Optimization of pulsed GTAW process parameters to obtain maximum tensile strength in AA7075-T6 Aluminium alloy

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ABSTRACT

Keywords:
Gas Tungsten Arc Welding Method (GTAW)
AA7075-T6 Aluminium Alloy,
Response Surface Methodology,
Central Composite Design Matrix,
Ultimate Tensile Strength,
Optimization.

The mathematical model is developed to predict pulsed gas tungsten arc welded (GTAW) joints of AA 7075-T6 aluminium alloy. The mathematical model is developed by incorporating the process parameters like peak current, base current, welding speed, and pulse on time. All the experiments were conducted on the basis of four factors, four levels Composite Design Matrix. In this study an attempt is made to develop mathematical model by preplacing the filler wire in to the weld groove. The optimized GTAW process parameters illustrate that improvement in the tensile properties of welded joints. A mathematical model were developed at 95% confidence level and tested for adequacy. The developed model can be used in industry for predicting tensile strength of AA 7075-T6 aluminium alloy joints. The results shows that welding speed greatest influence on tensile strength subsequently with peak current, pulse on time, and base current when filler wire placed in to the weld groove before starting the welding.

1. Introduction

Now a day's aluminium is very versatile to use in industry because of its light weight, appearance, frabricability, strength, and corrosion resistance. Also it is one of the most versatile materials used in every industry. Among aluminium alloys AA7075-T6 alloy has many attractive properties compared to other alloys, it is economical and versatile to use, high strength, and light weight, is the reason it is very widely used in the aerospace, automobile and other industries. In Aerospace and other industries there are many situations wherein AA7075-T6 plates are joined together with fusion welding in particular Butt welding.

In recent past researchers are addressing AA7075-T6's weldability issues. Fusion welding of this alloy leads to loss of joint strength; this was mainly due to the coarse dendrite grains in the weld zone and loss of alloying elements at higher temperature. Addressing these issues without compromising on quality of weld joint through fusion welding route is a challenging task for practicing engineers and the manufacturing industries.

The GTAW welding technique is usually popular due to their portability, simplicity, less cost, and it is usually used in maintenance, repair and field construction sites [Akula, 2007]. The GTAW is gradually more employed for fabrication in several industries. The process is flexible, because it can be useful for all position welding; it can be automated without any difficulty and can be easily integrated into the robotized manufacturing centers. These beneficial features of GTAW process have provoked many researchers and engineers to study the process in detail [Nadkarni,1988].

Mannion and Heinzman, (1999) studied the effect of GTAW process parameters and identified significant process parameters and its selection. They stated that a classic GTAW welding system generally consists of the elements: power supply, controller, welding torch, and tungsten electrode. In addition to the equipment, one of the main aspects of the GTAW is the process parameters selection. The specific weld quality is achieved by selecting proper process parameters. Improper selection of any parameters will effect on the

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final weld quality, so the good quality welding process parameters normally are written down or stored in the memory of welding equipment.

The cracking susceptibility in welding of aluminium alloy has been studied by Haung and Kou (2000,2001,2002) in series of article and they pointed out that, the welding of aluminium alloy involves usage of non heat treatable filler wire ER5356 which increases cracking resistance. Leijun Li et al. (2005) have studied the effect of joint design in GTAW of AA 7075-T6 alloy using ER 5356 filler wire and they pointed that optimization of joint design and process parameters improve the mechanical properties.

Hassan et al.(2008) investigated that in the fusion welding quality of welded joint is judged by the responses: degree of dilution, microstructure, weld joint mechanical properties, and joint efficiency. The degree of dilution determines how much percentage of the filler material is diluted with base metal. Microstructure of the weld zone (WZ) and heat affected zone (HAZ) determines whether grains are coarse or fine. So GTAW process parameter plays an important role in determining the quality of welded joint.

Senthil Kumar. T et al.(2007) studied the effect of pulse current GTAW process parameters on thin section medium strength aluminium alloy Al-Mg-Si by applying full factorial design matrix and compared tensile properties with joints welded by continuous current GTAW process. They pointed out that Pulse current GTAW is beneficial in improving tensile properties because of optimal process parameters and grain refinement.

Balasubramanian. M et al.(2009) developed an mathematical model for predicting weld pool geometry using four factor five level central composite matrix and optimized by Lexicographic method. The optimized process parameters resulted strong weld pool geometry. Balasubramanian. M et al.(2010) studied the effect of pulse current GTAW process parameters on weld pool geometry by applying central composite matrix method at 90% confidence level and identified that pulse frequency have significant effect on weld pool geometry.

Kumar. A et al.(2009) employed Taguchi technique to optimize pulse GTAW process parameters and developed Regression model for predicting the tensile properties. They pointed out that tensile properties improved because of fine grain structure and further 10-15% improvement in mechanical properties by planishing process. The planishing process have relived internal stresses or redistributed in weld zone.

It is not so simple to select the values for GTAW process parameters, since for each welding situation i.e. base metal, electrode metal and diameter, shielding gas type, gas flow rate etc. there is an optimum process parameter combination which gives best quality in weld joints. In addition, automated applications of GTAW are challenging greater in the welding process family, which in turn makes more study about the effects of process parameters on weld pool geometry and extent of fusion. Considering all the above facts, previous papers are reviewed with aspects of GTAW process parameters and their selection to get good quality welds.

