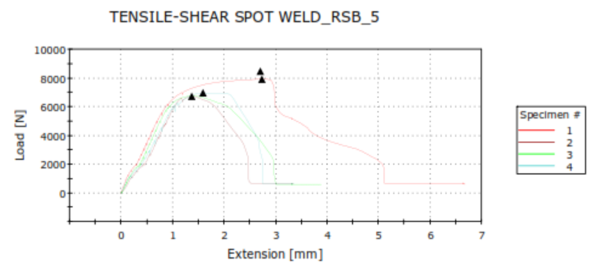
	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	8959.80176	3.01601
2	150.000	8244.84766	1.74602
3	150.000	8709.37793	2.15268
Mean	150.000	8638.00911	2.30490
Median	150.000	8709.37793	2.15268
Std dev	0.000	362.781	0.649

Fig.6: Tensile shear for Trial 3



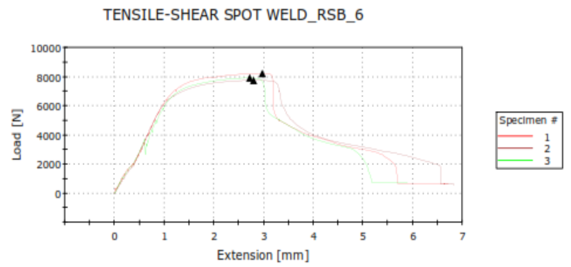
	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	8250.21680	2.47270
2	150.000	8530.13086	2.64265
3	150.000	8477.18848	2.69937
Mean	150.000	8419.17871	2.60491
Median	150.000	8477.18848	2.64265
Std dev	0.000	148.700	0.118

Fig.7: Tensile shear for Trial 4



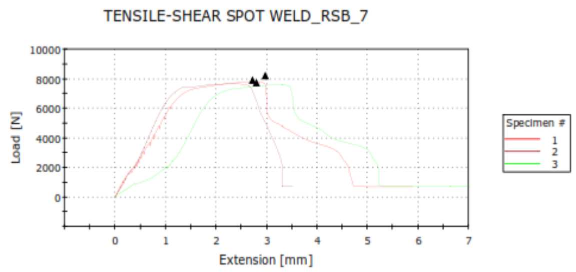
	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	7914.73242	2.72933
2	150.000	6736.53857	1.36936
3	150.000	6751.81299	1.34601
4	150.000	6971.62061	1.58935
Mean	150.000	7093.67615	1.75851
Median	150.000	6861.71680	1.47936
Std dev	0.000	557.808	0.656

Fig.8: Tensile shear for Trial 5



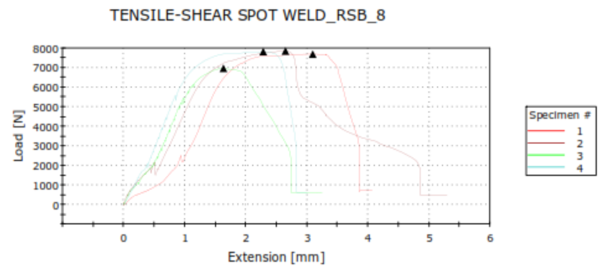
	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	8220.30469	2.97269
2	150.000	7748.47510	2.79606
3	150.000	7910.74072	2.71937
Mean	150.000	7959.84017	2.82937
Median	150.000	7910.74072	2.79606
Std dev	0.000	239.716	0.130

Fig.9: Tensile shear for Trial 6



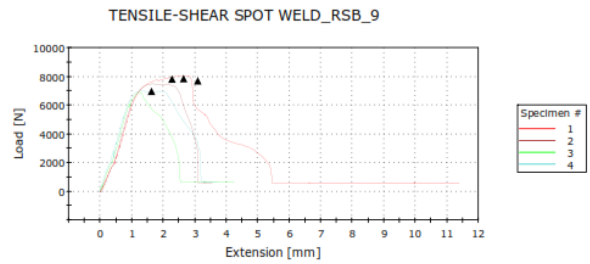
	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	7776.76709	2.76935
2	150.000	7661.21973	2.34599
3	150.000	7581.90918	3.23932
Mean	150.000	7673.29867	2.78489
Median	150.000	7661.21973	2.76935
Std dev	0.000	97.989	0.447

