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A STUDY AND ANALYSIS OF FSW WITH DISSIMILAR ALUMINIUM ALLOYS AA7075 AND AA3014

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Abstract--- Friction Stir Welding (FSW) may be a solid state welding process during which the relative motion between the tool and therefore the work piece produces heat which makes the material of two edges being joined by plastic atomic diffusion. This method relies on the direct conversion of energy to thermal energy to make the weld without the appliance of warmth from conventional sources. The rotational speed of the tools, the axial pressure, welding speed and therefore the tool profile are the principal variables that require to be controlled so as to produce the required combination of warmth and pressure to make the weld. The scope of this investigation is to guage the effect of joining parameter on the mechanical properties of dissimilar aluminium alloys AA3104 and AA7075 joints produced by Friction Stir welding using CNC vertical machining centre. The Brinnel hardness and durability of the joints are considered for the investigation. The results show that for optimal stir zone hardness, FSW parameter combination of 1200 rpm tool rotational speed, 10 mm/min welding speed and cylindrical tool profile should be used. For optimal joint durability, the acceptable parameters combination is 1200rpm, 20mm/min and taper thread tool profile. From the investigation, it's concluded that tool rotational speed is the major influencing factor for mechanical properties like durability and hardness.

Keywords: Frictions stir welding, Brinnel hardness, tensile strength, CNC vertical machining centre

1.0 INTRODUCTION

Friction stir welding (FSW) could be a solid-state joining process invented and patented by The Welding Institute, uk in 1991. During this process, a rotating non consumable cylindrical-shouldered tool with a profiled nib is transversely fed at a relentless rate through the butted interface of the 2 clamped pieces of fabric [1]. The nib is slightly shorter than the weld depth required, with the tool shoulder riding atop the surface. The frictional heat together with that generated by the mechanical mixing process and therefore the adiabatic heat within the fabric, cause the stirred materials to melt without melting[2]. Because the pin is moved forward, the plasticized material is moved from the front of the pin to the rear of the pin where axial force exerted by the shoulder along with clamping force assists in a very forged consolidation of the weldment. During the last stage of joining process, the tool compresses the plasticized material and allowing metallurgical bond to create between the 2 materials [3]. This method relies on the direct conversion of mechanical energy to thermal energy to create the weld without the application of heat from conventional sources. During this process, the fabric at the interface (stir zone) is subjected to severe solid state deformation involving dynamic recrystallization of the bottom material [4]. Aluminium alloys are difficult to weld by traditional methods, because of their high thermal conductivity, leading to defects like porosity, cracks etc. Hence FSW is being increasingly used. The method is particularly well matched to hitch aluminium within the joint configuration [5]. Recently, in many industrial fields, much attention has been focused on aluminium alloys thanks to their various unique properties. It's quite common that FSW is a horny technology for the welding of aluminium and every one other alloys[6]. Additionally, FSW between dissimilar materials has recently received much attention. During this study, dissimilar FSW between AA7075 and AA3104 aluminium alloy plates are carried out[7&8]. Then, the influences of the tool rotation speed, welding speed and pin profiles on surface appearance, tensile strength and hardness were experimentally investigated [9&10].

2.0 EXPERIMENTAL PROCEEDURE

The materials utilized in this atudy are 6mm thick plate of AA707 and AA3104 aluminium alloys. The plates were milled to realize parallelism and flatness tolerances. The chemical compositions of the identical are shown in tables 01. The rolled plates were rectangular samples of 100x50mm and also the welding was allotted using CNC vertical machining centre. The welding tool utilized in this study was High carbon-high chromium steel which has high resistance to thermal fatigue. The assorted pin profiles utilized in this work include cylindrical, cylindrical taper and taper threaded as shown in Fig 01-04. The work pieces were mounted firmly on the machine table by employing a fixture as shown in Fig 05 and checked for flatness. The experimental process consists of nine experiments (L9) array by combining the process parameters at three levels are as in table 02. The standard tensile test specimens were prepared as per the size given in Fig 06 by ASTM E8 standards. The dimensions are mentioned in table 03. The factors and levels are indicated in table 04.The simulation of CNC program is shown in Fig 07.The friction stir welded pieces for nine experiments is shown in Fig 08. The tensile test specimens before and after test is shown in Fig 09 and Fig 10 respectively. The Birnnel hardness tests were allotted at a load of 250kgf with indentor dia. 5mm ball and dwell time of 10 secs.