There are several methods to define desired output variable by developing mathematical model and identify the relationship between input process parameters and output variables. Benyounis K.Y. and A.G. Olabi (2008) have reviewed on different techniques of optimization and finally concluded that response surface methodology (RSM) is the best technique for optimizing the welding process parameters.It is mainly due to the appropriate model is approximated, being the function of surface models.

The strength of welded joint mainly depends upon weld pool geometry and uniform dilution of filler metal in to the molten base metal. As per the literature survey most of the scientist's feed filler wire manually in GTAW, this leads to non uniform weld pool geometry and non uniform dilution of filler metal in to the molten base metal. The uniform weld pool geometry and uniform dilution of filler metal in to the molten base metal can be obtained by preplacing the filler wire in to the groove of weld and maintaining uniform gap between electrode tip and preplaced filler wire surface. This procedure is adopted in present investigation to study the effect of GTAW process parameters, filler material composition, and also for developing mathematical model.

Attempts are essentially going on to enhance mechanical properties by selection of appropriate GTAW process parameters (by optimization technique) for AA7075-T6 aluminium alloy. This requires thorough investigation in the actual behaviour of parent elements with different levels of AC pulse GTAW process parameters in weld zone, and causes of the problems in joining of the high strength AA 7075-T6 alloy. In this investigation an attempt is made to develop mathematical models to predict tensile strength of AC pulse GTAW joints of AA-7075-T6 aluminium alloy using stastical analysis based on the design of experimental (RSM technique) results, analysis of variance (ANOVA) and regression analysis. Depicting the approximate role of major AC pulse GTAW process parameters on the tensile strength of AA 7075-T6 alloy welded joints.

2. Development of Mathematical Model

2.1 Identifying GTAW process parameters

Ben-Hamu. G et al. (2007), Balasubramanian. M et al.(2009), Balasubramanian.M et al.(2010) investigations and our preliminary work on AC pulse of GTAW of AA7075-T6 aluminium alloy the identified AC pulse GTAW process parameters are peak current (Ip), base current (Ib), welding speed (S), and pulse on time (Pon). Responses studied are: Ultimate tensile strength (UTS).

2.2 Working rage of GTAW process parameters

The base material AA7075- T6 of thickness 3.46mm is commercially available in the form of rolled sheet with size 1500 x 1500 mm. The chemical composition of the base material have been analyzed by the method of spectro spark emission (ASTM-E1251-07) using a Spark analyzer spectromax. The nominal compositions [Alcoa mill products] and composition of Aluminum alloy AA7075- T6 taken up for present welding shown in Table 1.

Table 1
Nominal and spectromax analyzed chemical composition of AA7075-T6.

Elements present	Nominal composition (Wt%)	Composition (Wt%) as per the spectro spark emission
Aluminium, Al	87.1-91.4 %	90.60%
Zinc, Zn	5.10-6.10%	5.28%
Magnesium, Mg	2.10-2.90%	2.15%
Manganese, Mn	≤ 0.300%	0.04%
Chromium, Cr	0.180-0.280%	0.23%
Copper, Cu	1.20-2.00%	1.31%
Iron, Fe	≤ 0.500%	0.21%
Other each	≤ 0.0500%	<00.004 %
Other total	≤ 0.150%	<00.009 %
Silicon, Si	≤ 0.400%	0.06%
Titanium, Ti	≤ 0.200%	0.05%

A several number of trials are conducted using 3.46 mm thick AA7075-T6 samples to find out the feasible working range of AC pulsed current GTAW process parameters. While GTAW the ER5356 (Al–5%Mg) aluminium alloy of 2x2 mm square cross sectioned wire has been used as the filler metal. Different combinations of AC pulse current parameters with argon gas are used to perform the trial runs. The trials are performed by pre placing the filler wire (ER5356) in to the groove. The bead contour, penetration, bead appearance and weld quality were inspected to identify the welding parameters.

From the above analysis, following observations were made:

1. If the peak current (Ip) is less than 195 A, incomplete penetration and lack of fusion is observed. At the same time, if the Ip greater than 205 A, under cut, spatters and overheating of base metal are observed.
2. If background current (Ib) is less than 93 A, arc length is created is very short, there is no proper mixing of filler metal with the molten metal of base metal. On the other hand, Ib greater than 103A, arc became unstable and arc length is increased and it starts wandering.
3. If the welding speed (S) is less than 200mm/min unacceptable protrusion of the root with more undercut and bead appearance not so good. For the welding speed greater than 400mm/min penetration decreases and weld pool become narrow.
4. If the pulse on time (Pon) is less than 40%, the heat input is very low which is not sufficient to melt the base metal. On the contrary, if the Pon greater than 60%, over melting of the base and filler metal and overheating of tungsten electrode is noticed.

2.3 Development of central composite design matrix

In this study an attempt is made to improve the quality of GTA welded joints of AA7075-T6 aluminium alloy. Quality of welded joints is

Table 2
Levels of the AC pulse GTAW process parameters.

Symbol	Process Parameter	Units	Level				
			-2	- 1	0	+1	+2
Ip	Peak current	Amps	195	197	200	203	205
Ib	Base current	Amps	93	95	98	102	105
S	Welding speed	mm/min	200	250	300	350	400
Pon	Pulse on time	%	40	45	50	55	60

Table 3
Constant process parameters.

