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Optimization of Process Parameters in Arc Welding On Material Mild Steel

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Abstract: The aim of this paper is to predict and optimize ARC welding of mild steel in house hold purpose, through applying tensile loads in ANSYS software, working practically on material and optimizing the welding operation by controlling selected welding parameters; tapered angles and welding current, to relate the ultimate tensile strength to the selected input welding parameters. The materials studied in this work are Mild steel. The experimental results which are obtain corresponding to the effect of different Tapered angles(30,45,60), and different welding currents (100,130and160Amp), on ultimate tensile strength of welding MILD STEEL , are use to find out the significance of input parameter on output by experimenting on UTM and thermal analysis in ANSYS software. This result shows its better ultimate tensile strength prediction capability and applicability to various purposes by ARC welding leading to effective selection of machining parameter for better ultimate tensile strength.

Keywords: Ultimate tensile strength, ARC welding, Modeling-PROE, Universal Tensile Machine-UTM, Thermal Analysis-ANSYS

I. INTRODUCTION

Welding is a manufacturing process of creating a permanent joint obtained by the fusion of the surface of the parts to be joined together, with or without the application of pressure and a filler material. The materials to be joined may be similar or dissimilar to each other. The heat required for the fusion of the material may be obtained by burning of gas or by an electric arc. The latter method is more extensively used because of greater welding speed.

Welding is extensively used in fabrication as an alternative method for casting or forging and as a replacement for bolted and riveted joints. It is also used as a repair medium e.g. to reunite a metal at a crack or to build up a small part that has broken off such as a gear tooth or to repair a worn surface such as a bearing surface.

Arc welding is the process, in which heat is generated by an electric arc struck between an electrode and a work piece or between two electrodes. Electric arc is luminous electrical discharge between two electrodes through ionized gas. This electric arc between the electrode and work piece close the electric circuit and create temperature up to 3600^0C, which is sufficient for fusion the work piece edges and join together. Most of these processes use some shielding gas while others employ coatings or fluxes to prevent the weld pool from the surrounding atmosphere. Joining of dissimilar metals has found its use extensively in power generation, electronic, nuclear reactors, petrochemical and chemical industries mainly to get tailor- made properties in a component and reduction in weight. However efficient welding of dissimilar metals has posed a major challenge due to difference in thermo-mechanical and chemical properties of the materials to be joined under a common welding condition. This causes a steep gradient of the thermo-mechanical properties along the weld. A variety of problems come up in dissimilar welding like cracking, large weld residual stresses, migration of atoms during welding causing stress concentration on one side of the weld, compressive and tensile thermal stresses, stress corrosion cracking, etc., Now before discussing these problems coming up during dissimilar welding, the passages coming below throw some light on some of the causes of these problems.

In dissimilar welds, weldability is determined by crystal structure, atomic diameter and compositional solubility of the parent metals in the solid and liquid states. Diffusion in the weld pool often results in the formation of inter metallic phases, the majority of which are hard and brittle and are thus detrimental to the mechanical strength and ductility of the joint.

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The thermal expansion coefficient and thermal conductivity of the materials being joined are different, which causes large misfit strains and consequently the residual stresses results in cracking during solidification.

A. Welding process variables

Weld quality and weld deposition rate both are influenced very much by the various welding parameters and joint geometry. Essentially a welded joint can be produced by various combinations of welding parameters as well as joint geometries.

These parameters are the process variables which control the weld deposition rate and weld quality. The weld bead geometry, depth of penetration and overall weld quality depends on the following operating variables. Electrode size, Welding current, Welding voltage, Arc travel speed, Welding position Gas Flow rate, Shielding Gas composition, Electrode extension (length of stick out).

S. A. A. Akbari Mousavi *et al* [1], During friction welding, temperature, stress, strain, and their variations govern welding parameters, and knowledge of them helps determine optimum parameters and ways to improve the design and manufacture of welding machines. . The effects of initial and final pressure on internal parameters are discussed. Moreover, the metallographical examinations, hardness, and tensile tests of the samples were carried out. In addition, in this study, the operational parameters of the friction welding process are related to the physical parameters of the process. Monika K. *et al*. **[3],** analyzed the Mechanical Properties of MIG Welded Dissimilar Joints under the effect of heat input. Welding current, voltage and speed of wire determines the heat input. The IS 2062, IS 45 C8, IS 103Cr1 were used as a base material.1.2mm diameter copper coated mild steel was used as a filler wire. The both joints (IS 2062 & IS 45 C8) and (IS2062 & IS 103 Cr1) increased the tensile strength when increased with the heat input and also increased the hardness value when decreased with the heat input.

