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Effect of Process Parameters on The Properties of Stainless Steel 304 For MIG Welding

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Abstract: MIG welding is an appropriate process to join stainless steel. In present thesis effect of welding parameters on mechanical properties of steel is being observed tensile strength and hardness were the mechanical properties and there optimization was done using MINITAB. Tensile test was done using UTM test and hardness is done by using the Vicker hardness test.

Introduction:

Welding is a one of the common process in which pieces of metal are joined together. Different welding techniques include: manual, semi automatic and automatic. Welding joint strength is dependent upon many parameters. The variables used in the welding have their own effect on the welding quality. The properly selected variables result in better weld quality. The values of the variables are taken according to the conditions of the base metal. These variables that are used in the welding have their effect on the geometry of welding piece and on the penetration depthand width. Some of the controllable parameters in welding are: Current, Voltage, Travelling speed, Shield gases, Angle of electrode, Size of wire, position of the welding joint etc.

Research has been conducted on effect of process parameters used inMIG welding on AISI321 steel.[1] investigated the parameters like welding voltage, speed, wire feed rate and the effect of gas flow rate on the geometry of bead. Another research[2] focused on parameters optimization in case of MIG welding for stainless steel grade 304 and carbon steel that is low carbon steel. Mechanical properties of austenitic steel for the MIG welding and TIG welding have been studied under the effect of voltage[3].For stainless steel, thermally induced stress by MIG welding for stainless steel has been analysed[4]. For MIG welding, the parameters like welding speed gas flow rate, voltage have been studied to find the effect on geometry of bead for high speed low alloy steel[5]. Optimization of parameters used in MIG weldinghas also been studied

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by Taguchi method where the effect of current, voltage, gas flow rate etc on the strength of welded material, geometry of welded pool of medium carbon steel type[6]. Further, effect of the parameters of MIG welding on the weld bead geometry,when automatic surfacing of stainless steel is done, has been analysed[7].

Research Methodology

The main aim of the study is to study the effect of parameters on the stainless steel properties and to optimize the parameters using the Taguchi method .the process parameters have their own effect on the geometry of the welding material. These process parameters play a significant role in welding.

Voltage, current, welding speed, gas flow rate is some process parameters used in the welding process. A proper nozzle to plate distance, electrode angle, and correct polarity is maintained. These process parameters values are chosen according to the material of weld, thickness of the material plate, weld bead, penetration, depth, height, width etc. Basedon the type of the welding used, the properties of the plates of different materials are also affected. In some cases the hardness increases and in some cases it decreases.Similar effect is on the other properties of the plates. In this research, experiments which are performed by taking three parameters and keeping one parameter constant. We take stainless steel grade 304 electrode as it is a corrosion resistance material and is also not very soft.

The torch used in working consists of a wire and while welding this torch hold at the particular required angles generally an angle of 45 degree is used in holding torch. The three parameters are taken current, voltage, gas flow rate and also experiment is by proper planning using the Taguchi method using the L9 method. So nine experiments done by taking current values of the current, voltage same and varying the gas flow rate after every three runs.

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Figure 1: Welded plates

While welding the position of the plates are horizontal and position of the torch is just vertical at a particular required angle. The plates used in the study process is of dimensions having the 100mm width and the length of the thickness 5mm. Figure 1 shows plates which are weld by taking different gas flow rate and the same values of the current and voltage. After this the tensile strength and the hardness of these plates that are welded plates are checked by the different tests. The joint formed in then plate is the single-v type. The material of stainless steel is grade is selected due to its property of resistance against the corrosion and it is useful in conditions when the temperature is high. This plate is of the thickness of medium range and in this study a semiautomatic welding machine process is used. In case of this welding machine is not fully automatic, controlling of wire is done by help of proper adjustment wire with torch help during the welding.

Table 1: L9 table showing different values of variables.

Sr. No.	Gas flow rate	Voltage	Current
1	12	20	70
2	12	25	90
3	12	30	100
4	14	20	75
5	14	25	90
6	14	30	100
7	16	20	75

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8	16	25	90
9	16	30	100

These parameters have their own effect on the properties of the stainless steel which is weld by the help of MIG welding. Parameters that are used in input are current, voltage, rate of gas flow and hardness and the tensile strength is taken in account as output. The gases that are of shielding type are carbon dioxide, argon, helium and may be the mixture of these gases. By using the values of parameters given in Table 1, these parameters are used in case of optimization. In this case Taguchi method is used. The parameters are optimized to improve the performance. In the design of experiment, orthogonal array has been used and nine experiments are performed.