Process parameter	Unit	Constant value
Frequency	Hz	6
Polarity	----	AC
Electrode diameter,	mm	2.4
Gap between electrode tip and base plate	mm	2
Torch position	-----	Vertical
Shielding gas	-----	Argon (99.99% purity)
Filler rod diameter	mm	2x2mm
Electrode material	-----	98% W + 2% Th

improved by studying the effect of GTAW process parameters. Totally four process parameters are selected that mainly affect the quality of welded joints. All the four process parameters are considered at five levels. All experiments were conducted based on four factors (process parameters) and five level central composite design matrix. The levels selected in the present study are shown in Table 2. The process parameters which are maintained constant are given in the Table 3. With reference to the Box and Hunter (1978) the experimental design of 31 set experiments in coded form and actual values is listed in the Table 4.

2.4 Experiments and results

The base metal (AA 7075-T6) of size 250mm X 150mm X 3.46 mm have been prepared by chemical cleaning. The butt joint welds were made as per the Central composite design matrix array. Automatic GTAW machine has been employed for conducting the experiments. Welding was performed by pre placing the filler wire in to the groove with mild steel back plate as shown in the Fig.1.

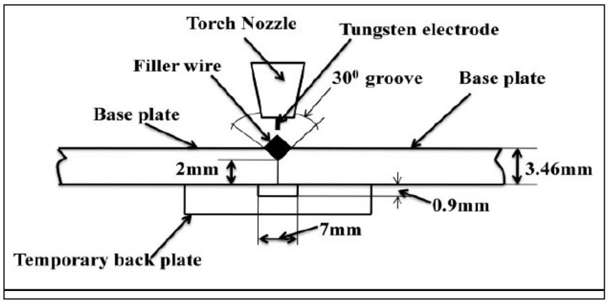

Fig. 1. Schematic view of filler materials preplaced in groove.

The specimens for tensile test are taken from the middle of the weld joints. The specimens prepared as per the ASTM-E8 specifications [Kumar. A et al. (2009)]. Tensile test is conducted on 60 Ton Universal testing machine (Model: FIE-Bluestar, UTES−60) at room temperature. The average values of three tensile test results (UTS) of the welded joints were evaluated for all the 31 experiments is listed in the Table 4.

2.5 Development of empirical relationship

The main objective of the study is to optimize the response of interest which is influenced by several input variables. The system problem analyzing and modeling can be done by collecting mathematical and stastical technique, for this Response surface Methodology (RSM) is selected. The ultimate tensile strength (UTS) is the response of the GTAW joint and it is function of Peak current (Ip), Base current (Ib), Welding speed (S), and Pulse on time (Pon) mathematically it is expressed as:

Table 4
Matrix design and experimental results.

Expt No	Coded value				Actual value				UTS (MPa)
	Ip	**Ib**	**S**	**Pon**	**Ip**	**Ib**	**S**	**Pon**	
1	-1	-1	-1	-1	197	95	250	45	349
2	1	-1	-1	-1	203	95	250	45	341
3	-1	1	-1	-1	197	102	250	45	362
4	1	1	-1	-1	197	95	250	45	349
5	-1	-1	1	-1	197	95	350	45	370
6	1	-1	1	-1	203	95	350	45	345
7	-1	1	1	-1	197	102	350	45	372
8	1	1	1	-1	203	102	350	45	343
9	-1	-1	-1	1	197	95	250	55	319
10	1	-1	-1	1	203	95	250	55	325
11	-1	1	-1	1	197	102	250	55	337
12	1	1	-1	1	203	102	250	55	339
13	-1	-1	1	1	197	95	350	55	357
14	1	-1	1	1	203	95	350	55	343
15	-1	1	1	1	197	102	350	55	364
16	1	1	1	1	203	102	350	55	343
17	-2	0	0	0	195	98	300	50	362
18	2	0	0	0	205	98	300	50	331
19	0	-2	0	0	200	93	300	50	329
20	0	2	0	0	200	105	300	50	345
21	0	0	-2	0	200	98	200	50	339
22	0	0	2	0	200	98	400	50	370
23	0	0	0	-2	200	98	300	40	360
24	0	0	0	2	200	98	300	60	341
25	0	0	0	0	200	98	300	50	378
26	0	0	0	0	200	98	300	50	378
27	0	0	0	0	200	98	300	50	382
28	0	0	0	0	200	98	300	50	382
29	0	0	0	0	200	98	300	50	380
30	0	0	0	0	200	98	300	50	382
31	0	0	0	0	200	98	300	50	382

$$UTS=f(Ip,Ib,S,Pon) \qquad (1)$$

Considering that the effect of variation of the GTAW process parameters on the responses (UTS) is quadratic. The following second order polynomial equation (regression) is considered for the mathematical model:

$$Y=b_0+\sum b_i x_i+\sum b_{ii} x_i^2+\sum b_{ij}\, x_i\, x_j+e_r \qquad (2)$$

where Y= predictive responses (UTS), b_0 average of responses UTS, b_i and b_{ij} are the regression coefficients (b_k) and these depend upon respective main and interaction of GTAW process parameters. The regression coefficients are determined by the following expression:

$$b_k = \frac{\sum_{i=1}^{N} X_{ik} Y_k}{N} \qquad (3)$$

Where k=0.1.2.3…n X_{ik} is the value of process parameters or interactions in coded form and Y_k is the value of mechanical property responses (UTS), N is the number of observations and n is the number of regression coefficients. All the coefficients are determined by using Design Expert stastical software.