3.0 RESULTS AND DISCUSSION

The results of Tensile strength and hardness are given in table 06.In order to assess influence of things on response, means and signal-to-noise ratios(S/N) for every control factor is calculated. Signals are indicators of effect on the average responses and measures of deviations from experiment output. During this study, S/N ratio was chosen in line with criterion larger- the- better, so as to maximise the response in Taguchi method, S/N ratio is employed to see deviation of quality characteristics from desired value

$$\eta_j=-10\log(1/n\sum[1/y_{ijk}^2])$$

where n is number of tests and Yijk is experimental value of its quality characteristic in jth experiment at kth test. In the percent study, tensile strength and hardness data were analysed to see the effect of FSW process parameters. Thus friction stir welding process has been successfully dispensed on dissimilar aluminium alloys AA7075 and AA3104.The weld ability and mechanical properties of those aluminium alloys were examined. ANOVA has been performed to spot statically significant process parameters, which affects tensile strength and hardness of FSW joints. Results of ANOVA give suitable parameters for best tensile strength and hardness. The weld ability and mechanical properties of those dissimilar alloys are examined. The simplest parameters for the speed, welding speed and tool profile are chosen among 3 levels. it's discovered using Taguchi method. For the simplest hardness nature of the welded area, the appropriate parameters are 1200rpm speed, 10mm/min welding speed and cylindrical tool profile. The proportion contribution of speed is 36.51%, welding speed is 16.69 %, and tool profile is 16.77 taking care of the hardness property using ANOVA. For the simplest tensile nature of the welded area, the appropriate parameters are 1200rpm speed, 20mm/min welding speed and taper thread tool profile. The proportion contribution of speed is 52.01%, welding speed is 3.30 %,and tool profile is 24.4% for the tensile property using ANOVA.

4.0 OPTIMIZATION OF FSW PARAMETERS

In this process three parameters are considered for optimization, the parameters are given optimum values that desired output variables are going to be high. During this method two outputs are considered namely strength and hardness. The observed values for nine experiments are shown in Table 06. The process parameters considered for Taguchi method involves control factors, noise factors and output variables as given in table 05.

4.1 OPTIMIZATION BASED ON HARDNESS

The hardness is optimized by finding the S/N ratio and Means for the values and evaluating as per procedure to seek out the most effective. The mean for all the nine experiments were found using the Minitab 17 software (fig 11 & 12). From the table 07 & 08, it's observed that best parameters for hardness are 1200 rpm, 10mm/min welding speed and cylindrical tool. From the ANOVAs table 09 & 10, it's concluded that the proportion contribution of speed is more with 36.51.

4.2 OPTIMIZATION BASED ON TENSILE STRENGTH

The tensile strength is optimized by finding the S/N ratio and Means for the values and evaluating as per procedure to seek out the most effective. The mean for all the nine experiments were found using the Minitab 17 software(fig 13 &14).Table 11 & 12 it's observed that best parameters for tensile strength are 1200 rpm, 20mm/min and cylindrical tool. From the ANOVAs table 13 it's observed that the proportion contribution of speed is more with 52.01.

5.0 CONCLUSION

Thus, friction stir welding process has been successfully administrated on dissimilar aluminium alloys of AA7075 and AA3104. From the experiments administrated, it's concluded that speed is the major factor influencing the mechanical properties like tensile strength and hardness. The most effective parameters are obtained by this experimental study. FSW process data base could also be developed in future for wide selection of metals and alloys for optimum process parameters for efficient weld.

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Table 01 Chemical compositions(wt %) of aluminium alloys AA7075 & AA310

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
AA7075	0.40	0.50	1.2-2.0	0.30	2.1-2.9	0.18-0.28	5.1-6.1	0.20	Rem
AA3104	0.50	0.70	0.10	1.50	0.05	0.10	0.20	0.10	Rem

Table 02 Process parameters for FSW of AA7075 and AA3104 Alu.Alloys

Sl.No	Rotational speed(RPM)	Welding speed(mm/min)	Tool
1	1000	10	C
2	1000	15	CT
3	1000	20	TT
4	1200	10	CT
5	1200	15	TT
6	1200	20	C
7	1400	10	TT
8	1400	15	CT

Table 03 Description of dimensions for ASTM E8 standard

Dimensions in mm				
	Standard size(ASTM E8)	Sub size 1	Sub size 2	Sub size 3
G-Gage length	50.0±0.1	25.0±0.1	25.0±0.1	12.5±0.1
W-width	12.5±0.2	6.0±0.1	4.8±0.1	3.2±0.05
R-Radius of fillet(min)	12.5	6.0	6.0	4.0
L-Overall length(min)	200	100	100	84
A-Length of reduced section((min)	57	32	32	16
B-Length of grip section(min)	50	30	30	30
C-Width of grip section(approx)	20	10	10	10

Table 04 Level and factors for Taguchi method

Parameters	Level		
	1	2	3
SPEED(rpm)-A	1000	1200	1400
FEED(mm/min)-B	10	15	20
Tool-c	C	CT	TT

C-cylindrical CT-cylindrical taper TT-taper threaded

Table 05 Observed value for FSW process

SI.No	Rotational Speed(rpm)	Welding speed(mm/min)	Tool	Tensile strength Mpa	Hardness BHN
1	1000	10	C	125.7	104.9
2	1000	15	CT	140.3	98.9
3	1000	20	TT	137.6	107
4	1200	10	C	196.8	121
5	1200	15	CT	142.8	83
6	1200	20	TT	202.5	114.7
7	1400	10	C	101.2	87.3
8	1400	15	CT	164.3	95
9	1400	20	TT	125.7	83.9

C-cylindrical CT-cylindrical taper TT-taper threaded

Table 06 Response of s/n ratio for hardness

Level	Rotational Speed(rpm)	Welding speed(mm/min)	Tool
1	40.30	40.30	40.39
2	40.41	39.28	40.01
3	38.95	40.08	39.26

Table 07 Response of mean for hardness

LEVEL	Rotational Speed(rpm)	Welding speed(mm/min)	TOOL
1	103.60	104.40	104.87
2	106.23	92.30	101.27
3	88.73	101.87	92.43

Table 08 Analysis of variance for hardness

Source	d.o.f	Adj. Sum of Squares	Mean Sum of Squares	F-Value	P %
Speed	2	534.2	267.1	1.22	36.51
Feed	2	244.3	122.2	0.56	16.69
Tool	2	245.6	122.8	0.56	16.77
Error	2	439.6	219.8		
Total	8	1463.8			

Table 09 Hardness value at three levels

LEVEL	FACTOR			TOTAL	X_1^2	X_2^2	X_3^2
	X_1	X_2	X_3				
1	104.9	98.9	107	310.80	11004.01	9781.21	114
2	121	83	114.7	318.70	14641	6889	131
3	87.3	95	83.9	266.40	7621.29	9025	703
TOTAL	313.20	276.90	305.60	895.90			

Table 10 S/N ratio for tensile strength

Level	Speed	Welding speed	Tool
1	42.57	42.66	44.14
2	45.03	43.45	43.60
3	42.13	43.63	41.99

Table 11 Mean for tensile strength

Level	Speed	Welding speed	Tool
1	134.5	141.2	164.2
2	180.7	149.1	154.3
3	130.4	155.3	127.2

Table 12 Tensile strength values at three levels

Level	Factors			Total	X_1^2	X_2^2	X_3^2
	X_1	X_2	X_3				
1	125.7	140.3	137.6	403.60	15800.09	19684.09	18933.76
2	196.8	142.8	202.5	542.10	38730.24	20391.84	41006.25
3	101.2	164.3	125.7	391.20	10241.44	26994.49	15800.49
Total	423.7	447.4	465.8	1336.9			

Table 13 ANOVA for tensile strength

Source	d.o.f	Adj. Sum of Squares	Mean Sum of squares	F-Value	P %
Speed	2	4678.5	2339.3	0.57	52.01
Feed	2	297	148.5	0.16	3.30
Tool	2	2197.1	1098.6	1.21	
Error	2	1821.4	910.7		
Total	8	8994			24.4

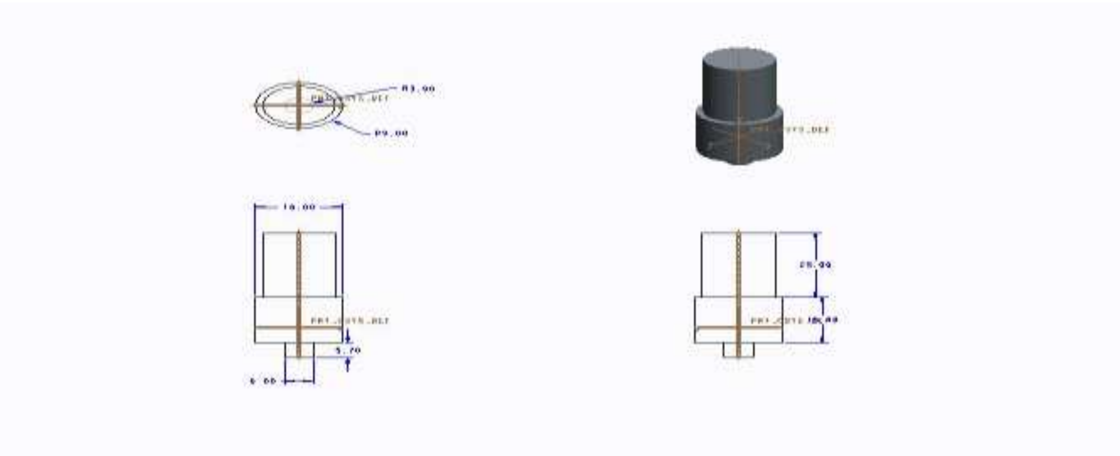


Figure 01 Friction stir welding tool (cylindrical)

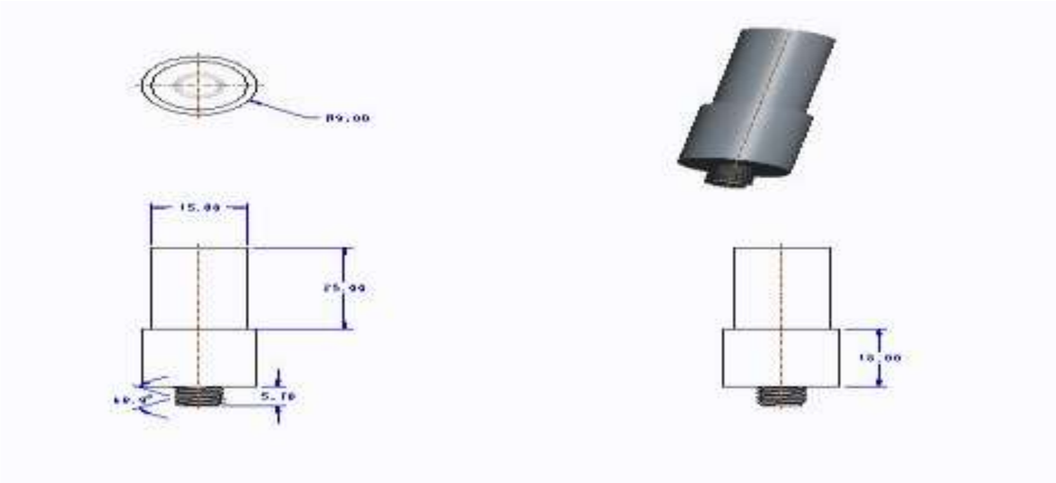


Figure 02 Friction stir welding tool (cylindrical threaded)

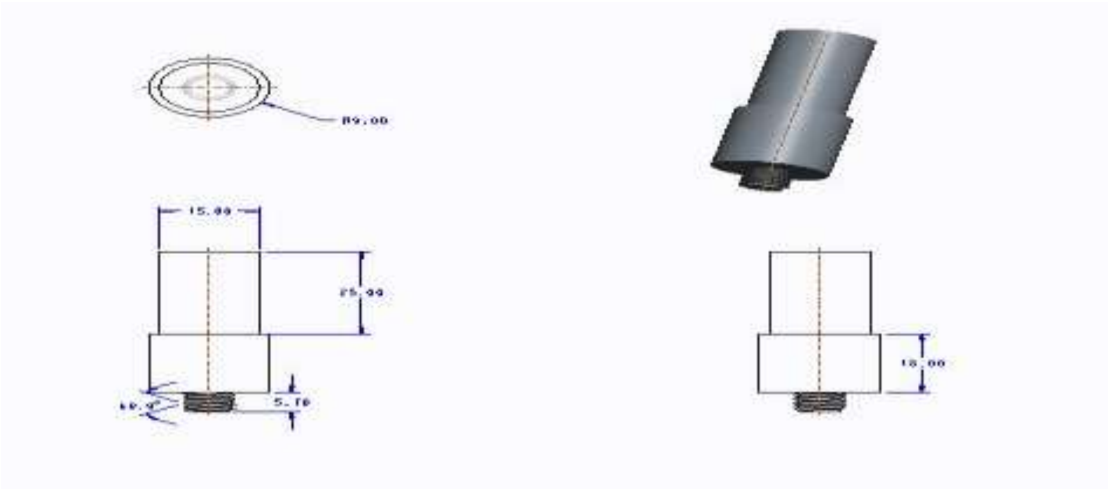


Figure 03 Friction stir welding tool (threaded tapered)

Figure 04 Tools used for friction stir welding process

Figure 05 Setting of work pieces in CNC

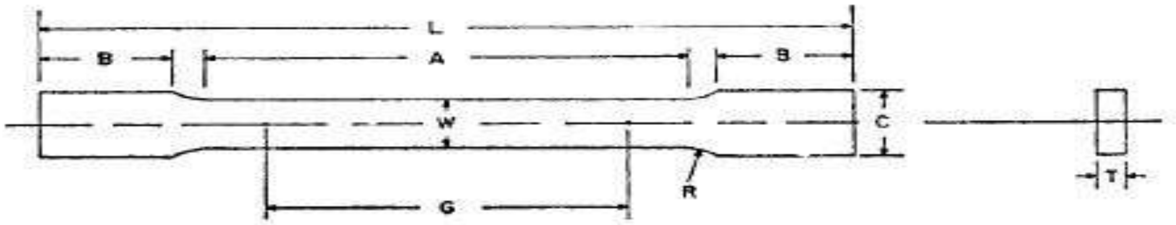


Figure 06 ASTM E8 standard with sub size 2

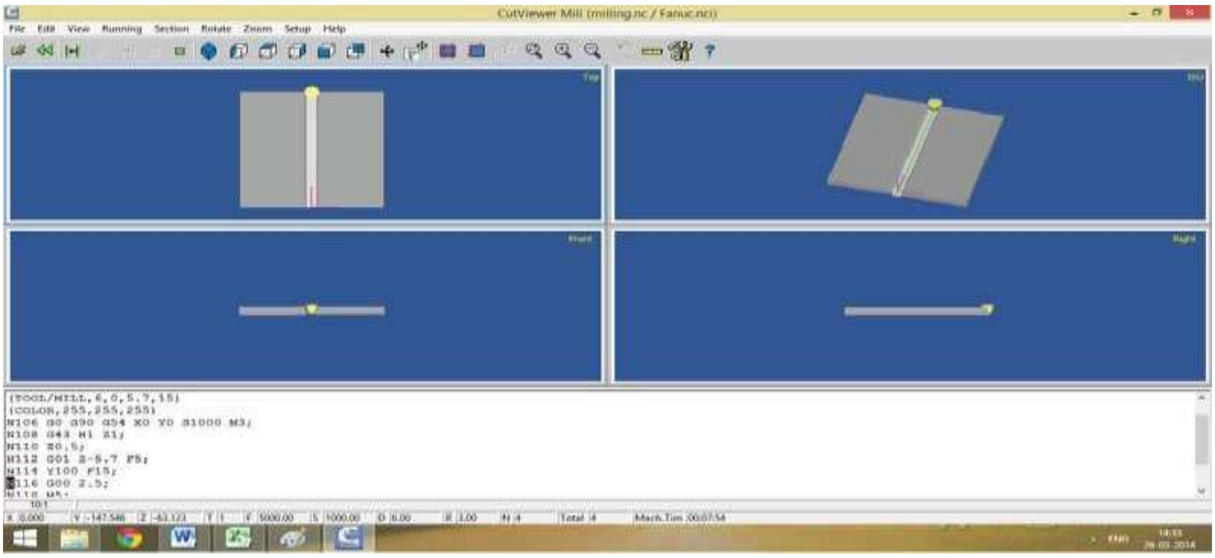


Figure 07 Simulation of CNC program

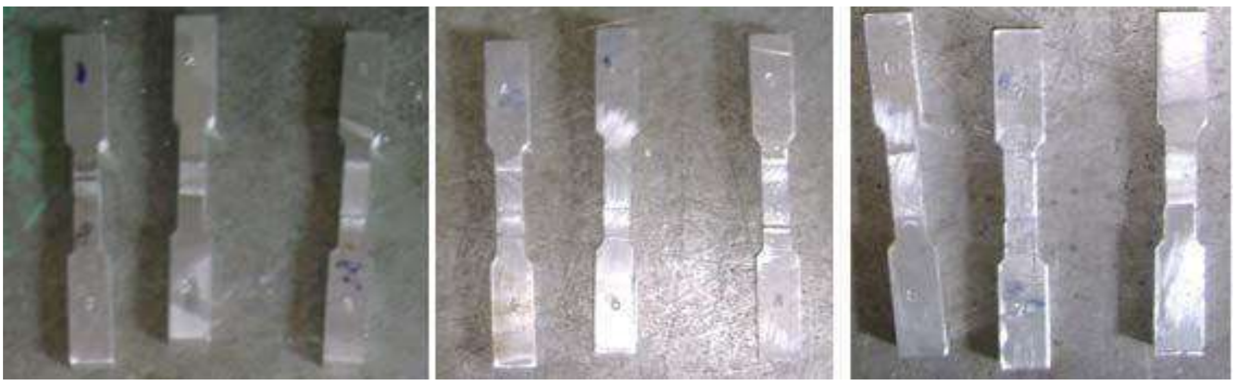


Figure 08 Friction stir welded pieces for all 9 experiments

Figure 09 Tensile test specimens before testing

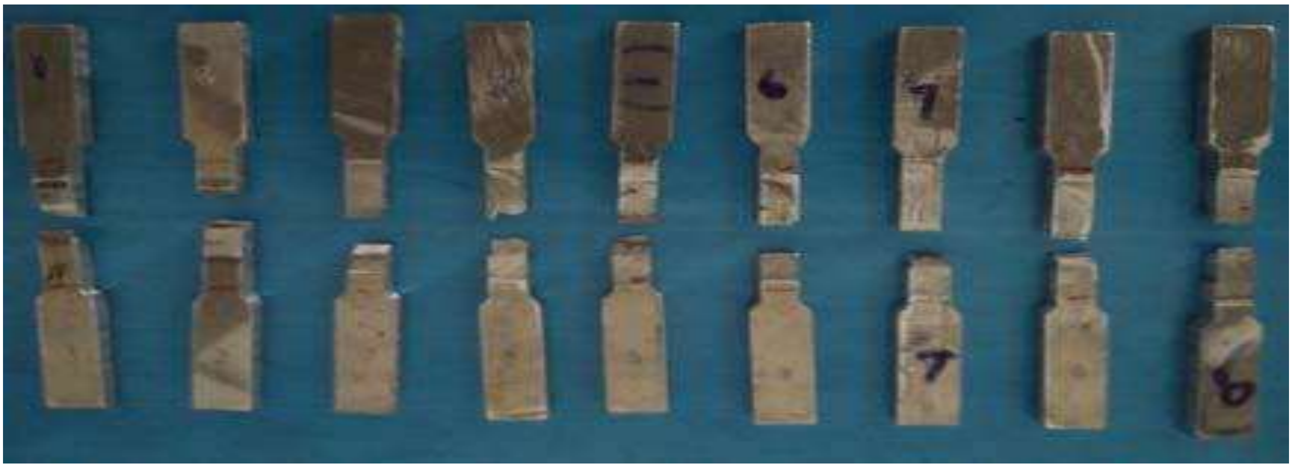


Figure 10 Tensile test specimens after testing

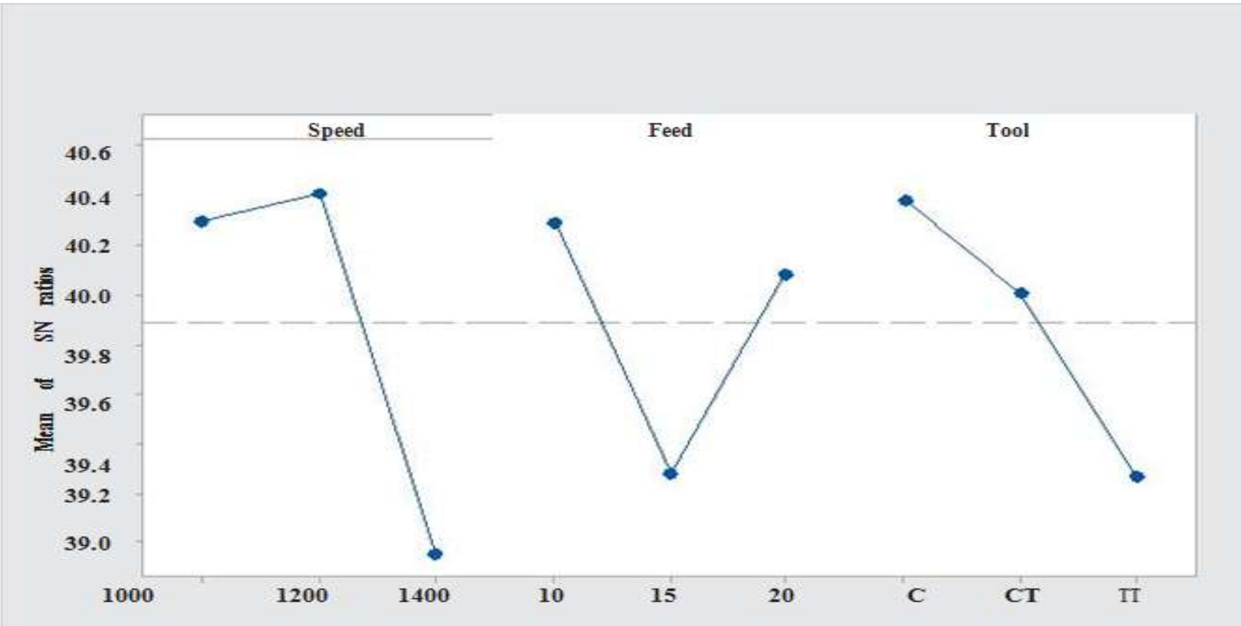


Figure 11 Graph for S/N Ratio Vs Factor Effects Main Effects Plot for SN ratios Data Means Signal-to-noise: Larger is better