Fig.10: Tensile shear for Trial 7



	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	7692.39746	3.09270
2	150.000	7844.62695	2.64600
3	150.000	6968.89844	1.63265
4	150.000	7815.50342	2.28271
Mean	150.000	7580.35657	2.41352
Median	150.000	7753.95044	2.46435
Std dev	0.000	412.944	0.617

Fig.11: Tensile shear for Trial 8



	Area [mm^2]	Maximum Load [N]	Extension at Maximum Load [mm]
1	150.000	8056.70850	2.76934
2	150.000	7485.74756	1.68934
3	150.000	6890.25244	1.24603
4	150.000	7023.99414	1.35599
Mean	150.000	7364.17566	1.76518
Median	150.000	7254.87085	1.52267
Std dev	0.000	527.481	0.695

Fig.12: Tensile shear for Trial 9

A series of experimental result from Design of experiment (DOE) and Taguchi Method, is used to find the optimal parameters for resistance spot welding. The steps to use the DOE start by defining the variables and measuring the response. A number of rates are specified for each input variable which reflect the scope for which the effect of that variable is desired, and then each test parameter was run. The response for each run is then evaluated. The evaluation approach is to look for discrepancies in response readings of different groups of input changes. These differences are then attributed to the input variables acting alone called a single effect.

Table VI shows the result of tensile shear strength for each trial. Each trial has three to four numbers of specimens and the tensile shear strength value is recorded by taking the average value for each trial.

Table VI: Tensile shear strength experimental results

Specimen label number	Tensile shear strength (kN)
1	8.25
2	8.01
3	8.
4	8.42
5	7.10
6	7.96
7	7.67
8	7.58
9	7.36

In this study, the tensile shear strength of the welded specimens belongs to the larger-the-better quality characteristics. It is because in tensile shear strength, the larger the value of tensile shear, indicates that it is lower yield ratio. By applying Eqn. 1, the results of Signal to Noise ratio are shown in Table VII.

Table VII: Signal to Noise Ratios results

Experiment number	Signal to Noise ratio
1	18.33
2	18.07
3	18.73
4	18.50
5	17.02
6	18.02
7	17.70
8	17.60
9	17.34

Using the Minitab V17 software, the Signal to Noise ratio was analyzed.

Each welding parameters at different levels has an effect on the Signal to Noise ratio and can be separated out because the experimental design is orthogonal. The Signal to Noise ratio for each level is summarized in Table VIII. The optimum value that needs to be obtained is the value that is good in welding with a lower cost. In this study, the optimum value is the largest value because this study is focusing on the tensile shear strength. In the Table VIII, the star sign indicates the optimum value for each parameter. Electrode force is in rank number 1 and it means that electrode force is the important parameter in this study.

The effects of different control factors on Signal to Noise ratio result is shown in Table VIII. Fig. 13 shows the mean of S/N ratio. It shows that the electrode force has the highest value of Signal to Noise ratio and this is strong enough to say that electrode force is the important parameter in this study. Basically, the larger the value of mean of Signal to Noise ratio, the better the quality of the specimen towards tensile shear strength. Optimum levels of various control factors for higher tensile shear are electrode force at level 1 (2.3kN), welding time at level 1 (10 cycles) and welding current at level 1 (8 kA).

Table VIII: S/N responses of the Tensile Shear Strength

Process parameter	S/N ratio			Rank
	Level 1	Level 2	Level 3	
Electrode force	18.38*	17.85	17.55	1
Welding time	18.18*	17.56	18.03	2
Welding current	17.98*	17.97	17.82	3

*optimum value

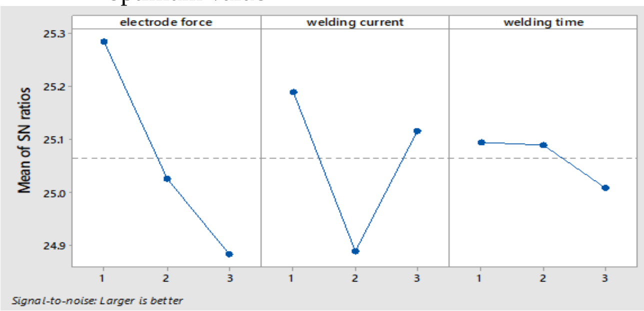


Fig.13: Mean of SN ratios results

Analysis of Variance (ANOVA) can be used to assess the relative significance of performance characteristics or responses. If the probability value known as p-value is less than the significance level (α), the factor is then regarded to be statistically significant. The relative significance of factors is often represented in terms of F-ratio or in percentage contribution. The higher the F-ratio means that the variance of the system parameter affects the output, or if the p-value is less than 0.05, the higher the variable. This technique quantified the effects of the spot-welding parameters on each response to check the significance of each welding parameter.