M. Aghakhani *et al*. [4], have done work on optimization of gas metal arc welding process parameter for increase quality and productivity of weldment. In this research work for increasing quality and productivity of weldment they have considered weld dilution as output parameter and effect of input parameter wire feed rate (W), welding voltage (V), nozzle-to-plate distance (N), welding speed (S) and gas flow rate (G) was found on it. The base material use for experiment is ST-37 steel plate and the mixture of 80% argon and 20% CO2 is use as shielding gas. The experiment was designed by Taguchi's L25 orthogonal array and analysis was carried out by ANOVA method also they develop mathematical model for weld dilution. From the experimental result they found that the wire feed rate has the most significant effect on the weld dilution while gasflow rate has no effect on weld dilution. **C. N.** Patel *et al*. [5], evaluated the parameters; welding current, wire diameter and wire feed rate to investigate their influence on weld bead hardness for MIG welding and TIG welding by Taguchi's method and Grey Relational Analysis (GRA). From the study it was concluded that the welding current was most significant parameter for MIG and TIG welding. By use of GRA optimization technique the optimal parameter combination was found to be welding current, 100 Amp; wire diameter 1.2 mm and wire feed rate, 3 m/min for MIG welding. Sheikh Irfan *et al*. [6], have done experimental study to find the effect of MIG welding process parameter for decrease the depth of penetration in weldability of galvenized steel. In this research work the welding current, arc voltage, welding speed, are chosen as welding parameters. The mixture of Argon-78%, Carbon Dioxide-20% and 2% Oxygen is considered as shielding gas. From the experiment they found that the penetration will increase with increase of speed of travel at constant arc voltage and current. Ghazvinloo H.R. *et al*. [8], analyzed robotic MIG welding AA6061 fatigue life, impact and bead penetration properties under the effect of welding speed, voltage and current.2.35 mm and 10mm thickness 60 degree V groove plates were welded by using 1mm diameter ER5356 filler material. The welding parameters welding speed, voltage and current were varied during the process. The increased voltage and current reduced the fatigue life but the welding speed increased the fatigue life. Decreased welding speed and increased current voltage improved the impact energy. Bead penetration mainly influenced and depends on the welding current. Pawan Kumar et *al*. [9], have investigate the use of Taguchi's parameter design methodology for parametric study of gas metal arc welding of dissimilar material. In this research work they have considered the AISI 304 and low carbon steel as base material and CO_2 as shielding gas. The parameters considered for experiment were welding current, welding voltage and gas flow rate as input parameter and tensile strength and Hardness (PM, WZ and HAZ) as output parameter. Form the analysis they found that the optimum parameter value for tensile strength are 25 V current is most significant parameter for tensile strength and it is effected by 52.45 %. Also they conclude the Taguchi method is very good approach for improve the hardness**.**

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Pradip D. Chaudhari *et al.* [7], have investigate the effects of welding process parameters of Gas Metal Arc Welding (GMAW) on tensile strengths of SS 3Cr12 steel material specimen. In this research work the welding voltage, wire feed rate, welding seed and gas flow rate were considered as inflating input parameter. The experiment was designed by central composite design matrix and the analysis was done by using Minitab software. From the analysis they found that the tensile strength was increasing with increasing with increase the value of welding speed and gas flow rate whereas the increasing with decrease the value of wire feed rate and welding voltage.

II. Experimental Setup and Design of Experiment

A. AC or DC arc welding machine

Adapted powerful MOSFET to change the supply frequency (up to 100KHZ), and then to come down the voltage as well as to change the AC current to DC current by the circuit, and eventually to turn out the powerful DC supply under the support of the PWM adjustment technology; in such an inverter design circuit, the weight and volume of main transformer comes down dramatically, and its efficiency is over 30% increased instead.