Table 2: Input and output parameters.

Input parameters	Output parameters
Current	Hardness
Voltage	Tensile strength
Gas flow rate	

Objective: The objective of this research is to optimize the input parameters so that we get the optimum conditions resulting in better values of hardness and tensile strength.

Results and discussion:

We describe the effects of different parameters of MIG welding on the welded portion. This has been carried out by taking nine samples of MIG welding done at different values of current, voltage and gas flow rate. After welding, we have done hardness and tensile strength testing in the jobs and optimization has been done by using the results taken from testing.

Table 3: Hardness response

Gas flow rate	Current	Voltage	HAZ	SNRA
12	70	20	215.5	46.66895
12	90	25	192.5	45.68861
12	100	30	228	47.15874
14	70	25	231.5	47.29102
14	90	30	198	45.93330

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14	100	20	215.5	46.66895
16	70	30	220.5	46.86817
16	90	20	219	46.80888
16	100	25	218.5	46.78903

From the above Table 3 it is perceived that Signal to noise ratio i.e. S/N ratio varies according to the hardness of Heat Affected Zone (HAZ). The hardness value of HAZ is affected by the different values of parameters i.e. current, voltage and gas flow rate. For the calculation of S/N ratio following formula is applied.

$$\eta = -10 * log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{yi^2}\right]$$

η is S/N ratio and yi is the experimental observed value. According the derived hardness the effective plot to obtain plot response is mean of hardness.

Table 4: Response table for S/N ratio

Level	Gas flow rate	Current	Voltage
1	46.51	46.94	46.72
2	46.63	46.14	46.59
3	46.82	46.87	46.65
Delta	0.32	0.80	0.13
Rank	2	1	3

Table 5: Response table for means

Level	Gas flow rate	Current	Voltage
1	212.0	222.5	216.7
2	215.0	203.2	214.2
3	219.3	220.7	215.5
Delta	7.3	19.3	2.5
Rank	2	1	3

In case of main effect plot, the maximum value of S/N ratio of hardness is at gas flow rate 14 and is minimum at GFR 12.

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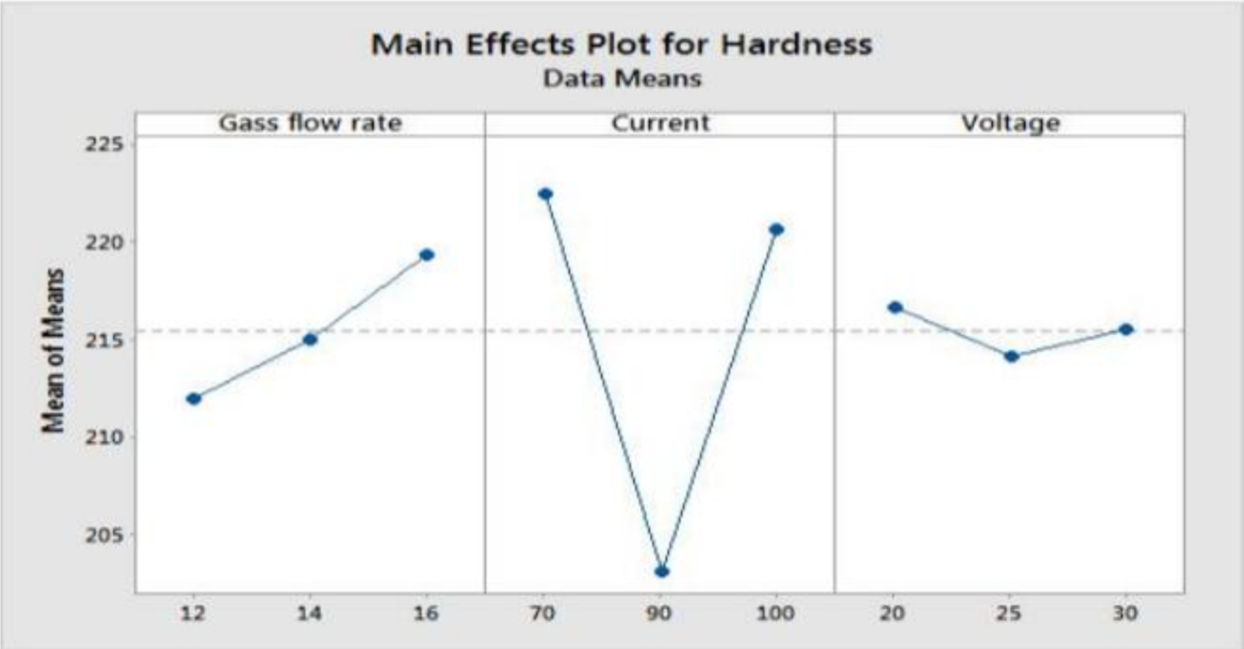