The selected polynomial for the four GTAW process parameters is expressed as:

$$UTS=b_0+b_1(I_p)+b_2(I_b)+b_3(S)+b_4(P_{on})+b_{11}(I_p^2)+b_{22}(I_b^2)+b_{33}(S^2)+b_{44}(P_{on}^2)+b_{12}(I_pI_b)+b_{13}(I_pS)+b_{14}(I_pP_{on})+b_{23}(I_b\,S)+b_{24}(I_b\,P_{on})+b_{34}(SP_{on}) \qquad (4)$$

The following empirical relationship is obtained using coded value to predict the mechanical properties UTS by substituting regression coefficients in the equation 4.

$$UTS=380.41-6.69(I_p)+3.81(I_b)+7.36(S)-5.84(P_{on})-8.46(IP^2)-10.75(I_b^2)-6.43(S^2)-7.44(P_{on}^2)-1.14(I_pI_b)-4.70(I_pS)+2.92(I_pP_{on})-2.92(I_bS)+1.14(I_bP_{on})+3.68(SP_{on}) \qquad (5)$$

2.6 Checking adequacy of developed empirical relationship

The developed empirical relation adequacy is tested by analysis of variance (ANOVA). In this technique adequacy of developed empirical relationship within the confidence limit is checked by knowing the value of F_{ratio} . The Fratio value of the developed empirical relationship must be less than the standard F_{ratio} (referring to the F-table). The ANOVA test result at 95% confidence level is shown in Table 5. The model F-value is 190.77 it implies that the developed mathematical model is significant. The model F- values have only 0.01% chance that could occur due to noise. All the process variables having p-value less than 0.05 are considered as significant. The

Table 5

ANOVA for response surface quadratic model.

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	10682.51	14	763.04	190.77	< 0.0001
A-Ip	1072.85	1	1072.85	268.22	< 0.0001
B-Ib	348.11	1	348.11	87.03	< 0.0001
C-S	1301.14	1	1301.14	325.30	< 0.0001
D-Pon	818.43	1	818.43	204.62	< 0.0001
AB	20.89	1	20.89	5.22	0.0363
AC	353.00	1	353.00	88.25	< 0.0001
AD	136.41	1	136.41	34.10	< 0.0001
BC	136.41	1	136.41	34.10	< 0.0001
BD	20.89	1	20.89	5.22	0.0363
CD	216.86	1	216.86	54.22	< 0.0001
A^2	2046.75	1	2046.75	511.71	< 0.0001
B^2	3301.71	1	3301.71	825.46	< 0.0001
C^2	1181.94	1	1181.94	295.50	< 0.0001
D^2	1584.85	1	1584.85	396.23	< 0.0001
Residual	64.00	16	4.00		
Lack of Fit	41.60	10	4.16	1.11	0.4676
Pure Error	22.40	6	3.73		
Cor Total	10746.51	30			

Std. Dev.	2.00	R-Squared	0.9940
Mean	354.80	Adj R-Squared	0.9888
C.V. %	0.56	Pred R-Squared	0.9749
PRESS	270.10	Adeq Precision	43.062

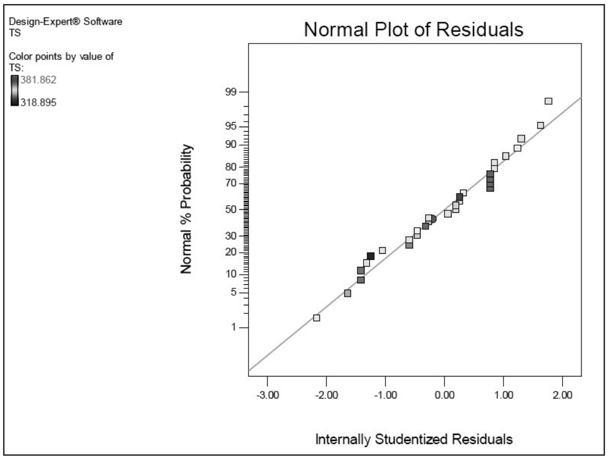

Fig. 2. Normal probability plots for residuals.

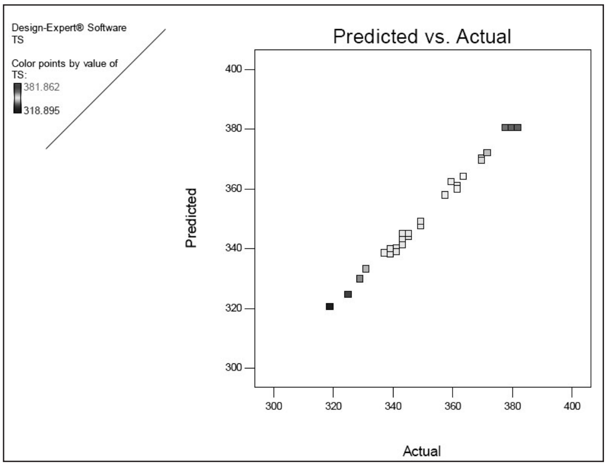

Fig. 3. Correlation graph, predicted Vs actual UTS values.

Table 6
Validation of optimum results.

Optimum condition		Optimum Response value (UTS) MPa	
Predicted by RSM	Actual value	Predicted by RSM	Actual value
Ip-205A, Ib-93A, S-200mm/min, Pon-60%	Ip-205A, Ib-93A, S-200mm/min, Pon-60%	381.40	379.49

ANOVA Table 5 indicates that A-Ip, B-Ib,C-S,D-Pon, AB, AC, AD, BC, BD, CD, A^2, B^2, C^2, and D^2 are significant process parameters. The p-value for Lack of fit is greater than 0.05 and F-value 1.11 indicates that not significant. There is 46.76% chance that lack of fit F-value of this order might happen due to noise.

The coefficient of correlation (R^2) describes the total variation in the observed response values that is explained by the process parameters R^2, always increases with additional process parameters or interaction. So, wherever the more number of process parameters and interactions in the model, higher is the value of R^2. Therefore, R^2 is very useful when comparing models of the same size. Kumar et al. (2007) used RSM to evaluate effect of casting process parameters and developed mathematical model and stated that higher the value of R^2 more is the adequacy of the developed mathematical model. The coefficient of correlation (R^2) for the above developed mathematical model is 99.40%. It is observed that coefficient of correlation (R^2) for all developed model more than 80%. Hence developed mathematical models are adequate and can be use to predict the ultimate tensile strength (UTS).

The "Pred.R-squared" of 0.9749 is in realistic conformity with "Adj R-squared" of 0.9888. "Adeq. precission" (43.062) measures the signal to noise ratio. The normal probability plots of the residuals for UTS are shown in the Fig. 2 it reveals that residuals are declining towards the straight line, indicating the errors are scattered normally [Kumar et al. 2007]. All the above reflection indicates a tremendous adequacy of the developed empirical relationship. Each observed value is compared with the predicted value calculated from the relationship in Fig.3.

3. Optimization of GTAW Process Parameters

The GTAW process parameters are optimized by response surface methodology technique. The Design Expert stastical software is used to optimize process parameters. The response surfaces are constructed for developed empirical relationship (eqn.5) considering two process parameters along X and Y coordinate and response along Z coordinate. The optimal response points are noticeably indicating on the response surfaces. The optimal UTS of GTAW AA7075-T6 alloy is exhibited by the apex of response surface as shown in Fig.4.

The Contour plots show unique circular heap shape which is indicative of possible independence of process parameters with response to display the region of optimal process parameter setting. The optimum value in the contour plot is located by characterizing the shape of the surface. With reference to the book by Montgomery D.C (2001) if contour plots pattern is more circular then it suggest that process parameters are independent while elliptical pattern indicates process parameter interaction. The contour plots for various process parameters shown in Fig.8. The optimal

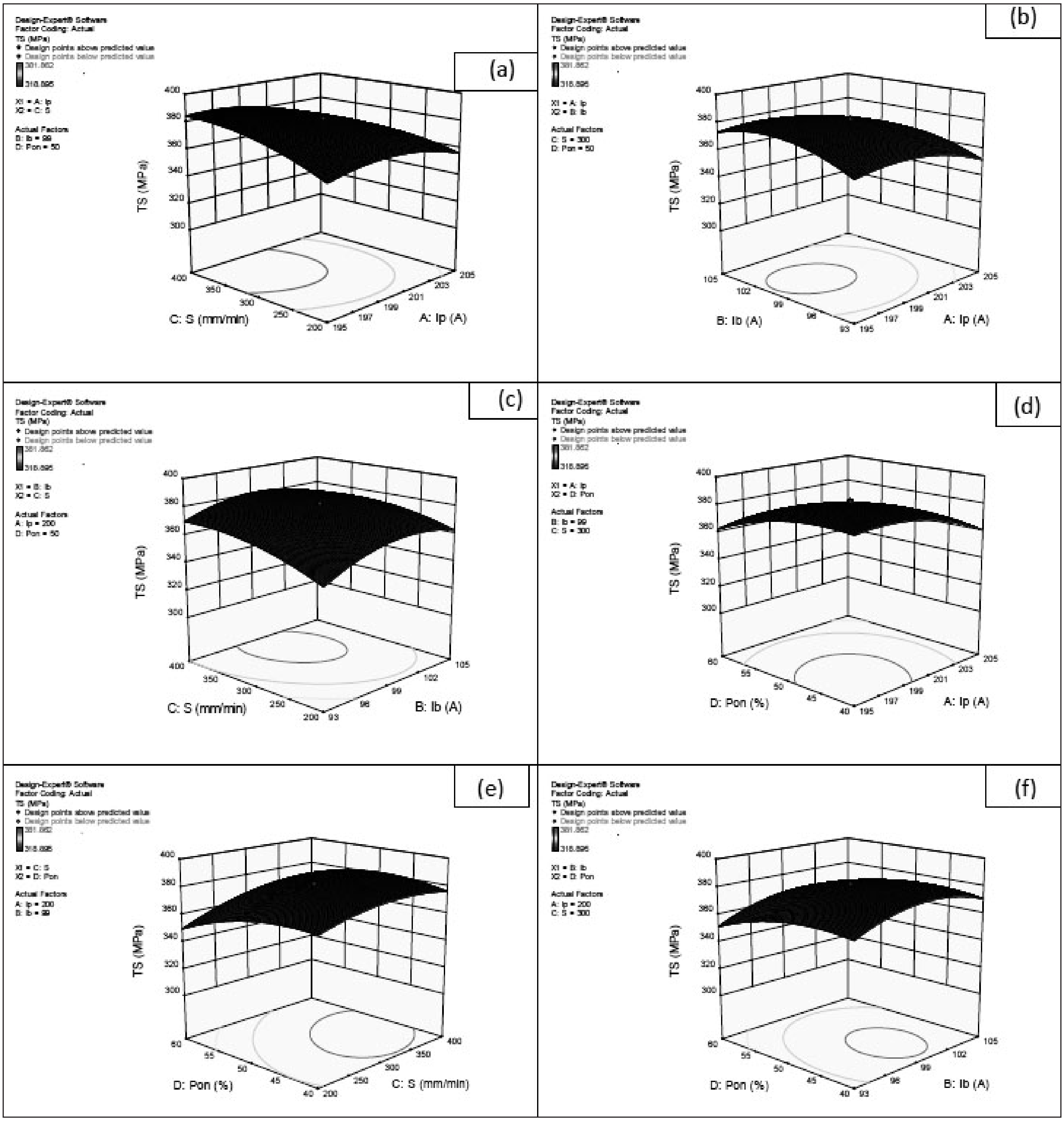

Fig. 4. Response surface graph.

values for various GTAW process parameters predicted by RSM and its optimal response value given in the following Table 6.

4. Analysis of Response Graphs and Contour Plots

The optimum conditions with reasonable precision are obtained by generating response graphs and contour plots for surface analysis using Design Expert software. The regression model gives a three dimensional response graph and contour plots for UTS as shown in the Fig.4 and Fig.8. Fig.4 (a) shows that the apex point of the response surface exhibits optimum value of the UTS at peak current (Ip) 200 A and welding speed (S) 300 mm/min, this is mainly because of equiaxed grain in the weld zone (WZ) of the joint. As the peak current increases, more the heat input and slower the cooling rate, this leads to formation of coarse grains in the weld zone. In contrast, the decrease in the peak current, lower the heat input, faster cooling rate and fine grain structure, but in complete penetration and dilution of base elements with the filler material. This is the cause of decrease in ultimate tensile strength (UTS). When welding speed (S) increase beyond 300 mm/min lesser the contact time with base metal.

Fig.4 (b) shows the variation of UTS with respect to peak current (Ip) and base current lower the base current (Ib) lower the UTS value when base current increased UTS value also increased and it is maximum when base current is 99 A. The increase in UTS value is mainly because of sufficient heat at peak current 200 A and finer grain structure in the weld zone. When the base current increases to 105 A, the UTS value decreases, this is because of coarsening of grain structure in the weld zone.

Fig.4 (c) shows three dimensional response surface plots from the obtained regression model. Surface plot shows that at base current 99 A and welding speed 300 mm/min gives maximum ultimate tensile strength, this is because of fine grain structure in the weld zone. Further increase in welding speed, reduces the heat required for melting the base metal, it leads to lower penetration and decreases the ultimate tensile strength.

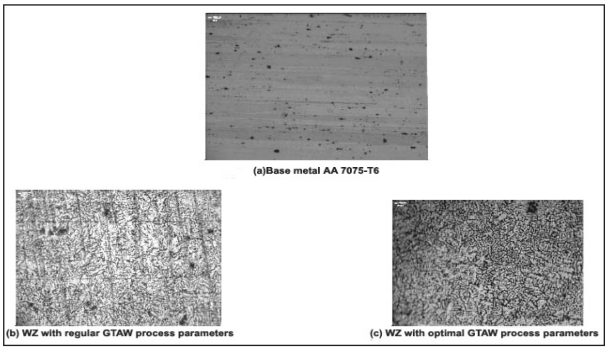

Fig. 5. (a) Base metal AA 7075-T6, WZ with (b) regular GTAW process parameters and (c) optimal GTAW process parameters.

Fig.4(d) shows the three dimensional response surface plots for process parameters peak current and pulse on time, obtained from regression model. The response ultimate tensile strength shows maximum at 200 A peak current and 50% pulse on time, this is because of sufficient heat, penetration and fine grain structure in the weld zone. Pulse on time determines how much percent of a cycle is utilized for, welding the base metal and removing oxide layer from base metal surface. As pulse on time increases more heat in to the weld zone and it creates coarsening of the grain structure.

Fig.4(e) shows the three dimensional response surface plots for process parameters welding speed and pulse on time, obtained from regression model. The response ultimate tensile strength shows maximum at 300 mm/min welding speed and 50% pulse on time, this is because of sufficient heat, penetration and fine grain structure in the weld zone.

Fig.4(f) shows the three dimensional response surface plots for process parameters base current and pulse on time, obtained from regression model. The response ultimate tensile strength shows maximum at 99 A base current and 50% pulse on time, this is because of sufficient heat, penetration and fine grain structure in the weld zone.