B. Standard Accessories:

Earth Clamp with Cable, ARC Holder with Cable

Parameter	ARC 200Amps-1 Phase Mosfet
Parameter model	Arc 200 1p
Input voltage (V)	Ac230+-15%
Frequency(HZ)	50/60
Rated input current(A)	43.6
No-load voltage (V)	58
Output current range(A)	10-200
Input power capacity(KVA)	6
Duty cycle (%)	60
No-load loss(W)	40
Efficiency (%)	80
Power factor	0.73
Insulation grade	F
Housing protection grade	IP21
Net weight(kg)	8
Dimension(inch)	15.5x 6 x 11.5

C. Work piece material

Material selection in manufacturing process is most important think as per process availability and customer's requirement. There is number of material used in modern industry but steel have corrosion resistive property and IS 2062 steel are shown in table 1.1

Table 1: Chemical composition of material and IS: 2062 Specification of Mild Steel for Fabrication

Chemical Composition					
Grade	C%	Mn%	S%	P%	Si%
	Max.	Max.	Max.	Max.	Max.
I	0.12	0.5	0.05	0.05	0.08
II	0.2		0.05	0.05	
III	0.3		0.05	0.05	

Mechanical Properties			
Grade	UTS(Min)	YS(Min)	EL
	Mpa	Mpa	5.65 Min So
I	330	210	25
II	410	240	20
III	540	310	15

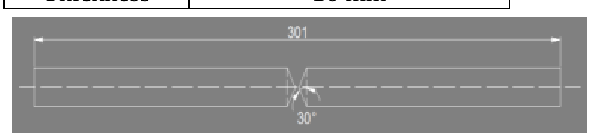
Filler metal

The filler material use for the experiment is copper coated MS material electrodes with size of 3.15mm diameter.

Sample preparation

Mild steel round bars with the dimensions of 150mm in length and 16mm dia are prepared with the tapered level of 5mm, the tapered angle of these specimens are then welded with a root gap distance 1 millimeter. Figure shows the tapered groove butt joint preparations.

Material	Mild Steel
Grade	IS-2062
Length	150 mm
Thickness	16 mm



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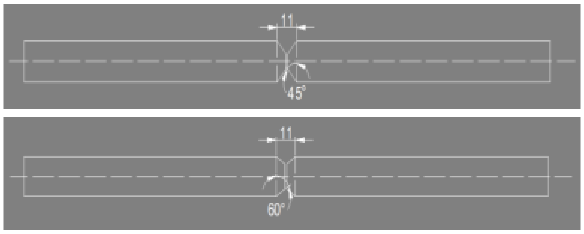

Fig 1. Sample preparation

After preparation, plates are placed on the workbench. In each placement, distance between the nozzle and workpiece and the electrode extension were 20 and 10 millimeter, respectively. The welding electrode is held perpendicular to the welding surface. Welding is started and the flow rate of shielding gas is adjusted by using knob. The plates were welded at three passes.

Fig.2. tapered angled and welded mild steel rods

III. Results And Discussions

A. Experimental set up for Ultimate Tensile Strength measurement

The whole experimental investigation were done using 'FIE' Electronic Universal Testing machine (UTM), model UTS-100 which can be used for conduction test in tension, compression and transverse test of metals and other material. Maximum capacity of the machine is of 400 kN with measuring range between 0 to 400 kN. The accuracy of measurement of the machine is ± 5.0 kN Because load required for extrusion is of compressive type so, experiments were conducted using compression test. M/C Specifications: Capacity: 400KN. Model:MUT-40.SR.No:2013/1073.Mfd. By: Krystal Equipments, Ichalkaranji, M.S, India.

B. Ultimate Tensile strength measurement

Tensile testing was done using ASME Section IX-2004 standards. The equipment used was a UTM Machine with a maximum capacity of 1000 kN. The welded specimen was prepared according to the procedures given in ASME Section ix-2004 and typical dimensions of the specimen are shown below in fig.3

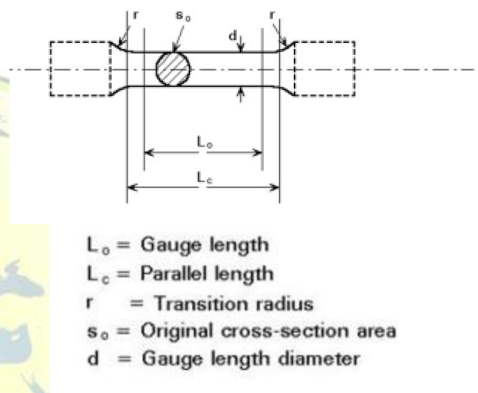

Fig.3. Geometry of standard specimen used in UTM to measure tensile strength

Table 2: Tensile strength results for MS rods at different tapered angle and temperature by UTM.

S.No	Tapered angle	Temp. In ^{0}C	Ultimate tensile load KN	Ultimate tensile Strength N/mm^2	Displacement at Load
1	30	100	69080	343	6.6
2	45	100	76640	381	12.4
3	60	100	86,240	428	16.4
4	30	130	76640	381	12.4
5	45	130	81640	406	10.8
6	60	160	86400	429	13.8
7	30	160	69080	343	6.6
8	45	160	71760	356	9.8
9	60	130	87800	436	17.9

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c. Thermal Phenomena

A thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are: The temperature, distributions, the amount of heat lost or gained, thermal gradients and Thermal fluxes. Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate thermal stresses (that is, stresses caused by thermal expansions or contractions).

Table 2: Tensile strength results for MS rods at different tapered angle and temperature by UTM.

S. No	Max. Load	Breakin g Load KN	Breaking Stress N/mm^2	Yield Load KN	Yield Stress N/mm2
1	7.2	36920	183	67600	0.306
2	12.8	51680	257	68,680	0.341
3	17.4	49,240	244	56280	0.286
4	12.8	51680	257	68680	0.341
5	11.3	75240	374	42160	0.216
6	14.2	85720	426	70280	0.351
7	7.2	36920	183	67600	0.306
8	10.4	67320	334	68480	0.341
9	18.7	24840	223	67560	0.336

The finite element solution you perform via Mechanical APDL calculates nodal temperatures, and then uses the nodal temperatures to obtain other thermal quantities. The ANSYS program handles all three primary modes of heat transfer: conduction, convection, and radiation. Mild steel specimens designed using ANSYS software for thermal analysis at different tapered without assembly and with assembly is shown in figure 7 and 8 respectively.

The finite element solution you perform via Mechanical APDL calculates nodal temperatures, and then uses the nodal temperatures to obtain other thermal quantities. The ANSYS program handles all three primary modes of heat transfer: conduction, convection, and radiation. Mild steel specimens designed using ANSYS software for thermal analysis at different tapered without assembly and with assembly is shown in figure 7 and 8 respectively.

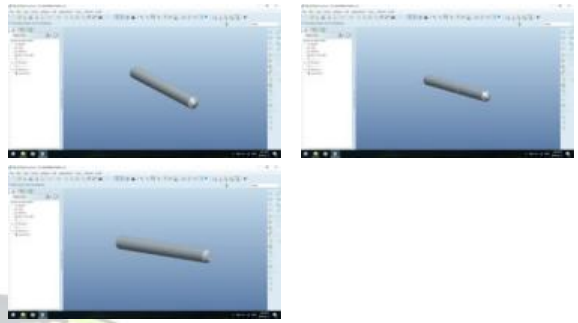

Fig 4: Mild steel Specimens designed in ANSYS at different tapered angle (a) MS_30 deg (b) MS_45 deg (c) MS_60 deg

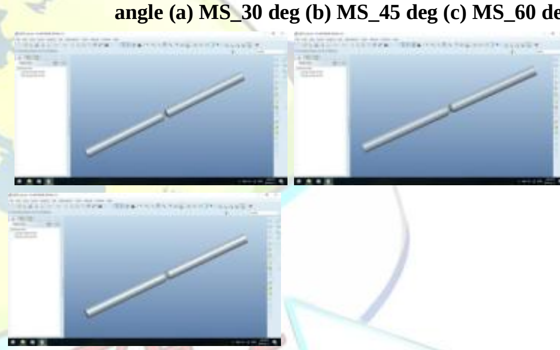

Fig 5: Mild steel assembled Specimens designed in ANSYS at different tapered angle (a) MS_30 deg (b) MS_45 deg (c) MS_60 deg

