FABRICATION OF A PUNCHING DIE USING P-20 MATERIAL ON WIRE ELECTRIC DISCHARGE MACHINE BY TAGUCHI METHOD

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Abstract: - *Wire Electrical Discharge Machine (WEDM) plays a vital role in the manufacturing industry to cut the hard and difficult tool and Die material which has the ability to generate intricate and complex shapes with high precision and accuracy. The material P-20, used in the present work study finds out the application as the mould steel. The main aim of the present investigation is to optimize the Process parameter for single response Characteristics. In this study, we are using the Taguchi method using the L-27 orthogonal array to find out the performance characteristics from the desired value. Experiments are carried out on P-20 mould steel as work piece electrode and zinc coated brass wire as a tool electrode. Response parameters are cutting speed, surface roughness and die width & material removal rate. Three trial experiments are conducted and the average is chosen as the particular experimental condition. Experiments are performed by using the different input variable such as Pulse ON(T-On),Pulse off (T-Off), Wire feed, Wire tension, Servo feed and Input current(I_P). In the end, the confirmation experiment is carried out to validate the effectiveness of proposed optimal condition.*

Keywords: - P-20 mould steel, WEDM, L_{27} Orthogonal Array, S/N ratio, ANOVA.

INTRODUCTION

Wire Electrical Discharge Machine (WEDM) is a metal removing machine in which material is eroded from a conductive work piece by means of electrical erosion and it uses the Zinc Coated copper wire of dia. 0.25mm. This wire does not come in contact with the conductive work piece. Erosion of the material takes place by the discrete spark between the work piece and the wire which is separated by the thin film of the dielectric fluid. The gap between the wire and the work piece is usually up to 0.025- 0.075 mm and is maintained constant with the help of the computer controlled WEDM. The selection of the optimum process parameter is an important step. The improper selection of the process parameter may result in the problem i.e short-Circuiting of wire, wire breakage and may cause damage to the work piece which result in reducing the productivity. Number of studies has been done on the various responses Material Removal Rate(MRR), Surface Roughness, Cutting Speed and Die width which in turn depend upon the machining parameter like Discharge Current, Pulse Duration, Pulse frequency, Di-electric flow rate and many more.

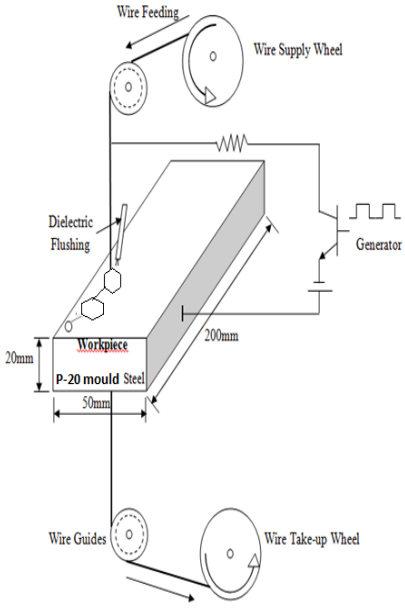


Figure.1

So, for the optimal selection of the process parameter in the present investigation we are using the Taguchi Method which has been widely used in the manufacturing to improve the process with single performance characteristics. The objective of present study is to investigate the Single response optimization of the WEDM process for machining of P-20 material to achieve the higher Material removal rate, lower surface finish, higher cutting Speed, and Nominal Die Width. In the end, the Analysis of Variances (ANOVA) and the confirmation experiment is conducted to validate the experimental result. The figure.1 shows the Systematic set-up of WEDM.

Taguchi method has envisaged a new method of conducting the design of experiment which are based on well defined guidelines. It uses a special set of array called orthogonal array. These standard array stipulates the way of conducting the minimal no. of experiments which could give the full information of all the factor that affects the performance parameter. The crux of orthogonal array method lies in choosing the level combination of Input design variables for each experiment.

EXPERIMENTAL SET-UP AND SELECTION OF PROCESS PARAMETERS

The pulse generator capacity of the machine is 40A. The pulse generator supplies the electrical energy to the spark gap in the form of pulses. The machine tool unit comprises of a main worktable (called X-Y table) by which the work piece is clamped on

auxiliary table (called U-V table) and wire drive mechanism. *Figure 2.* shows the stepwise procedure for Taguchi experimental design and analysis.

Figure 3. shows the experiments are carried out in CNC sprint cut wire EDM of Electronic a Machine tool ltd.

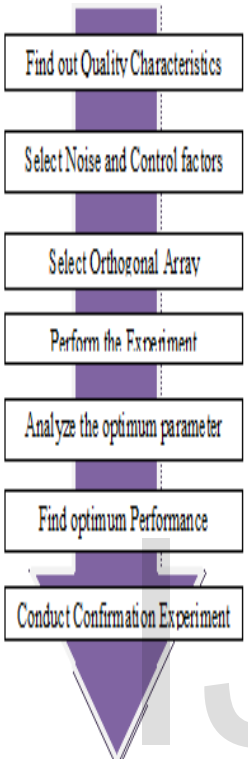


Figure 2.

Figure3.

Work piece Electrode: - The work piece material used in this investigation is P-20 mould steel. Composition of P-20 mould steel is C= 0.31%, Mn= 0.75% , Si=0.40% ,Cr= 1.2%, Ni=0.8%, Mo= 0.41%and S=0.03. A P-20 mould steel plate sized as 200x50x20 (L x b x w) is used.

Tool Electrode: - Wire is used as an electrode and the electrode material used in this investigation is Zinc coated copper wire which has the dia of 0.25mm. Zinc coated Copper wire electrode can conduct high current as compare to simple copper wire.

Selection of Process Parameters and their Ranges: - In order to obtain high cutting speed, accurate dimension, better quality of surface roughness and the Good Material removal rate can be obtained by WEDM process. The optimal level of WEDM process parameters need to be determined. Based on the critical review of literature, process variables of the WEDM are selected according to transient state.

The process parameters selected for this study are as following:

a. Pulse-ON time
b. Pulse- OFF time.
c. Wire Feed
d. Wire Tension
e. Servo Feed
f. Input Current

In Sprint-cut WEDM, the value of current ranges b/w 10 to 230A, Pulse-ON time b/w 110 to 131, Pulse-OFF varies b/w 0-63, Wire speed 1-15m/min and Wire tension ranges between1 to 15N.

Sr. No	Level	Control factors					
		A	B	C	D	E	F
1	1	120	48	3	5	2100	140
2	2	124	52	4	6	2150	170
3	3	128	56	5	7	2200	210

Table 1. Levels for various control factors.

SELECTION OF ORTHOGONAL ARRAY (OA) AND PARAMETER ASSIGNMENT: -

Before selecting a particular OA to be used as a matrix for conducting the experiments, the following two points are first considered:

1. The number of parameters and interactions of interest.
2. The number of levels for the parameters of interest.

Degree of freedom (DOF) associated with each factor is equal to no. of level -1. Therefore, total degree of freedom for the five factors is (2+2+2+2+2+2) 12. As per Taguchi's method, the total DOF of selected OA must be greater than or equal to the total DOF required for the experiment. So, L27 OA having 26 (=17-1) degree of freedom is selected for the present analysis. The experiments are conducted at each trial conditions as given in *table 2.* For each trial, the experiments is repeated by three times.

Sr. No.	Parametric Trial Condition					
	A	B	C	D	E	F
1	1	1	1	1	1	1
2	1	1	1	1	2	2
3	1	1	1	1	3	3
4	1	2	2	2	1	1
5	1	2	2	2	2	2
6	1	2	2	2	3	3
7	1	3	3	3	1	1
8	1	3	3	3	2	2
9	1	3	3	3	3	3
10	2	1	2	3	1	2
11	2	1	2	3	2	3
12	2	1	2	3	3	1
13	2	2	3	1	1	2
14	2	2	3	1	2	3
15	2	2	3	1	3	1
16	2	3	1	2	1	2
17	2	3	1	2	2	3
18	2	3	1	2	3	1
19	3	1	3	2	1	3
20	3	1	3	2	2	1
21	3	1	3	2	3	2
22	3	2	1	3	1	3
23	3	2	1	3	2	1
24	3	2	1	3	3	2
25	3	3	2	1	1	3
26	3	3	2	1	2	1
27	3	3	2	1	3	2

Table 2. L_{27} orthogonal array

RESULT AND DISCUSSION

In this section, we are discussing the effect of WEDM process parameters(peak current, pulse on time, pulse off time, current, wire speed and wire tension) on the basis of response characteristics(cutting speed, die width and surface roughness). The average value of response characteristics, mean data and S/N ratio for each parameter, at all levels, is calculated from *table 3.* These

effects are plotted by using MINITAB 15 SOFTWARE *(Minitab is a statistical package designated mainly as a teaching tool. Although, it is easy to use, it is quite powerful & flexible for moderate size data set. Minitab allows to store a worksheet of data & does some statistical manipulation with it)* .

Effect Of Parameters On Die Width

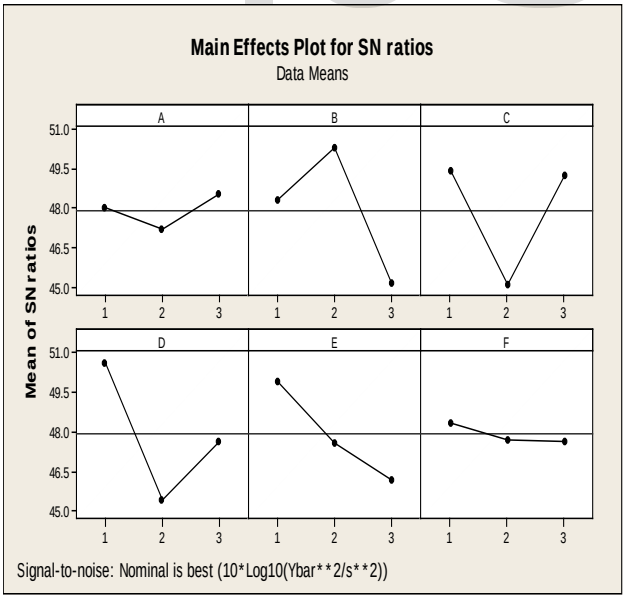
For better performance of the die it should be dimensionally accurate so that it should be matched with the punch. In this experiment, die width is measured from all the six sides. Average value of Cutting speed calculated from raw data is 2.66 mm/min. it is clear from the S/N plots where the maximum S/N ratio occur correspond to A3, B2, C3, D1, E1 and F1. Dimensional accuracy is a "nominal is best" type characteristic. Main effects of each parameter are calculated from response table 3 and 4 as shown in figure 4.

Table 3. Response table for S/N ratio (Nominal is best)

Level	A	B	C	D	E	F
1	47.99	48.29	49.43	50.66	49.93	48.36
2	47.19	50.31	45.05	45.42	47.6	47.74
3	48.56	45.14	49.25	47.66	46.18	47.63
Delta	**1.37**	**5.17**	**4.38**	**5.25**	**3.76**	**0.73**
Rank	**5**	**2**	**3**	**1**	**4**	**6**

Table 4. Response Table for Mean

Level	A	B	C	D	E	F
1	12.09	12.06	12.12	12.13	12.11	12.11
2	12.1	12.1	12.06	12.04	12.07	12.05
3	12.04	12.07	12.06	12.06	12.06	12.07
Delta	**0.06**	**0.04**	**0.06**	**0.09**	**0.05**	**0.06**
Rank	**4**	**6**	**2**	**1**	**5**	**3**