The results of ANOVA for the welding responses are shown in Table IX. The larger the F value indicates that there is a big change on the rank of the welding parameters. In this study, electrode force is the most important parameters affecting the responses whereas welding current is less important. It is because the welding current gives the lowest value as compared to electrode force and welding time. Besides, a variable with a high percentage contribution will make a small difference and will have a significant impact on performance [13]. The most important parameter of Resistance Spot Welding (RSW) that influences the tensile shear strength is electrode force with 66.96% contribution. It is only 0.3853 of variance that caused by experimental errors, indicating that the experimental design has been successful.

Table IX: ANOVA results for Tensile Shear Strength

Factors	**DoF**	**Sum of squares**	**Mean of squares**	**F**	**P**	**Cont. (%)**
Electrode force	2	50.812	25.406	120.44	0.007	66.96
Welding current	2	5.815	2.9075	13.11	0.011	7.29
Welding time	2	17.767	8.8835	46.32	0.022	25.75
Error	2	0.3853	0.1927			
Total	8	74.7793				100

The results are just a bit different to Farizah et al [14] study on Tri-objective Taguchi method and response surface approach in optimizing welding process parameters, in which they found that the most important parameter of RSW that influence the tensile shear strength, fusion zone and heat affected zone is welding current with 68.68% contribution. This is due to the different objectives of these two papers even though the varying parameters are the same.

IV. CONCLUSIONS

Based on the experimental and optimization results obtained, the following conclusions can be drawn:

- The developed response has been found well fitted and can be effectively used for the prediction of tensile shear strength.
- The optimum parameters achieved were electrode force 2.3 kN, welding time 10 cycles and welding current 8 kA.
- From the Analysis of Variance (ANOVA), the electrode force was found to be more significant parameter than welding time and welding current in controlling the tensile shear strength. It can be concluded that the chosen parameters of Resistance Spot Welding (RSW) were successfully optimized by using Taguchi method. Thus, leads to the well prediction of the tensile shear strength of the jointed metals.

ACKNOWLEDGMENT

The authors would like to acknowledge the financial support for this work from Universiti Teknologi MARA (UiTM), in particular; Faculty of Civil Engineering, Faculty of Mechanical Engineering and Institute for Infrastructure Engineering and Sustainable Management (IIESM). The collaboration support from Universiti Kuala Lumpur – Malaysia France Institute (UniKL-MFI), is also gratefully appreciated.