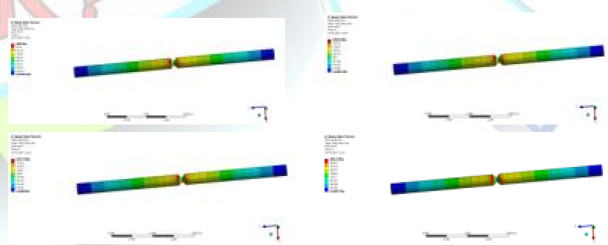

Fig 6: Total heat flux of assembled mild steel at 45^0_(a) 180 x 250 (b) 180 x 350 (c) 180 x 450 (d) 180 x 550

Internal Heat Generation in the Mild Steel at 250 deg c at 45 deg tapered with the electrode temperature of 180 deg c, and Fig.9 shows the total heat flux distribution at the time of welding. Internal Heat Generation in the Mild Steel at 350 deg c at 45 deg tapered with the electrode temperature of 180 deg c, and Fig.9 shows the total heat flux distribution at the time of welding. Internal Heat Generation in the Mild Steel at 450 deg c at 45 deg tapered with the electrode temperature of 180 deg c, and Fig.9 shows the total heat flux

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distribution at the time of welding. Internal Heat Generation in the Mild Steel at 550 deg c at 45 deg tapered with the electrode temperature of 180 deg c, and Fig.9 shows the total heat flux distribution at the time of welding. Table 3 shows the heat flux values at different internal heat.

Table 3: MS_45_assembled_total_heat flux

Internal heat generation of material	Temperature of electrode	Total Heat Flux
250	180	1096
350	180	1534.4
450	180	1972.7
550	180	2411.1

Internal Heat Generation in the Mild Steel at 45 deg tapered specimen with the electrode temperature of 180 deg c constant, and Fig.9 shows the total heat flux values at different temperatures at the time of welding.

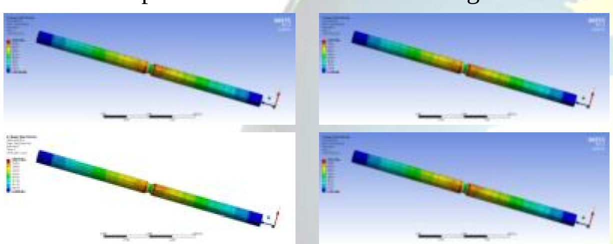

Fig 7: Total heat flux of assembled mild steel at 60⁰_(a) 180 x 250 (b) 180 x 350 (c) 180 x 450 (d) 180 x 550

Internal Heat Generation in the Mild Steel at 250 deg c at 60 deg tapered with the electrode temperature of 180 deg c, and Fig.10 shows the total heat flux distribution at the time of welding. Internal Heat Generation in the Mild Steel at 350 deg c at 60 deg tapered with the electrode temperature of 180 deg c, and Fig.10 shows the total heat flux distribution at the time of welding. Internal Heat Generation in the Mild Steel at 450 deg c at 60 deg tapered with the electrode temperature of 180 deg c, and Fig.10 shows the total heat flux distribution at the time of welding. Internal Heat Generation in the Mild Steel at 550 deg c at 60 deg tapered with the electrode temperature of 180 deg c, and Fig.10 shows the total heat flux distribution at the time of welding. Table 4 shows the heat flux values at different internal heat.

Table 4: MS_60_assm_total_heat flux

Internal heat generation of material	Temperature of electrode	Total Heat Flux
250	180	1028
350	180	1439.5
450	180	1880.8
550	180	2262.1

Internal Heat Generation in the Mild Steel at 60 deg tapered specimen with the electrode temperature of 180 deg c, and Figure shows the total heat flux values at different temperatures at the time of welding.

Figure shows the failure design of the specimen at an angle of 30 deg since the pressure developed in the area of weld is not withstanding and hence the design is a failure. The above diagram shows the procedure of the analysis on the specimen.

Analysis report: Element Type = Solid90, Total Nodes = 2202, Contact Elements = 56, Solid Elements = 420

Total Elements = 476, Electrode temperature = 180°c, Internal heat generation = 250°c, 350°c, 450°c, 550°c, Thermal conductivity = K = 36 W/m-K, Initial temperature = 30°c

UTM Results and Heat Flux Graph

Total Heat Flux Graph

Figure 8 shows the graph is used to analyze the internal heat generation of the specimen at temperatures 250 deg c, 350 deg c, 450 deg c, 550 deg c and the result is the lower the internal heat generation the higher the feasibility of specimen. The graph is used to analyze the internal heat generation of the specimen at temperatures 250 deg c, 350 deg c, 450 deg c, 550 deg c and the result is the lower the internal heat generation the higher the feasibility of specimen.

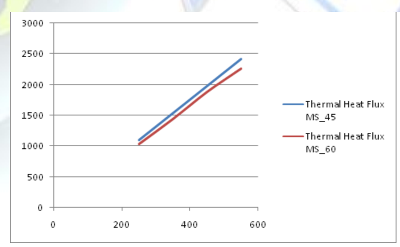

Fig. 8: Combined assembly total heat flux

The graph is used to analyze the internal heat generation of the specimen at temperatures 250 deg c, 350 deg c, 450 deg c, 550 deg c and the result is the lower the internal heat generation the higher the feasibility of specimen and hence the MS_60⁰ is feasible for the current experiment.

Ultimate Tensile Strength Graph

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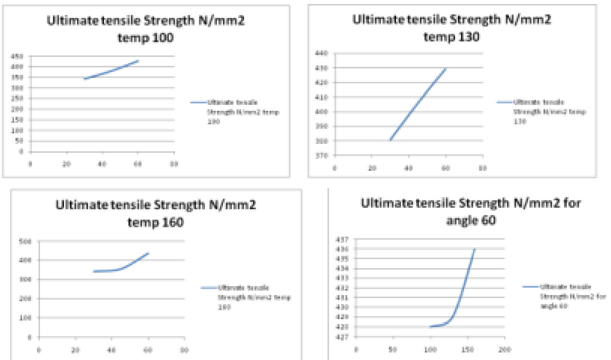

Fig 9: Tapering angle verses Ultimate tensile strength at temperatures (a) 100 deg c (b) 130 deg c (c) 160 deg c (c) MS angle 60

The graph is used to analyze ultimate tensile strength at various angles (30 deg, 45 deg, 60 deg) at constant temperature of 100deg c. The graph is used to analyze ultimate tensile strength at various angles (30 deg, 45 deg, 60 deg) at constant temperature of 130 deg c. The graph is used to analyze ultimate tensile strength at various angles (30 deg, 45 deg, 60 deg) at constant temperature of 160 deg c. The graph is used for the analyzing of ultimate tensile strength for various temperatures of welding parameters at an angle of 60 deg. At the temperature 160 deg c, the strength of the specimen is higher compare to other temperatures (100 deg c, 130 deg c, 160 deg c).

Ultimate tensile strength vs Total heat flux at constant angles 45, 60 deg.

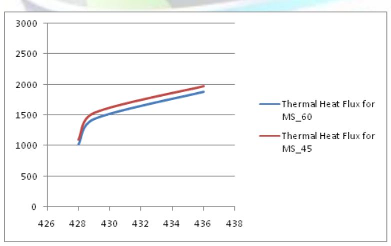

Fig 10: Ultimate tensile strength verses Total heat flux at constant angles 45, 60 deg

Figure 10 shows the graph is used to analyze the utm results to the total heat flux of the specimen, and by this the lower the total heat flux of MS_60 is the higher feasible than the higher total heat flux of MS_45 .

IV. Conclusion

In this paper, Experiments are carried out for ultimate tensile strength with respect to variation of current and angles of tapered-butt joint. There are 9 experimental readings taken for all variations in input parameter and they are used to conduct the parametric study for optimization of welding process parameter during welding of Mild Steel material.

The experimental results shows that the ultimate tensile strength will increase or decrease for the different angles. It is shown that the ultimate tensile strength increased with increase of current and voltage. Also from the experimental result, it shows that the ultimate tensile strength is increase initially with increase of current.

Since the filler material of the electrode is not deposited properly and the welding was not done properly are leads to failure of the material at the welding spot has took place.

The ANSYS 17.2 academic version, the analysis shows that the material MS is described by the total heat flux, and as the internal heat generation of the material is increasing which results in increase of the total heat flux will be safe when it is welded keeping an angle of 60^0 at lower, the internal heat generation at 250°c and in thermal analysis we can see that the total heat flux of the material and heat affected zone, total deformation at various angles by varying input parameters. By using UTM we will be able to know the maximum strength of the material and as the total heat flux generated in the material should be lesser for the selection of feasible material.

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