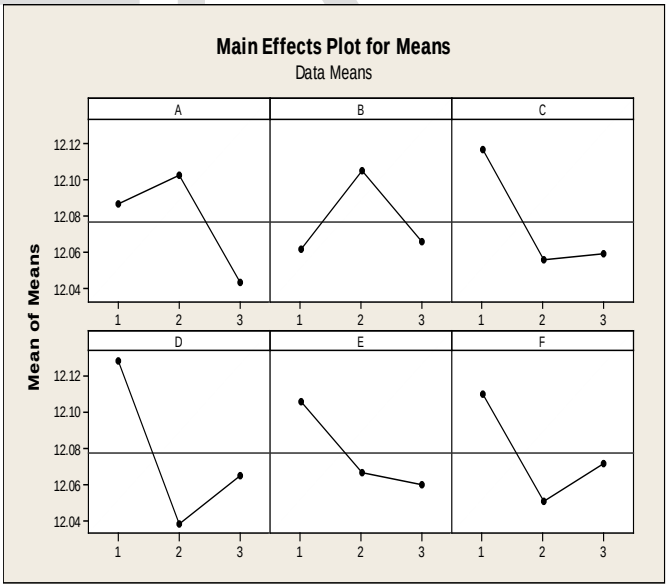


Figure 4. Main Effect Plot for S/N ratio and MEAN

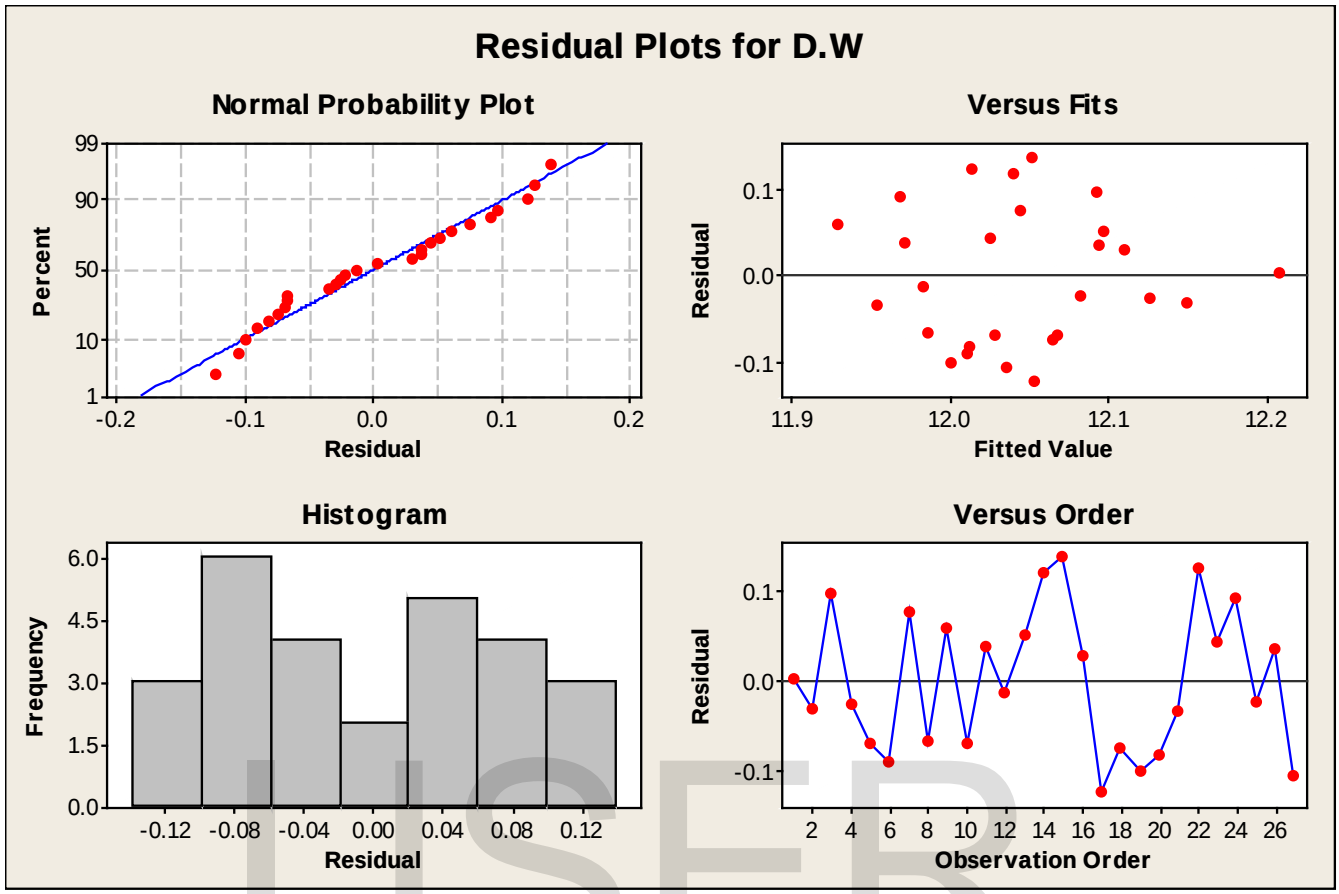


Figure 5. Residual Plot for Die Width

Effect of Parameters On Surface Roughness

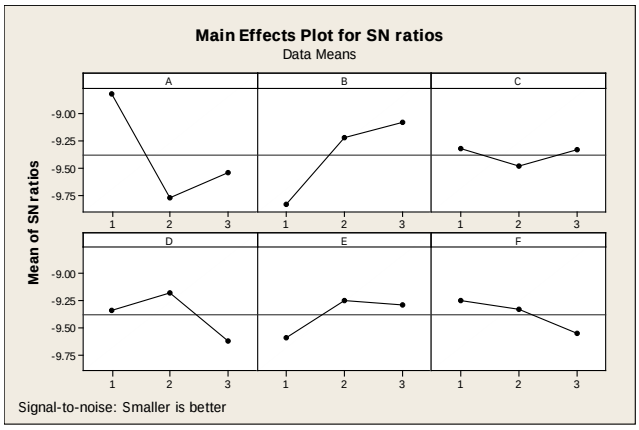
Surface roughness is a key factor in die making and depends upon the energy drop across the electrodes. Surface roughness is a "smaller is better" type characteristics. So, the optimum value of surface roughness should be low so that depth of recast layer remains minimum or equal to zero. Average value of surface roughness is 2.93. Main effects of each parameter are calculated from response table 5 and 6 as shown in fig 5. These effects are plotted by using MINITAB 15.

Table 5. Response Table for S/N Ratios (Smaller is better).

Level	A	B	C	D	E	F
1	-8.82	-9.83	-9.32	-9.34	-9.59	-9.25
2	-9.77	-9.22	-9.48	-9.18	-9.25	-9.33
3	-9.54	-9.08	-9.33	-9.62	-9.29	-9.55
Delta	**0.94**	**0.75**	**0.16**	**0.43**	**0.34**	**0.30**
Rank	**1**	**2**	**6**	**3**	**4**	**5**

Table 6. Response Table for Means

Level	A	B	C	D	E	F
1	2.748	3.091	2.909	2.911	3.012	2.886
2	3.065	2.879	2.974	2.868	2.891	2.921
3	2.984	2.828	2.914	3.019	2.894	2.99
Delta	**0.317**	**0.263**	**0.065**	**0.151**	**0.121**	**0.105**
Rank	**1**	**2**	**6**	**3**	**4**	**5**



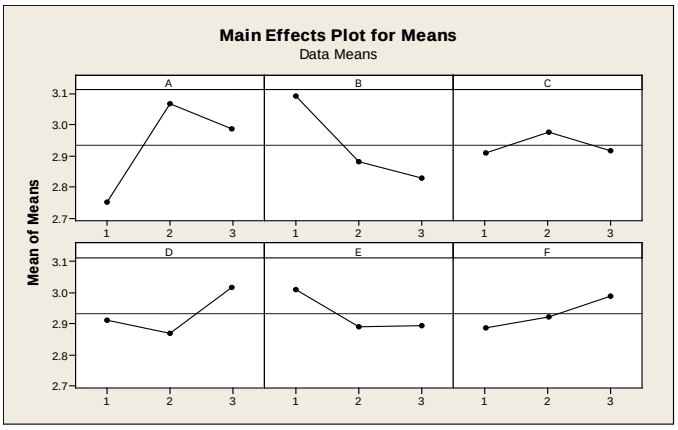


Figure 6 Main Effect Plot for S/N ratio and MEAN

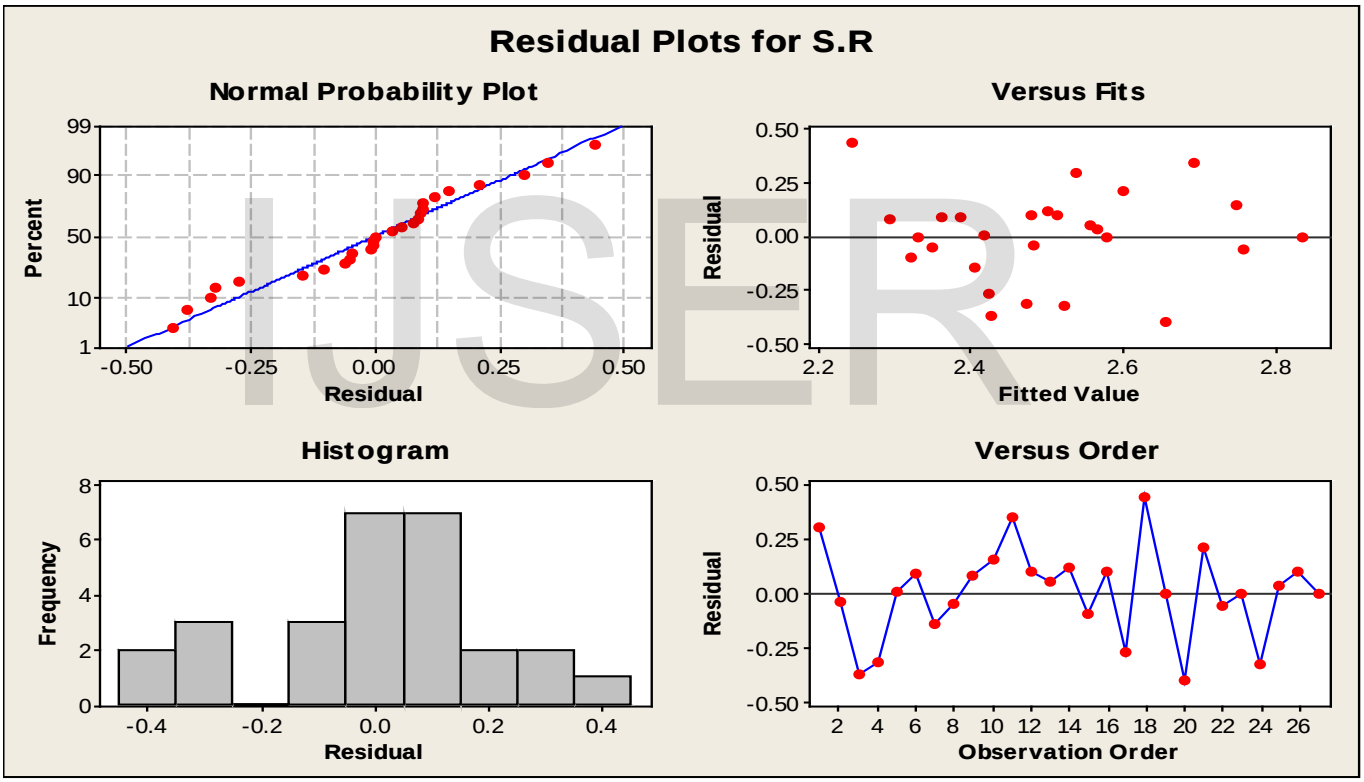


Figure 7. Residual Plot for Die Width

Effect of Parameters On Material Removal Rate:- Wherever cutting is required, we need high Material removal rate. MRR is a "Larger is better" type characteristics which denotes the optimum value of MRR should be high so that production can be increased and we can save the time. Average value of MRR is Main effects of each parameter are calculated from response table 7 and 8 as shown in fig 8. These effects are plotted by using MINITAB 15. It is clear from the S/N plots that the maximum S/N ratio occurs corresponding to A3, B1, C3, D1 and E3.

Level	A	B	C	D	E	F
1	29.3	33.3	31.19	31.0	31.1	30.8
2	31.5	30.9	31.09	31.1	31	30.5
3	32.5	28.9	31.03	31.1	31.1	31.9
Delta	**3.22**	**4.46**	**0.16**	**0.1**	**0.2**	**1.48**
Rank	**2**	**1**	**5**	**6**	**4**	**3**

Table 7. Response Table for S/N Ratios

Level	A	B	C	D	E	F
1	30	47.37	36.84	35.87	37.99	36.11
2	38.5	36.06	36.92	37.77	36.83	34.75
3	43.31	28.4	38.02	38.18	37.2	40.97
Delta	**13.31**	**18.97**	**1.18**	**2.3**	**0.95**	**6.22**
Rank	**2**	**1**	**5**	**4**	**6**	**3**