REFERENCES

1. M. Jou, Real time monitoring weld quality of resistance spot welding for the fabrication of sheet metal assemblies, Journal of Materials Processing Technology, 132 (2003)102–113.
2. A. M. Saed, Z. Hussain, A. Badri and T. Ariga, The effects of welding parameters on the weldability of different materials using brazing alloy fillers, Materials and Design, 31 (7) (2010) 3339-3345.
3. H. Pal, H. Singh and J. Kumar, Single Response optimization of abrasive waterjet machining process by Taguchi’s parameter design approach, International Journal of Latest Engineering Research and Applications (IJLERA), ISSN: 2455-7137, Vol 2, Issue 9 (2017) 23–31.
4. U. Esme, Application of Taguchi Method for the Optimization of Resistance of Spot-Welding Process, 34(2), The Arabian Journal for Science and Engineering, Vol. 34 2B (2009) 519–528.
5. M. He, F. Li, and Z. Wang, Forming limit stress diagram prediction of aluminum alloy 5052 based on GTN model parameters determined by in situ tensile test, Chinese Journal of Aeronautics, 24(3), (2011) 378–386.
6. K. Kim, T. Choi, M. Na, and H. Jung, Butt-welded area by electronic speckele pattern interferometry, Nuclear Engineering and Technology, 47(1), (2015) 115–125.
7. H. Moshayedi and I. Sattari-far, Journal of Materials Processing Technology Resistance spot welding and the effects of welding time and current on residual stresses**.** Journal of Materials Processing Tech., 214(11), (2014) 2545–2552
8. D. Rodĝtn and P. Nachtnebl, Influence of Diffusion Welding Time on Homogenous Steel, Joints, 100 (2015) 1678–1685
9. B. Kocabekir, R. Kacar, S. Gunduz and F. Hayat, An effect of heat input, weld atmosphere and weld cooling conditions on the resistance spot weldability of 316L austenitic stainless steel, J Mater Process Technol, (2008) 195:327–35.
10. D. W. Zhao, Y. X. Wang, L. Zhang and P. Zhang, Effects of electrode force on microstructure and mechanical behavior of the resistance spot welded DP600 joint**.** Materials and Design, 50 (2013) 72–77.
11. A. M. Saeed, Z. Hussain, A. Badri and T. Ariga, The effects of welding parameters on the weldability of different materials using brazing alloy fillers**.** Materials and Design, 31(7), (2010)3339–3345.
12. Z. Xu, P. Lu, and Y. Shu, Microstructure and fracture mechanism of a flash butt welded 380CL steel, Engineering Failure Analysis, 62 (2015) 199–207
13. H. Ahmadi, N. B. M. Arab and F. A. Ghasemi, Optimization of process parameters for friction stir lap welding of carbon fibre reinforced thermoplastic composites by Taguchi method, Journal of Mechanical Science and Technology, 28 (2014) 279-284.
14. F. A. Ghazali, M. N. Berhan, Y. HP. Manurung, Z. Salleh and S. Abdullah, Tri-objective optimization of carbon steel spot-welded joints, Jurnal Teknologi, eISSN 2180-3722, 76:11 (2015) 69-73.

AUTHORS PROFILE

Nor Atirah Mat Yasin is currently a Junior Infra Engineer at Malaysia Rail Link Sdn Bhd. She graduated from Universiti Teknologi MARA (UiTM) in January 2018 and has worked at Malaysia Rail Link Sdn Bhd ever since.

Anizahyati Alisibramulisi is currently a Senior lecturer at Faculty of Civil Engineering and Researcher at Institute for Infrastructure Engineering and Sustainable Management (IIESM), UiTM Shah Alam. Her research areas are in through process modeling, welded metal, Finite Element Analysis (FEA), structural, material and bridge engineering. She obtained her Ph.D in Structural Engineering from Norges Teknisk-Naturvitenskapelige Universitet (NTNU), Norway. She is also a registered Professional Engineer (P.Eng.), Professional Technologist (P.Tech.), Member of Institute of Engineers Malaysia (IEM), Honorary Treasurer of Concrete Society Malaysia (CSM), Education Committee of Malaysian Structural Steel Association (MSSA) and Senior Member of Universal Association of Civil, Structural and Environmental Engineers (UACSE), United States.

Zuraidah Salleh is currently a senior lecturer at Faculty of Mechanical Engineering, UiTM Shah Alam. Her research areas are in welding, mechanical properties of metal, fatigue and corrosion. She obtained her Ph.D in Mechanical Engineering from UiTM.

Farizah Adliza Ghazali is a Senior Lecturer at Fabrication and Joining Section, Universiti Kuala Lumpur Malaysia France Institute (UniKL MFI). She received her BSc and MSc. in Mechanical Engineering at Faculty of Mechanical Engineering, Universiti Teknologi MARA as well as Ph.D in Mechanical Engineering (Mechanics and Materials). She is also a Professional Technologist recognized by Malaysia Board of Technologists (MBOT). She is an active member of Materials Sub-Cluster for Advanced Manufacturing, Mechanical and Innovation Research (AMMIR) at UniKL MFI. She was appointed as principal researcher for several grants. Her research interests include mechanics of materials, welding mechanics, process optimization and natural fibre composites.

Anuar Pawan obtained his Bachelor’s in Mechanical Engineering from University of Wollongong, Australia and his MSc in Railway Systems Engineering and Integration from the University of Birmingham, UK. He has more than 15 years working experience in the railway industry serving different roles such as railway regulator, inspector, auditor, planner and project manager. He is currently working with Malaysian Public Works (JKR Malaysia) and affiliates in railway/welding research with Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia.