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Experimental Investigation to Determine Optimum Welding Parameters for MIG Welding

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Abstract: Metal Inert Gas welding is one of the most widely used processes in industry. The input parameters play a very significant role in determining the quality of a welded joint. In fact, weld geometry directly affects the complexity of weld schedules and thereby the construction and manufacturing costs of steel structures and mechanical devices. Therefore, these parameters affecting the arc and welding should be estimated and their changing conditions during process must be known before in order to obtain optimum results; in fact a perfect arc can be achieved when all the parameters are in conformity. In this thesis, MIG welding is performed on the mild steel pieces. Different mild steel pieces are welded by varying the currents, 180amp, 200amp and 230amps and weld speeds 3mm/sec, 3.5mm/sec and 4mm/sec. The hardness and tensile tests are performed to determine the optimal welding currents and weld speeds. Taguchi method is used to determine the optimal process parameters for high tensile strength and hardness. Thermal analysis and structural analysis is performed to determine the heat transfer rates and the strength of the pieces at the applied load respectively. Modeling is done in Pro/Engineer and analysis is done in Ansys.

Keywords: MIG, Welding Machine.

I. INTRODUCTION

Metal Inert Gas welding is one of the most widely used processes in industry. The input parameters play a very significant role in determining the quality of a welded joint. In fact, weld geometry directly affects the complexity of weld schedules and thereby the construction and manufacturing costs of steel structures and mechanical devices. Therefore, these parameters affecting the arc and welding should be estimated and their changing conditions during process must be known before in order to obtain optimum results; in fact a perfect arc can be achieved when all the parameters are in conformity. These are combined in two groups as first order adjustable and second order adjustable parameters defined before welding process. Former are welding current, arc voltage and welding speed. These parameters will affect the weld characteristics to a great extent. Because these factors can be varied over a large range, they are considered the primary adjustments in any welding operation. Their values should be recorded for every different type of weld to permit reproducibility. The illustration that follows provides a look at a typical MIG welding process showing an arc that is formed between the wire electrode and the work piece. During the MIG welding process, the electrode melts within the arc and becomes deposited as filler material as shown in Fig.1. The shielding gas that is used prevents atmospheric contamination from atmospheric contamination and protects the weld during solidification. The shielding gas also assists with stabilizing the arc which provides a smooth transfer of metal from the weld wire to the molten weld pool.

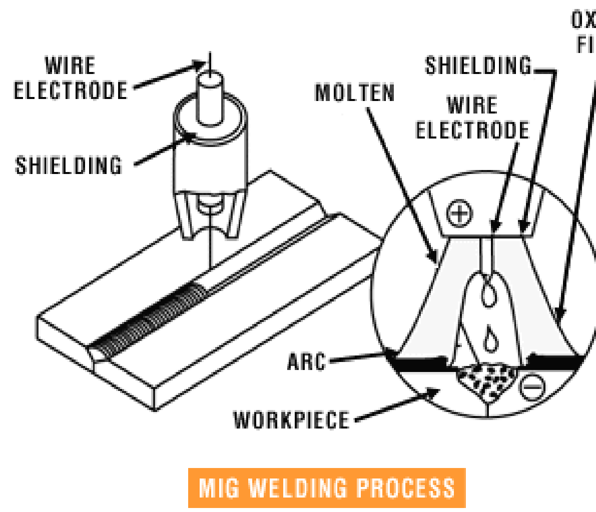


Fig.1 MIG welding process.

Versatility is the major benefit of the MIG welding process. It is capable of joining most types of metals and it can be performed in most positions, even though flat horizontal is most optimum.

II. EXPERIMENTAL INVESTIGATION AND TESTING OF MIG WELDING OF MILD STEEL PIECES

Experimental investigation is done to verify the mechanical properties of MIG welding of mild steel. The properties investigated are tensile strength and hardness compared before and after welding. The welding is done on Conventional MIG welding machine as shown in Fig2.

Fig.2. MIG Welding Machine.

A. Machine Specifications

MODEL	MIG-180	MIG-250	MIG-350	MIG-400
Input Supply! V)	U220/230	3x380/415	3x380/415	3x380/415/440
Frequency (Hz)	50	50	50	50
Off-Load Voltage(VDC)	15-34	17-36	17-38	18-50
Max. Welding Current	120	200	230	315
Load 100%				
Load 60%	140	250	275	400
Load 40%	180	-	350	-
Welding Current (A)	30-180	50 - 250	50 - 350	60 - 400
(Min. lo Max.)				
Power Consumption(KVA)	6.2	9	13.5	20
Voltage Level	9	10	20	36
Inductance Tapping	2	2	2	3
Insulation (Class)	H	H	H	H
Cooling	Fan	Fan	Fan	Fan
IS Cum forms to	7931	7931	7931	7931
Fuse Rating (A)	DP 16/25	TP 16	TP 16/25	TP 25/32
Cross section of input	2x4	3x2.5	3x4	3x4
cable (mm2)				
Rectifier Bridge	SIL Diodes.	SIL Diodes.	SIL Diodes.	SIL Diodes.
Cross section of Weld	16/25	25/35	35/50	50
Cable (mm2)				
Dimension (LXBXH) cm	50x35x59	58x40x59	63x45x59	83x52x75
Weight	60	80	95	140

Fig.3.Machine Specifications.

The table below specifies the process parameters used for welding different pieces as shown in Figs.4 to 8.

TABLE I: Process Parameters And Their Values

SAMPLES	CURRENT (amps)	WIRE FEED RATE (mm/sec)
Sample 1	180	3
Sample 2	200	3.5
Sample 3	230	4

Fig.4.Welding Process is being done.

Fig.5. Welding on pieces.

Fig.6. Welding on pieces.

Fig.7. Final Welded Pieces.

Fig.8.Final Welded Pieces.

B. Tensile Test And Hardness Test Results

1. Tensile Test

Type of test – Mechanical Tensile

Machine Model – TUE-C-600

Machine Serial No – 2008/23

Fig.9.8- UTM – 600.

2. Technical Specifications of UTM

Model	UTM - 100	UTM - 200	UTM - 400	UTM - 600	UTM - 1000
Capacity KN	100	200	400	600	1000
1ST Range KN Least Count KN	0-100 0.2	0-200 0.4	0-400 0.8	0-600 1	0-1000 2
II nd Range KN Least Count KN	0-50 0.1	0-100 0.2	0-200 0.4	0-300 0.5	0-500 1
IIIrd Range kN Least Count kN	0-25 0.05	0-50 0.1	0-100 0.2	0-120 0.2	0-250 0.5
IV th Range KN Least count KN	0-10 0.02	0-20 0.04	0-40 0.08	0-60 0.1	0-100 0.2
Max. Tensile Clearance or full decended piston position mm	50-700	50-700	50-700	50-800	50-850
Max. clearance for compression test mm.	0-700	0-700	0-700	0-800	0-850
Distance between columns mm	450	500	500	600	750
Piston stroke mm	150	200	200	250	250
Max. Straining speed of No load mm/min	300	150	150	100	80
Power supply	3 phase	440 volts	50 cycles	A.C.	
H.P. (Total)	1.5	1.5	2.5	2.5	4
Overall Dimensions (Approx) mm	1950x800x1850	2000x800x1900	2100x800x2060	2200x800x2400	2350x800x2700
Weights in kgs.(Approx)	1300	1400	2300	3200	5100

Fig.10.Specimen Description – 30x12x3 mm.

TABLE II: Load, UTS Values

	BEFORE WELDING
MTERIAL	TENSILE STRENGTH (N/mm²)
MILD STEEL	250

	LOAD AT PEAK (KN)	UTS (MPa)
Sample 1	14.18	315.45
Sample 2	19.21	392.865
Sample 3	22.31	445.195

3. Brinell Hardness Test

Machine Details

Equipment Used – BRINELL / ROCKWELL HARDNESS TESTER

Machine Model – 2008/073, MRB 250, MAKE: META – TEST

Fig.11. Brinell/Rockwell hardness tester.

Metal testing requires various stages and Rockwell Cum Brinell Hardness Tester is essential for calculating the hardness of metal as shown in Fig.11. The process is automated and you can rely on the automatic load selection in accordance to the varying sample. They can measure the hardness of metal and its alloys irrespective of their natural hardness and softness.

Test Details:
Test Method – ASTM E10-15
Test Method – HARDNESS (BRINELL)
Hardness of Mild Steel – 120HRB

TABLE III: Hardness Values

	Location	Hardness value
Sample 1	Weld zone	76HRB
Sample 2	Weld zone	81 HRB
Sample 3	Weld zone	88 HRB

III. TAGUCHI PARAMETER DESIGN FOR MIG WELDING PROCESS

In order to identify the process parameters affecting the selected machine quality characteristics of welding, the following process parameters are selected for the present work: Current (A), Wire Feed Rate (B). The selection of parameters of interest and their ranges is based on literature experiments conducted.

A. Selection of Orthogonal Array

The process parameters and their values are given in table. It was also decided to study the two – factor interaction effects of process parameters on the selected characteristics while machining Mild Steel. These interactions were considered between Current, Wire Feed Rate (AxB).

TABLE IV:

FACTORS	PROCESS PARAMETERS	LE VEL1	LEVEL2
A	CURRENT (Amps)	180	230
B	WIRE FEED RATE (mm/sec)	3	4

B. Results

Using randomization technique, specimens were machined and Tensile Strength and Hardness were measured. The experimental data for the Tensile Strength and Hardness have been reported in Tables. Tensile Strength and Hardness 'larger the better' type of machining quality characteristics, the S/N ratio for this type of response was and is given below:

$$\text{S/N ratio} = -10 \log\left[\frac{1}{n}(y_1^2 + y_2^2 + \ldots + y_n^2)\right] \quad (1)$$

Where $y_1, y_2, \ldots, y_n$ are the responses of the machining characteristics for each parameter at different levels.

C. Taguchi Orthogonal Array

TABLE V: TAGUCHI ORTHOGONAL ARRAY OBSERVATION

JOB NO.	CURRENT (Amp)	WIRE FEED RATE (mm/sec)
1	180	3
2	180	4
3	230	3
4	230	4

TABLE VI: OBSERVATION

JOB NO.	CURRENT (Amp)	WIRE FEED RATE (mm/sec)	ULTIMATE TENSILE STRENGTH (N/mm²)	HARDNESS (HRB)
1	180	3	315.45	76
2	180	4	320.714	78
3	230	3	445.195	88
4	230	4	458.213	90

IV. 3D MODELING AND ANALYSIS OF WELDED PIECES

3D model of the welded pieces is done in Creo 2.0.

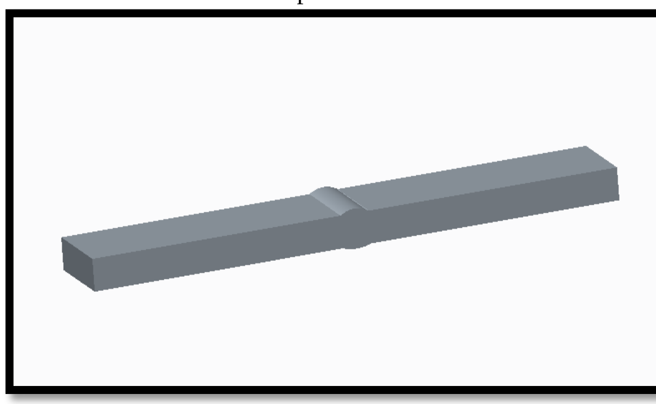


Fig.11. 3D model of welded pieces.

A. Thermal Analysis Of MIG Welding

CASE 1: 180 Amps (1502^{0}C)

Open work bench 14.5>select **steady state thermal** in analysis systems>select geometry>right click on the geometry>import geometry>select **IGES** file>open

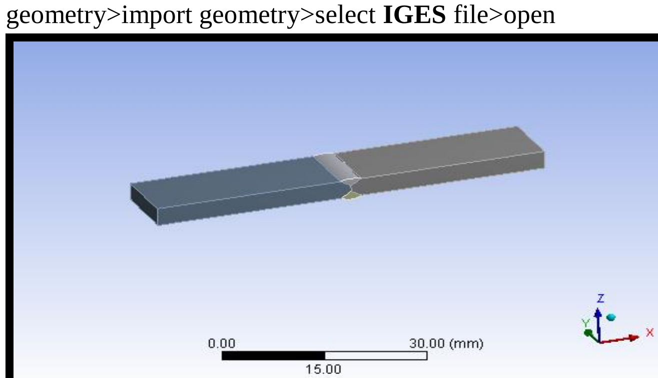


Fig.12. Imported Model from Creo 2.0.

B. Material Properties of Mild Steel

Thermal Conductivity Of Aluminum = 60.5w/Mk

Specific heat =380 J/Kg K

Density = 0.00000785Kg/mm^3

Model >right click>edit>select generate mesh

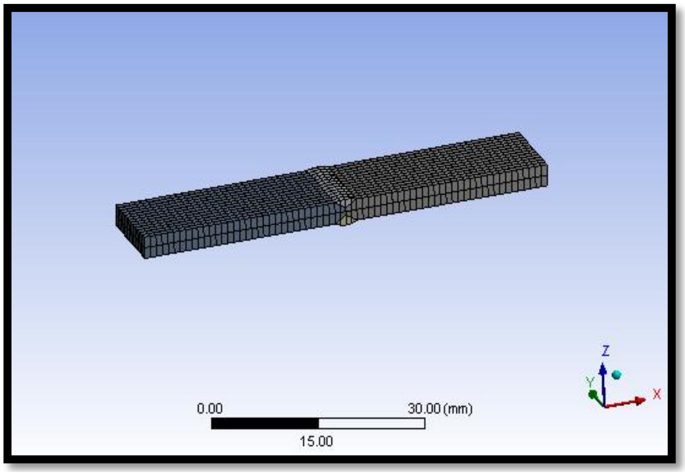


Fig.13. Meshed model.

Boundary Conditions:

$T_1 = 1502^0C$

Select steadystatethermal>rightclick>insert>select convection

Select steady state thermal >right click>insert>select heat flux

Select steady state thermal >right click>solve

Solution>right click on solution>insert>select temperature

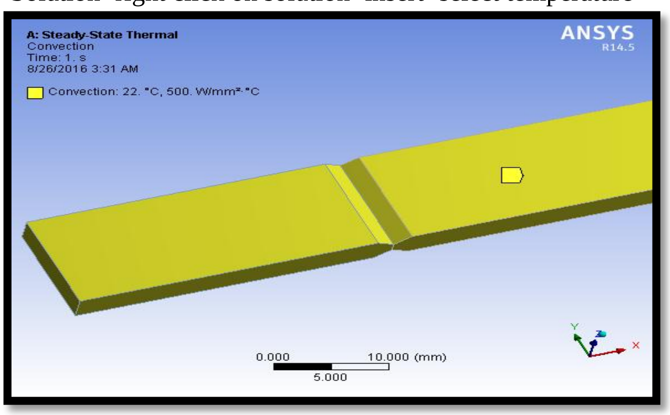


Fig.14. Applying of convection.

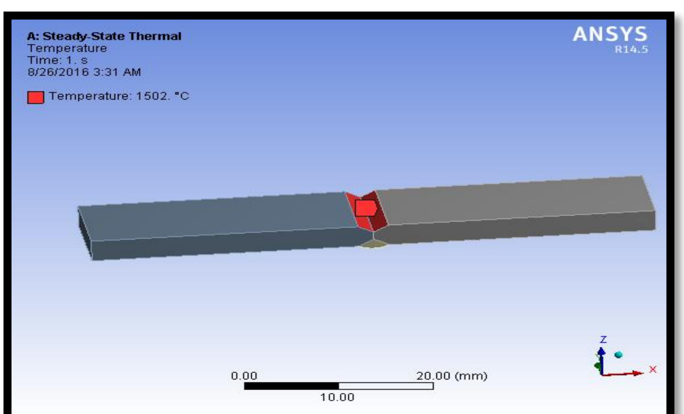


Fig.15. Temperature is applied at the welded region.

Solution - Select Temperature and Heat Flux

Evaluate all Results:

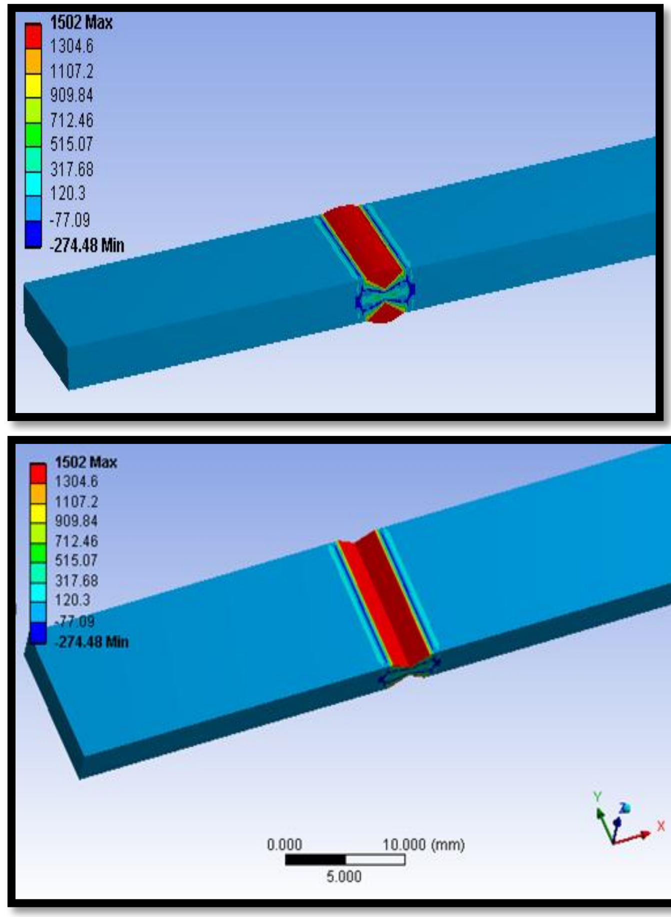


Fig.16.Temperature distribution on the welded pieces.

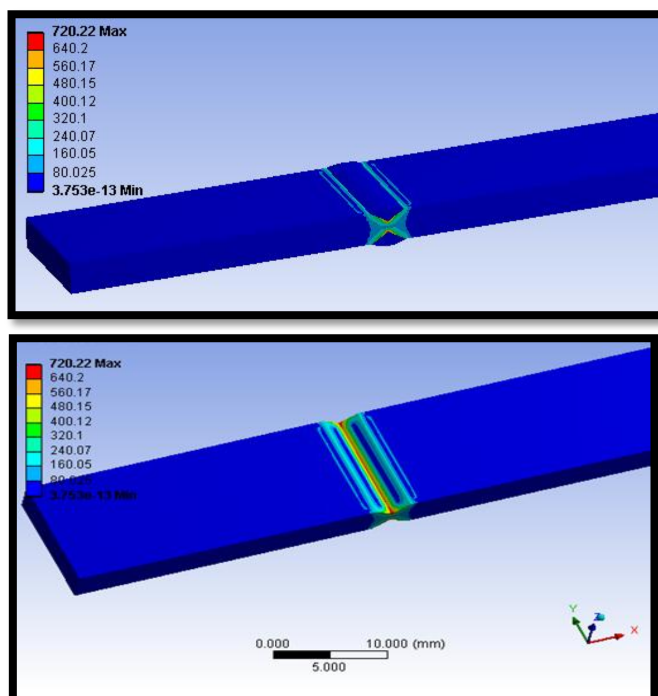


Fig.17. Heat Flux on the welded pieces.

Case 2: 200 Amps (1650^{0}C)

Temperature:

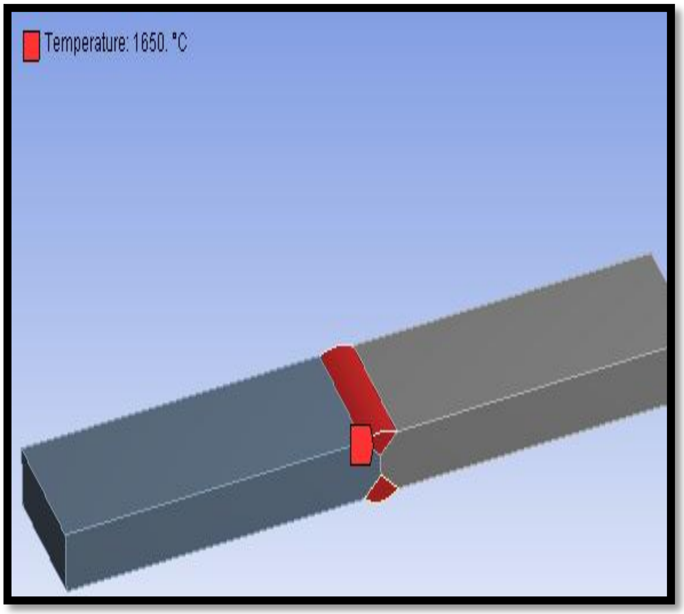


Fig.18.Applied Temperature at the welded region.

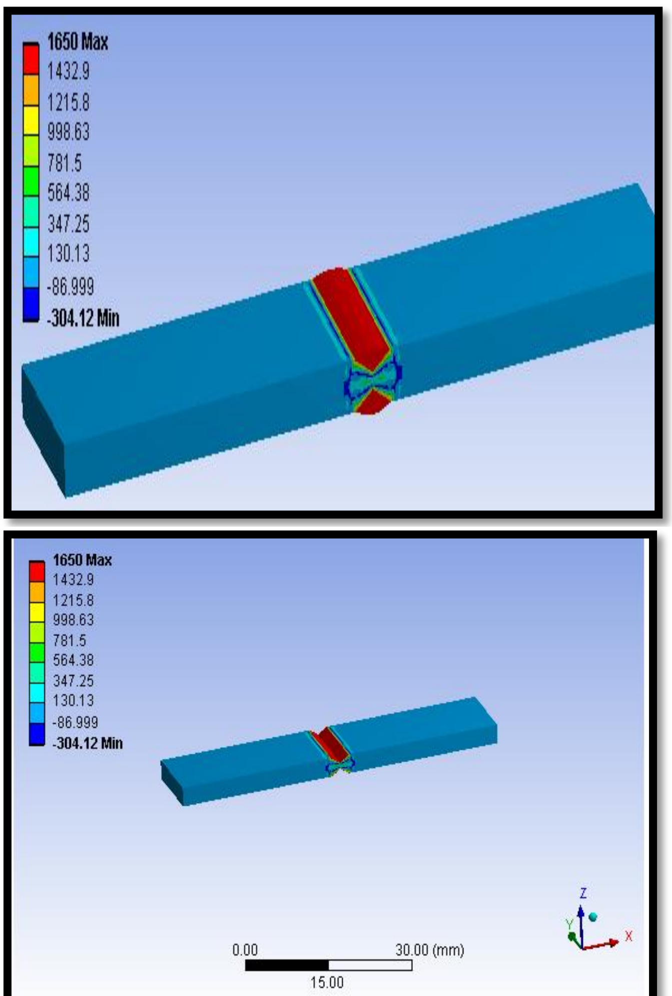


Fig.19.Temperature distribution on the welded pieces.

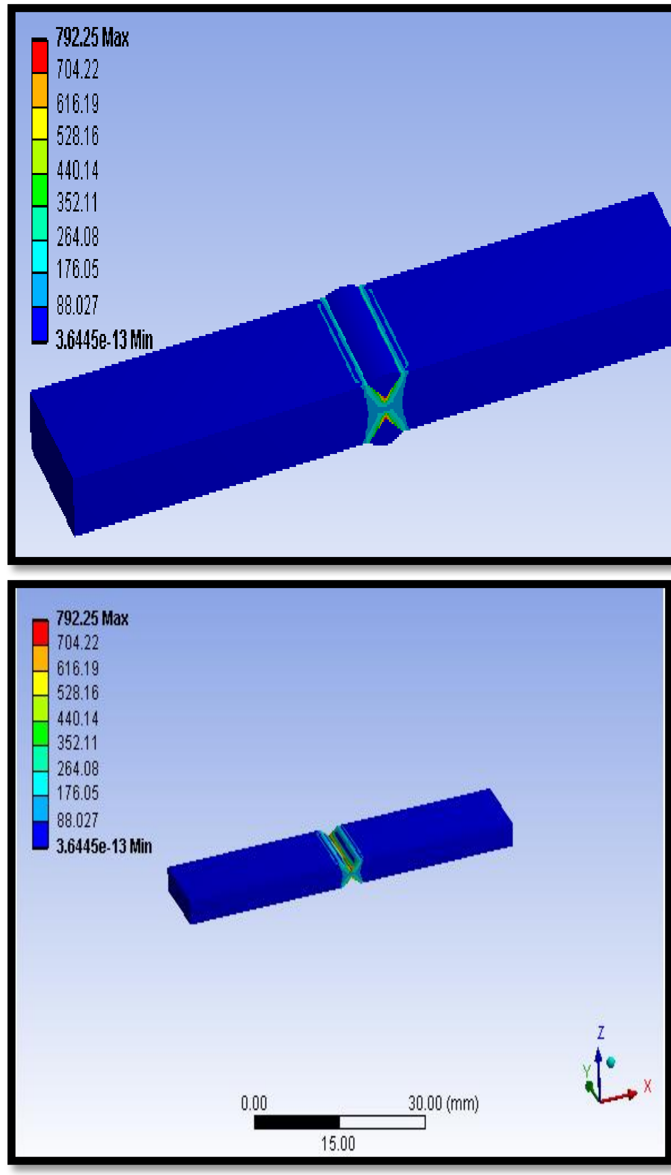


Fig.20. Heat Flux on the welded pieces.

Case 3: 230 Amps (1800^{0}C)

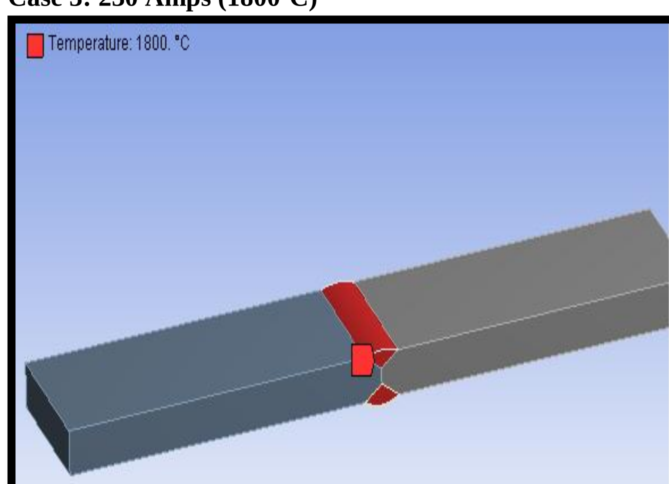


Fig.21. Temperature is applied at the welded region.

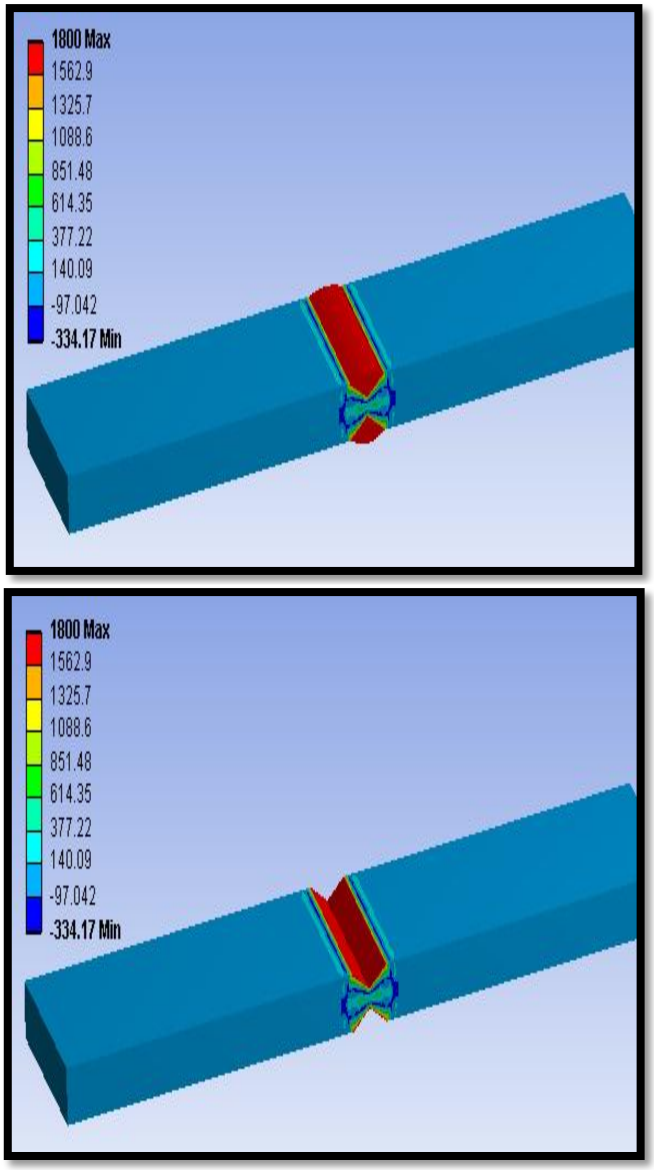
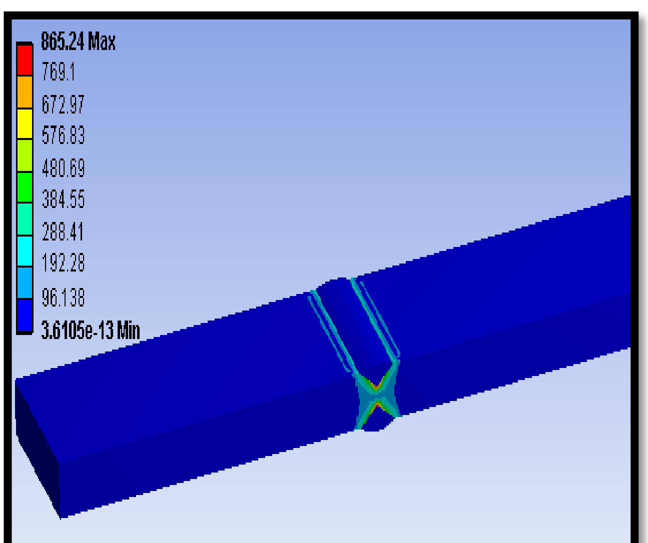


Fig.22.Temperature distribution on the welded pieces.



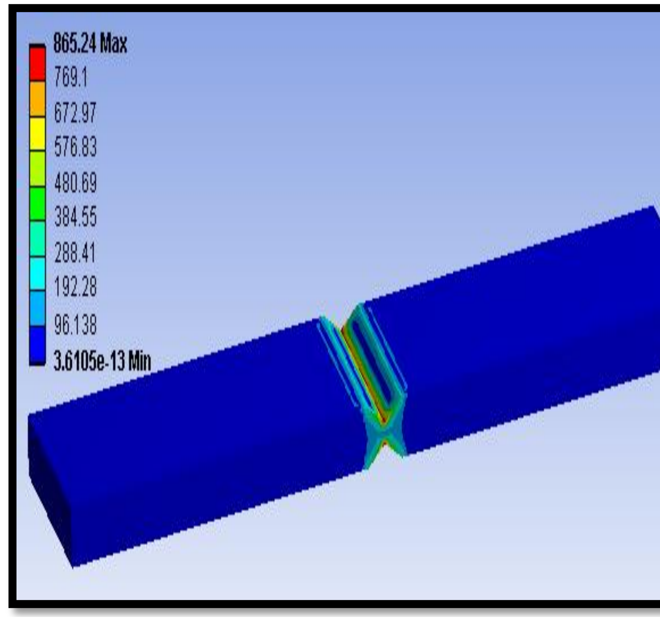


Fig.23. Heat Flux on the welded pieces.

C. Results Table

TABLE VII: Thermal Analysis

Cases	Temperature (^0C)	Heat flux(W/mm^2)
Case1	1502	720.22
Case2	1650	792.25
Case3	1800	865.24

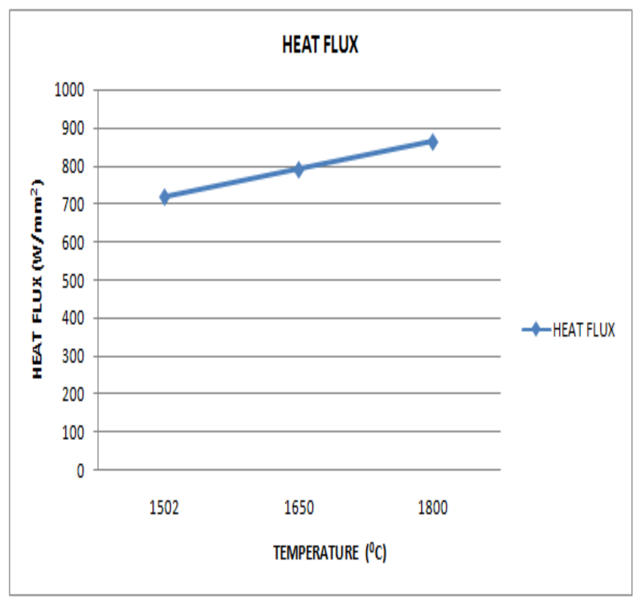


Fig.24. Heat Flux.

TABLE VIII: Structural analysis

Load(KN)	Deformation(mm)	Stress(N/mm^2)	Strain
14.31	0.0010905	237.13	0.0011864
16.95	0.0012899	280.48	0.0014032
17.19	0.00131	284.85	0.0014251

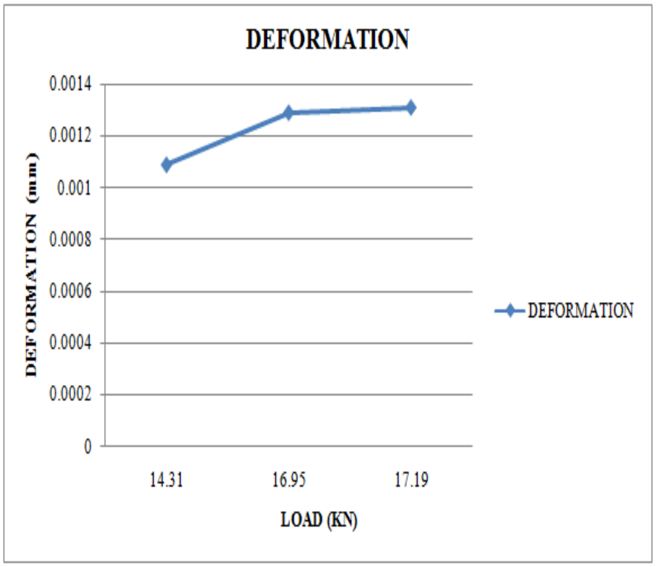


Fig.25. Deformation.

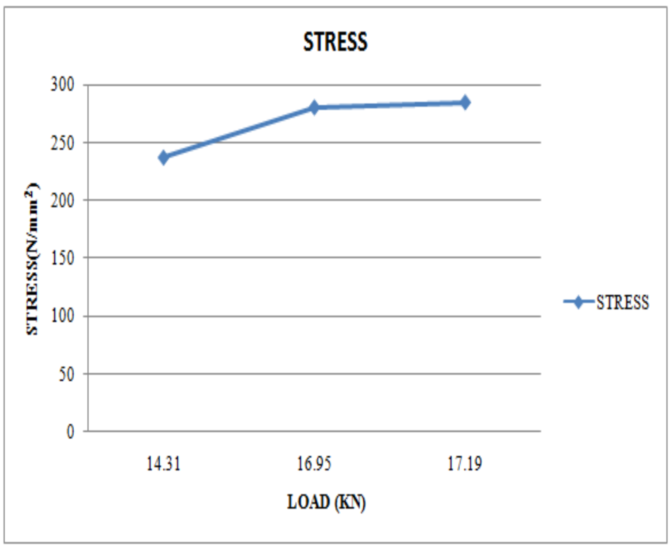


Fig.26. Stress.

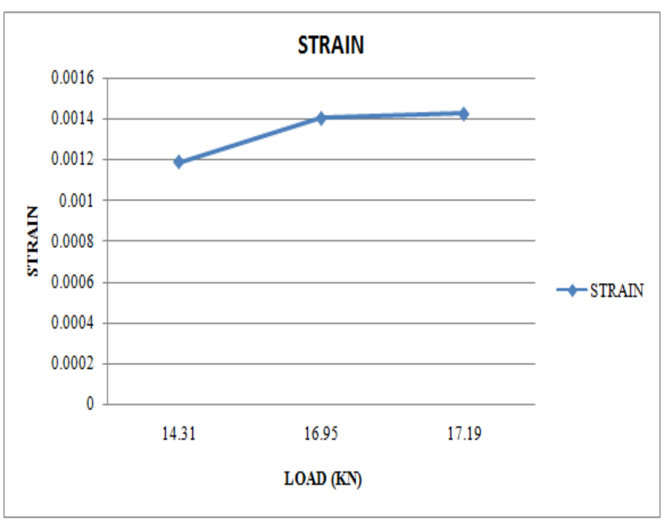


Fig.27. Strain.