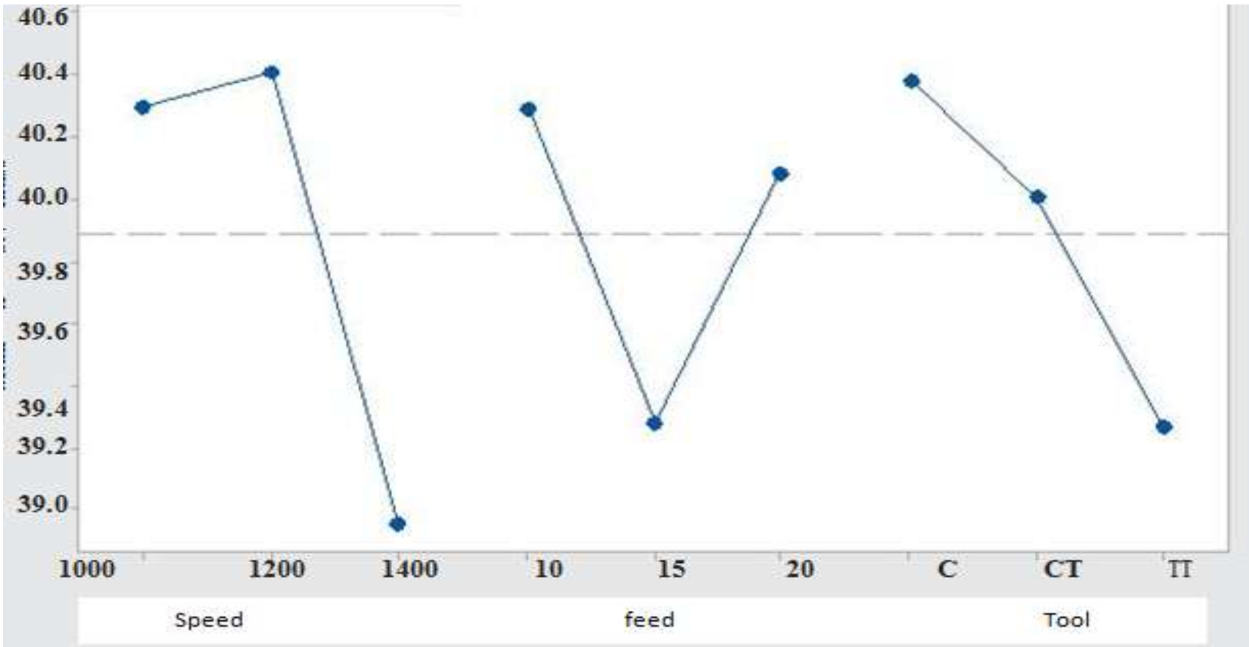


Figure 12 Graph for Mean Vs Factor

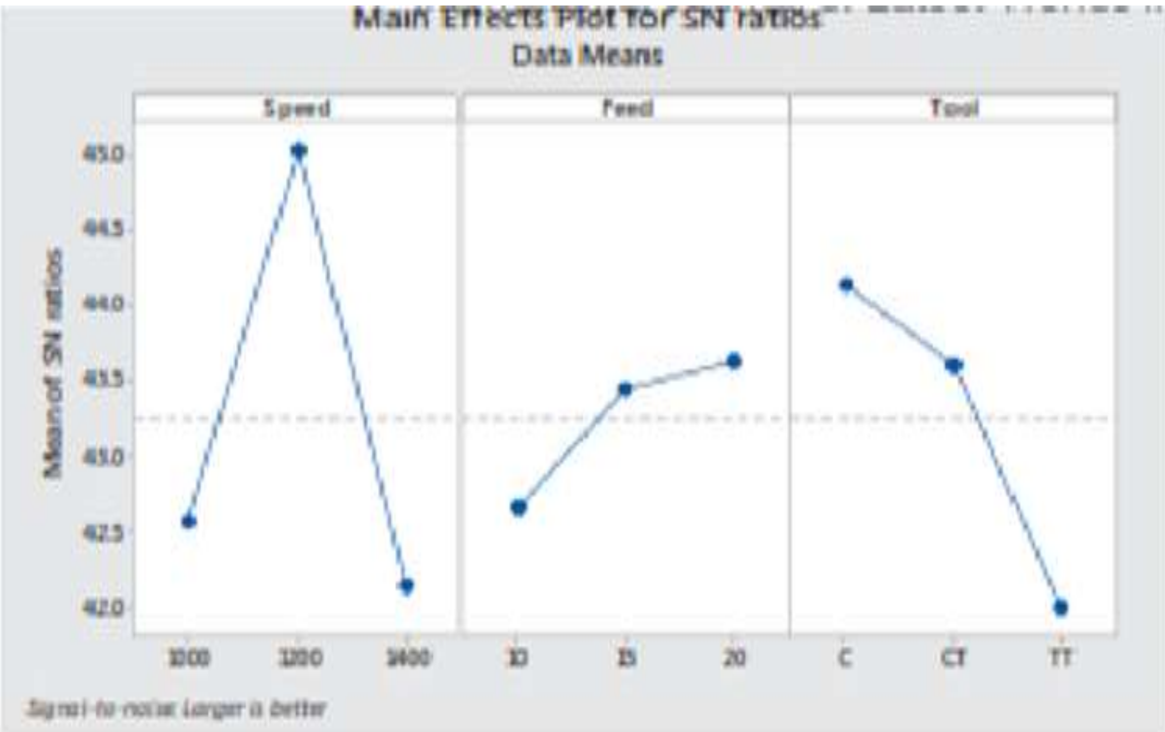
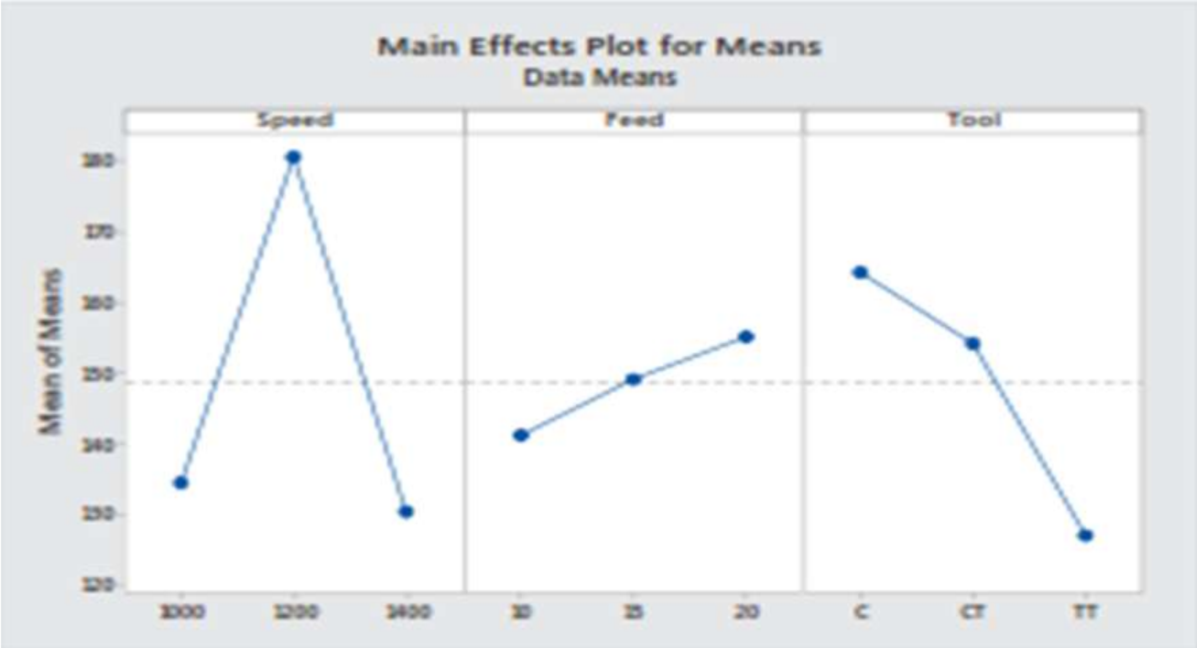


Figure 13 Main Effects Plot for SN ratios data Mean



Data Means

Figure 14 Graphs for Mean Vs Factor