The GTAW carried out at the optimal values of; peak current 200 A, base current 99A, welding speed 300 mm/min, and pulse on time 50% and tensile test conducted to determine ultimate tensile strength welded joints. These results correlated

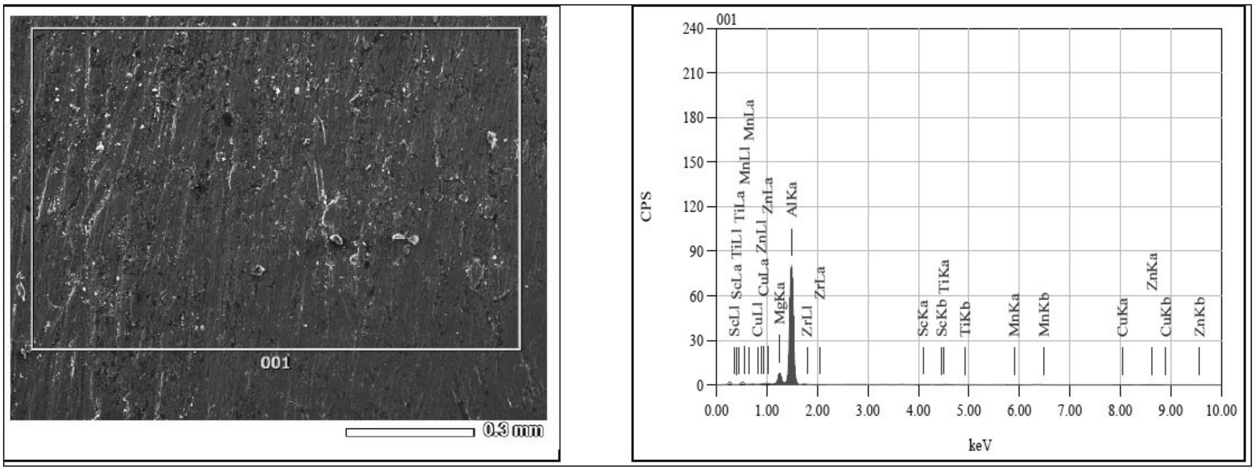

Fig. 6. (a) SEM photographs and (b) EDS of the WZ with optimal GTAW process parameters.

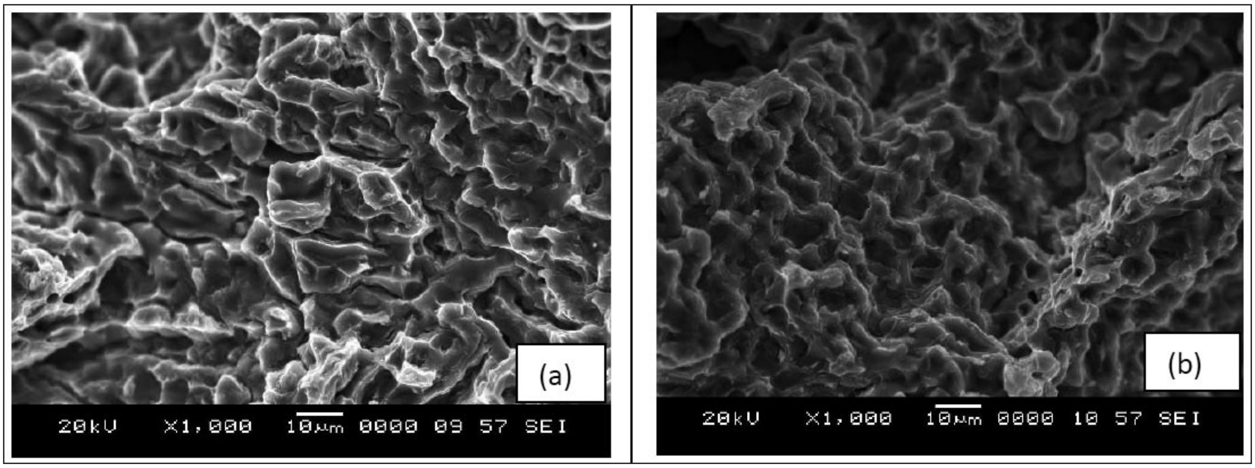

Fig. 7. SEM Fractography of tensile specimens welded at optimized process parameters.