V. RESULTS & DISCUSSIONS

A. Taguchi Results Table And Sn Ratio Graph For Tensile Strength

TABLE IX: Results of SN Ratio and Means for Tensile Strength

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6
	CURRENT (Amps)	WFR (mm/sec)	UTS	UTS1	SNRA1	MEAN1
1	150	3.2	318.975	318.810	50.0729	318.893
2	150	4.2	321.174	321.145	50.1344	321.159
3	250	3.2	443.915	443.790	52.9448	443.853
4	250	4.2	457.312	456.580	53.1973	456.946

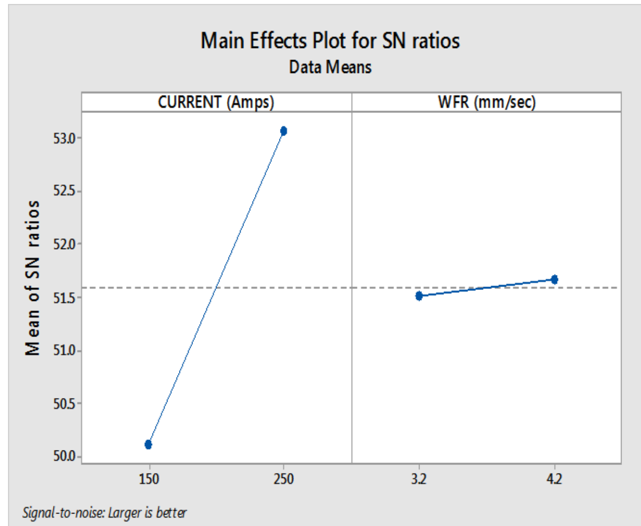


Fig.28. Plot for SN Ratio.

B. Taguchi Results Table And Sn Ratio Graph For Hardness

TABLE X: Results of SN Ratio and Means for Hardness

Worksheet 2 ***

↓	C1	C2	C3	C4	C5	C6
	CURRENT (Amps)	WFR (mm/sec)	HARDNESS	HARDNESS1	SNRA1	MEAN1
1	150	3.2	78	78.1	37.8475	78.05
2	150	4.2	79	79.0	37.9525	79.00
3	250	3.2	89	89.2	38.9975	89.10
4	250	4.2	90	90.0	39.0849	90.00
5						

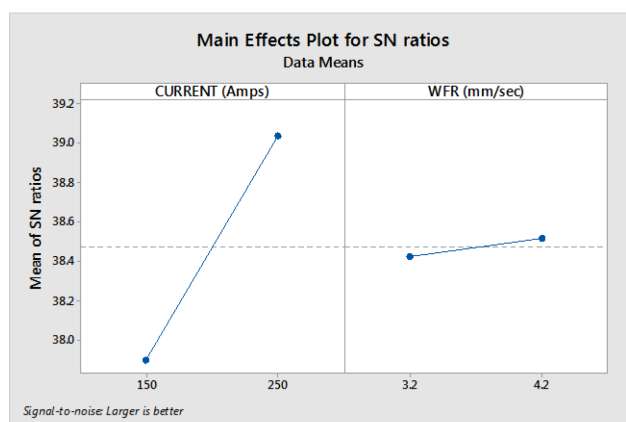


Fig.29. Plot for SN Ratio.

In this project work effect of main input welding parameters on the tensile strength of and hardness welded joint in MIG welding is investigated. Results show that among main input welding parameters the effect of the current is significant. Increasing the current and increasing the weld speed increases the ultimate tensile strength and hardness of welded joint. The weld speed did not contribute as such to weld strength. Regardless of the set of the quality characteristic, a greater S/N ratio relates to better quality characteristics. Therefore, the optimal level of the process variables is the level with the greatest S/N ratio.

VI. CONCLUSION

In this thesis MIG welding is performed on the Mild steel pieces by varying the welding current at weld speeds of 3mm/sec, 3.5mm/sec and 4mm/sec. The welding currents are 180amps, 200amps and 230 amps. Hardness and tensile tests are performed on the pieces. The brinell hardness of mild steel is 120HRB. By observing the hardness test results, the hardness is decreased after welding. By increasing the welding current the hardness is increased from 180amp to 230amp. From the tensile test results, the strength of the welded pieces is increasing by increasing the current. By observing the Taguchi method, results show that among main input welding parameters the effect of the current is significant. Increasing the current and increasing the weld speed increases the ultimate tensile strength and hardness of welded joint. The weld speed did not contribute as such to weld strength. Regardless of the set of the quality characteristic, a greater S/N ratio relates to better quality characteristics. Therefore, the optimal level of the process variables is the level with the greatest S/N ratio. Thermal analysis is done. By observing the results, the heat flux is increasing by increasing the welding current. Structural analysis is also done. By observing the result, the stress values obtained are less than that of the experimental tensile strength values.

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