Figure 2: Main effects plot for hardness

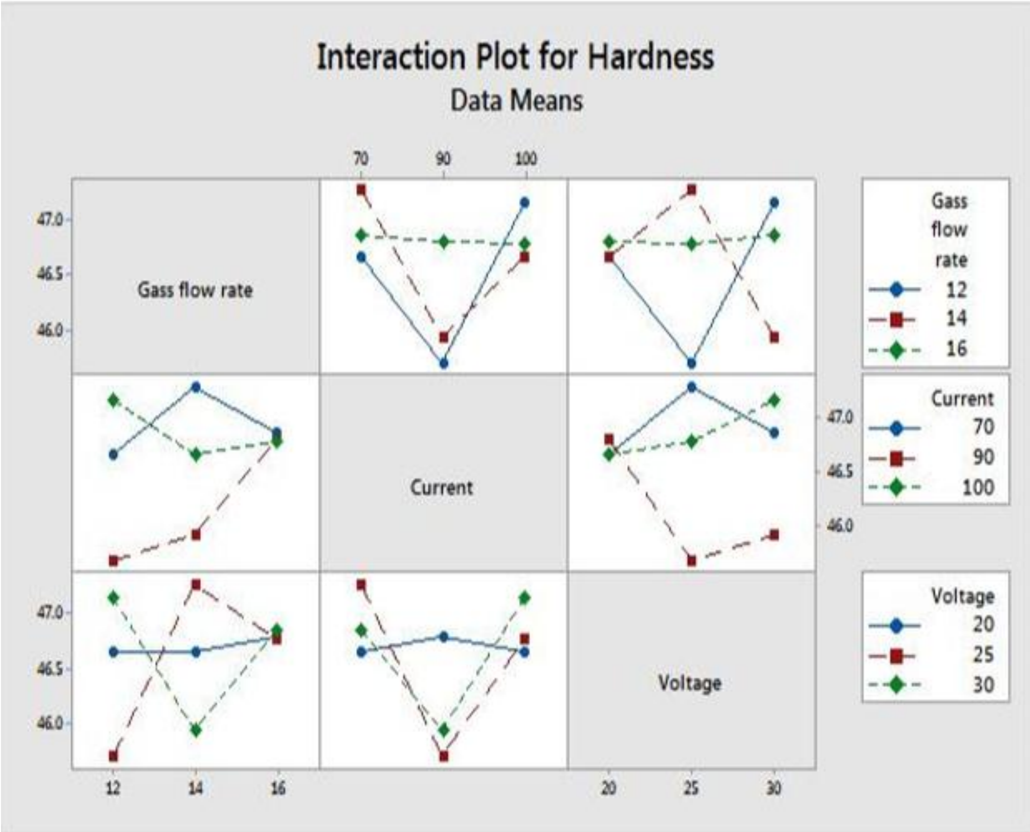

Figure 3: Interaction plot for hardness

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Table 6: ANOVA table for S/N ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
GFR	2	0.15241	0.15241	0.07625	0.18	0.848
Current	2	1.17444	1.17444	0.58722	1.38	0.420
Voltage	2	0.02383	0.02383	0.01191	0.02	0.973
Residual error	2	0.84965	0.84965	0.42482		
Total	8	2.20041				

The residual plot in case of hardness represents the model layout. Above are the some plots in which normal probability plot indicates data is distributed between normal probability plot and standardized residual plot and it lies between -1 to -1.5. In other plot, versus fit graph is drawn between standardized residual and fitted value, also the histogram is created between frequency and standard residual. Versus order is shown by observation order and standard residual and it shows the systematic effect of the data

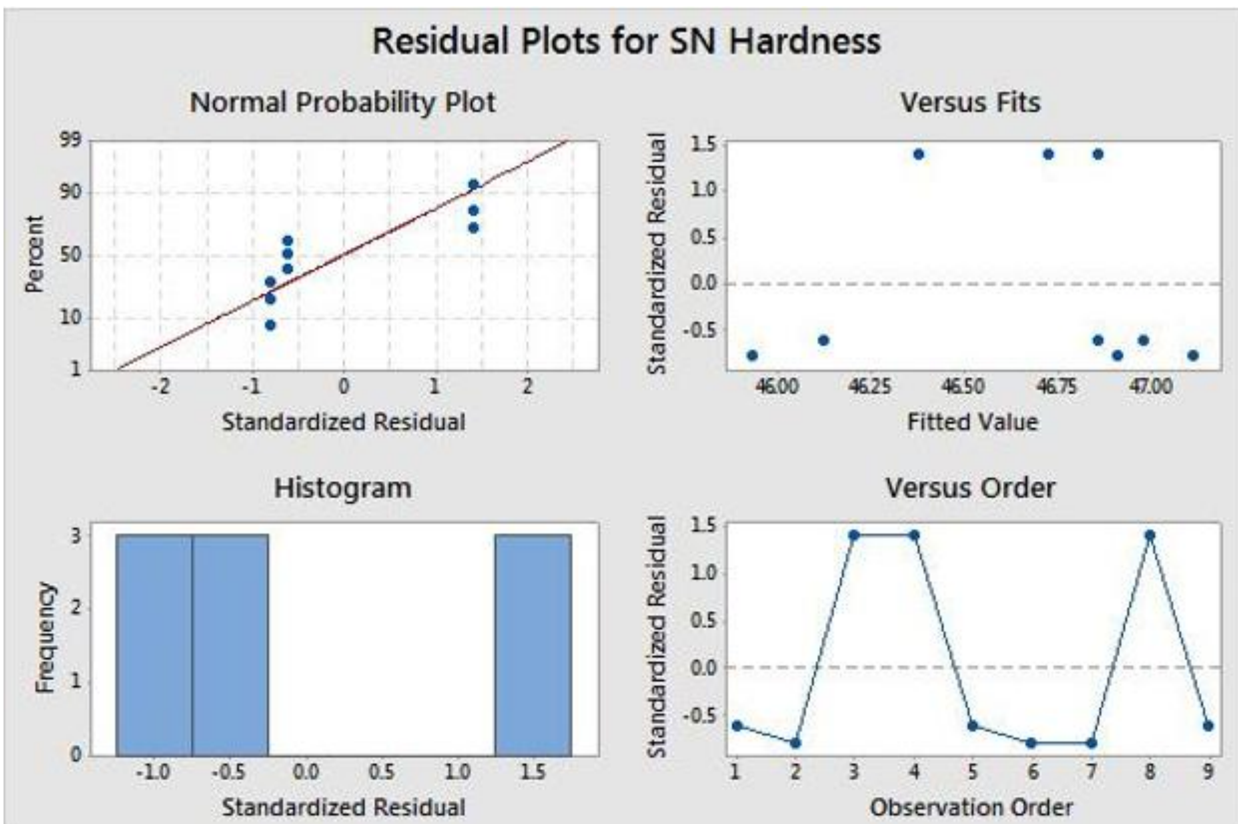

Figure 4: Residual plot for S/N hardness

From the table of mean response of the hardness it is clear that at level 3 for gas flow rate of value 219.3 MPA is pointed as the best condition for getting optimum value of hardness, In case when there is variation of GFR. At level 1 for the value of current 70 ampere, it results the value 222.5 which shows the optimum condition for hardness, when there is variation of current is considered. At level 1for the value of voltage 20 volt, it results in value 216.7 which is pointed as the best condition of optimum hardness.

Interaction plot for hardness is shown in figure given below which shows the interaction between the input parameters with the hardness. Now we will describe results for tensile strength.

UTM is used to perform the tensile strength test and the regions where fracture occurred are examined. Between the range 273 MPA and 633 MPA, the parametric conditions are considerably better. The maximum value of tensile strength is highest in the case of sample 8 and its value is minimum for sample 6.

Table 7: Result of tensile strength

Sr. no	Gas flow rate	Current	Voltage	Tensile strength	S/N ratio
1	12	70	20	384	-8.313
2	12	90	25	441	-7.111
3	12	100	30	402	-7.915
4	14	70	25	516	-5.747
5	14	90	30	583	-4.686
6	14	100	20	272	-11.308
7	16	70	30	585	-4.656
8	16	90	20	633	-3.971
9	16	100	25	379	-8.427

Table 8: Response table for S/N ratio

Level	GFR	Current	Voltage
1	-7.780	-6.239	-7.865
2	-7.247	-5.257	-7.095
3	-5.685	-9.217	-5.753
Delta	2.095	3.961	2.112
Rank	3	1	2

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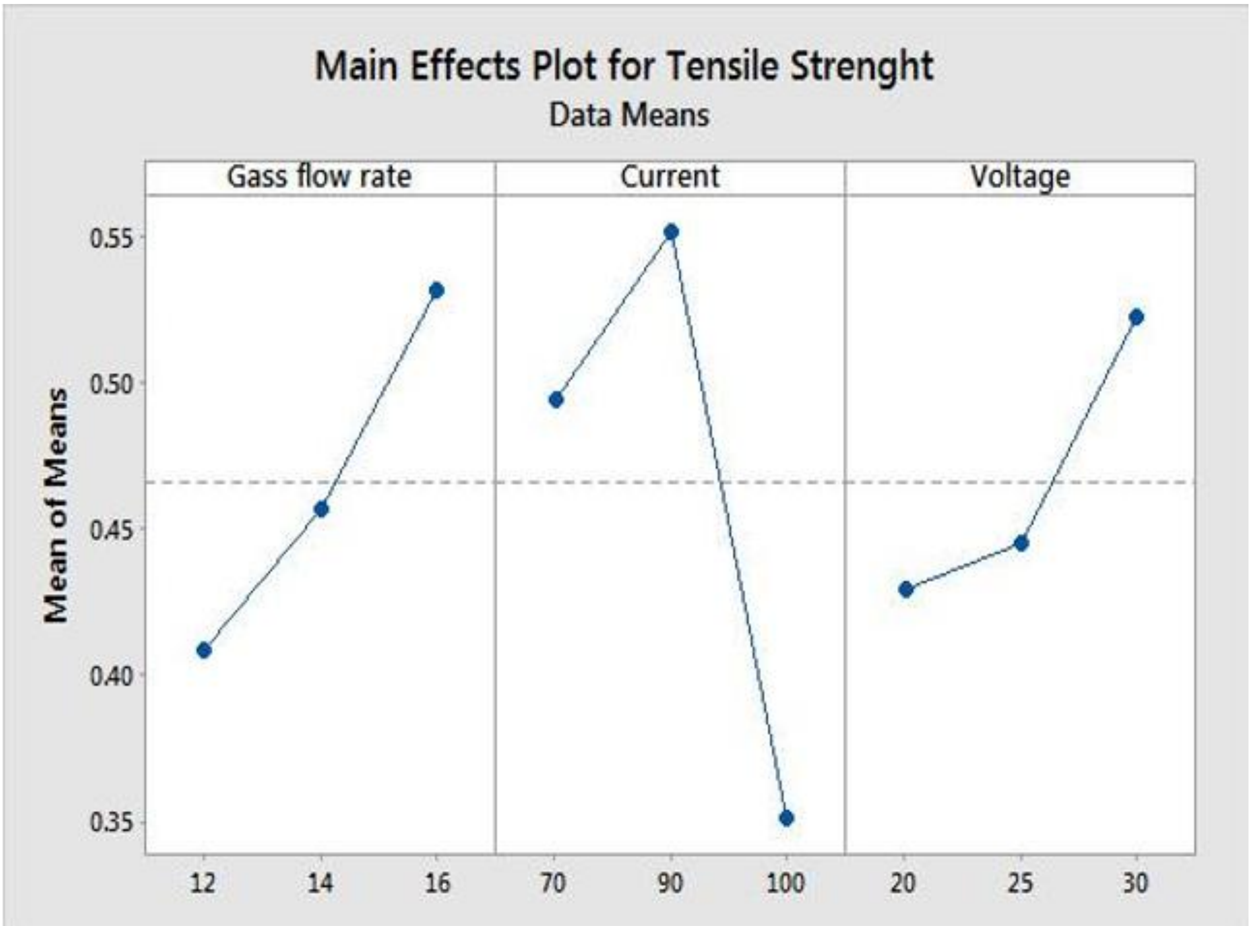
Table 9: Response table for means

Level	Gas flow rate	Current	Voltage
1	0.4090	0.4950	0.4297
2	0.4570	0.5523	0.4453
3	0.5323	0.3510	0.5233
Delta	0.1233	0.2013	0.0937
Rank	2	1	3

Figure 5: Main effects plots for tensile strength



The main effects plot represents that the value of the tensile strength is increasing and then its value decreases, similarly the graph of voltage and gas flow rate shows the variation in the value of tensile strength.

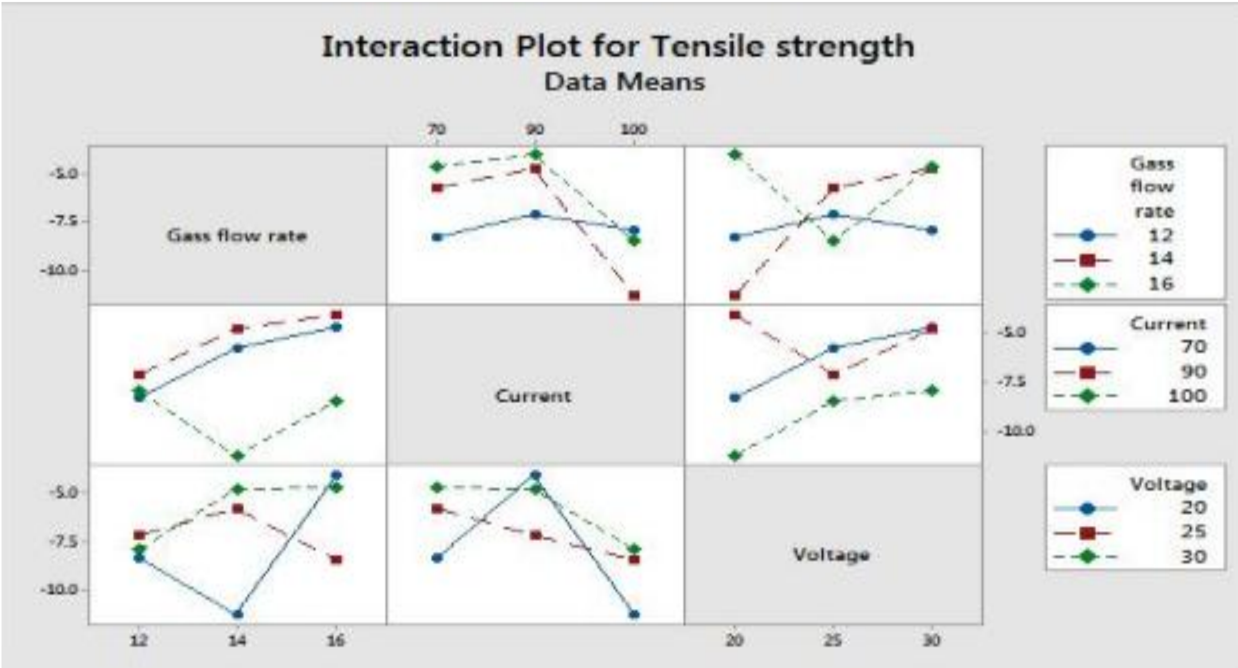


Figure 6: Interaction plots for tensile strength

Table 10: Anova table for mean of tensile strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P
GFR	2	0.02319	0.02319	0.011595	1.93	0.342
Current	2	0.06456	0.06456	0.032279	5.36	0.157
Voltage	2	0.01510	0.01510	0.007551	1.25	0.444
Residual error	2	0.01204	0.01204	0.006019		
Total	8	0.11489				

From the figure of main effects plot and table for mean response for the tensile strength we come to the conclusion of the best optimization condition for tensile strength. At level 3 when the flow rate is 16 litre/minute it results in value 532.3 MPa which indicates the best optimum value in the case of tensile strength when gas flow rate varying.. At level 2 for the current value i.e. 90 ampere it results in value 552.2 Mpa which indicates the optimum value for the tensile strength while current is varying. At level 3 for the voltage value i.e. 30 volts results in value of 523.3 Mpa which shows the optimum value for tensile strength when voltage is varying.Therefore from the above figure of main effects plot for tensile strength it is clear that current at level 2, GFR in

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case of level 3 and voltage in case of level 1i.e. current 90 ampere, GFR value 16litre/minute and the voltage 30 volts are the optimum conditions for getting the maximum tensile strength

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