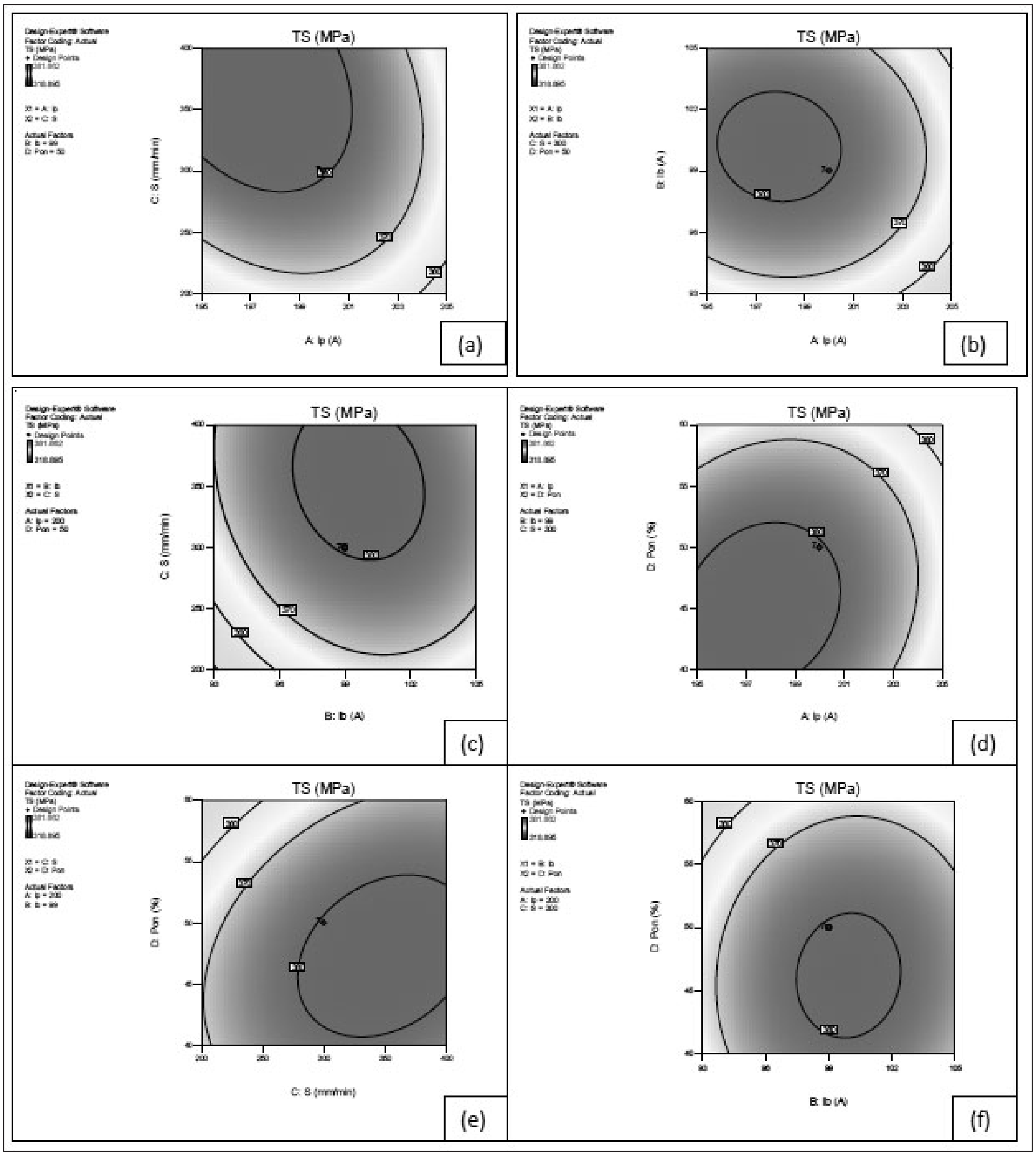

Fig. 8. Contour plots.

with optical micro graphs of base metal and weld zone as shown in Fig. 5.

The strength of the weld joint mainly influenced by grain structure at weld zone from the Fig.5 it reveals that formation of fine grain structure at weld zone is the main reason for increase in ultimate tensile strength of the joint. And also large number of precipitates in the weld zone and moderately spread throughout the weld zone this is also one of the reason for higher tensile strength. The SEM EDS of the weld zone shown in Fig.6 it indicates presence of zinc, magnesium, elements with its precipitates.

The optimized process parameter improved in the mechanical properties of welded joint. This improvement in the mechanical properties is correlated with fractography as shown in the Fig.7. There is a significant difference found in the size of the dimples with respect to the optimal GTAW process parameters in welding of AA7075-T6 alloy. Fine dimples are seen in optimal GTAW process parameters in weld joint (Fig.7), fine dimples are characteristic feature of ductile materials and hence optimal GTAW process parameters joints have shown higher ductility compared to traditional GTAW process parameters weld joint.

The Fig.8 shows the contour plots for developed regression model, from Fig.8 (a) it is observed ultimate tensile strength (UTS) is more sensitive when changes welding speed (S) compared to peak current (Ip), Fig.8 (b) shows that variation in UTS is more sensitive for peak current (Ip) compared to base current (Ib), Fig.8 (c) shows that variation in UTS is more sensitive for welding speed (S) compared to base current (Ib), Fig.8 (d) shows that variation in UTS is more sensitive for peak current (Ip) compared to pulse on time (Pon), Fig.8 (e) shows that variation in UTS is more sensitive for welding speed (S) compared to pulse on time (Pon), Fig.8 (f) shows that variation in UTS is more sensitive for base current (Ib)compared to pulse on time (Pon), peak current (Ip).

4. Conclusion

The following conclusions are drawn from the experimental results conducted during the present work.

i) The developed empirical relationship may be used in industry for predicting the ultimate tensile strength of AA7075-T6 welded joints at 95% confidence level.

ii) Automatic GTAW by preplacing the filler wire in to groove of weld gives better bead appearance, good penetration, and bead contour.

iii) Higher the Peak current lead to increase in the tensile properties, microhardnes, and penetration (A). Where as in base current (Ib), welding speed (S) inversely proportional to ultimate tensile strength (UTS), i.e. if base current (Ib), welding speed (S) are increased, the ultimate tensile strength decreases.

iv) The maximum ultimate tensile strength of 354 MPa is obtained at optimal GTAW process parameters of Peak current (Ip) =205 A, Base current (Ib) = 93 A, welding speed (S) =200 mm/min, Pulse on time (Pon) =60%.

v) There is improvement in ultimate tensile strength when AA7075-T6 alloy welded by optimal AC pulse GTAW process parameters compared to traditional process parameters. This is mainly due to reduction in porosity and formation of fine precipitates.

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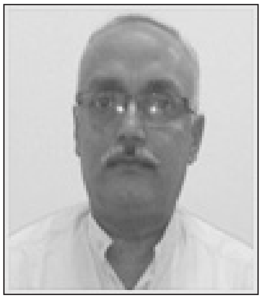

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