Table 8. Response Table for Means

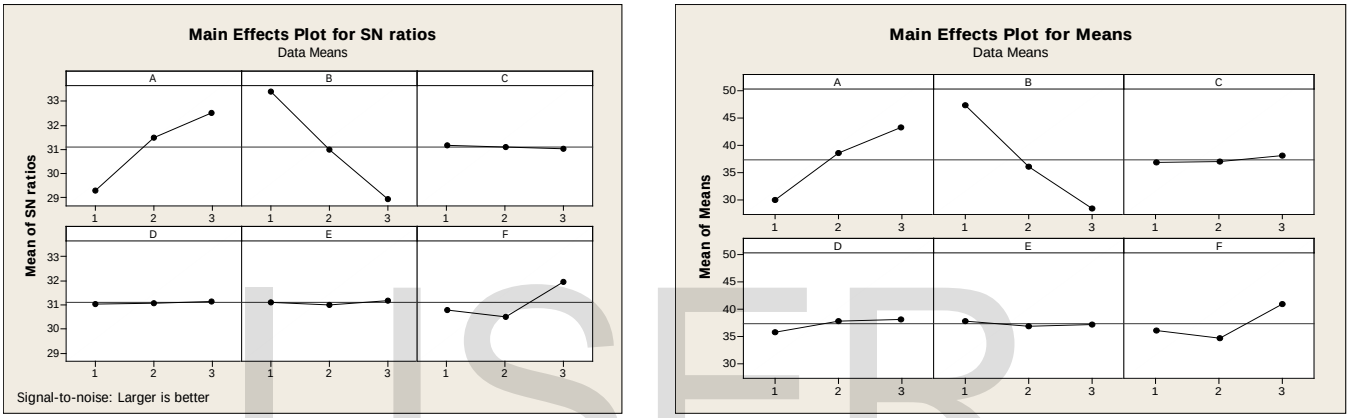


Figure8. Main Effect Plot for S/N ratio and MEAN

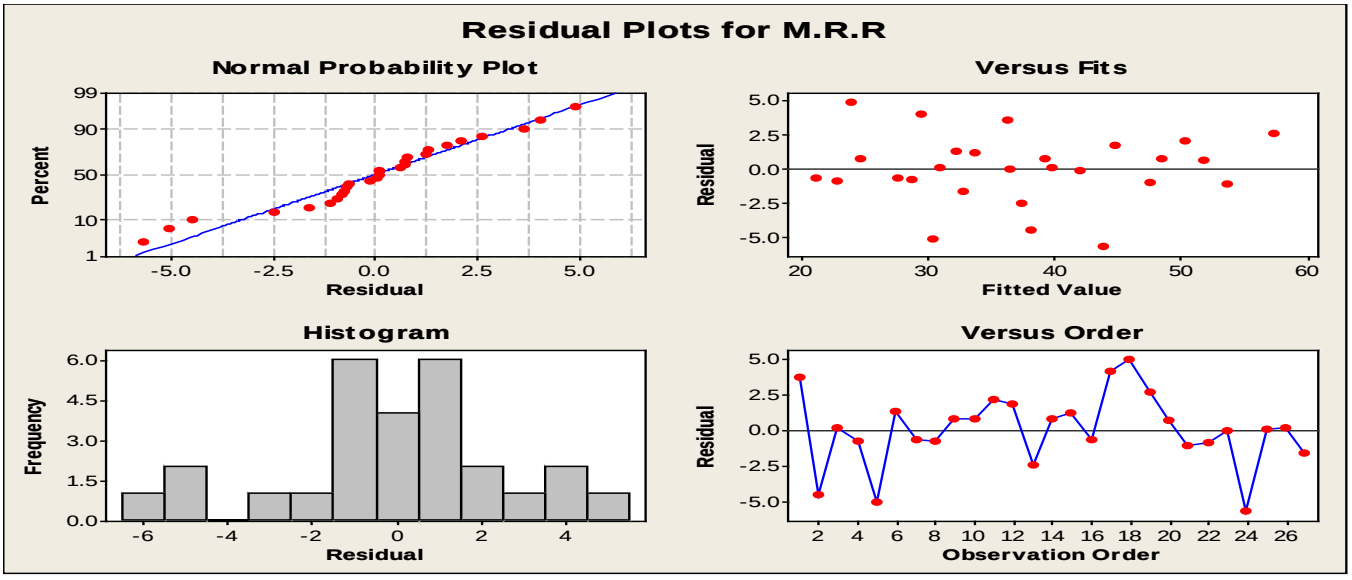


Figure 9. Residual Plot for Die Width

Effect Of Parameters On Cutting Speed

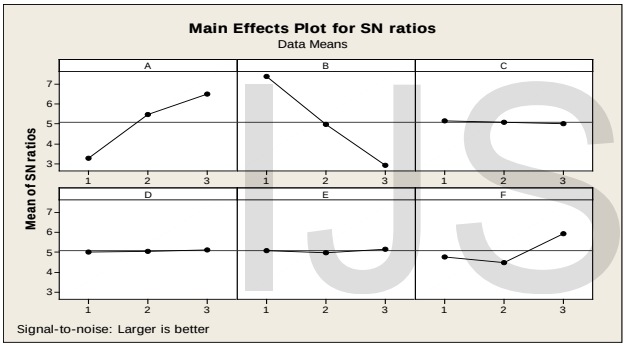
Average value of Cutting speed calculated from raw data is 2.59mm/min. It is clear from the S/N plots. That the maximum S/N ratio occurs correspond to A6, B3, C3, D1 and E3. Therefore, the optimum value will correspond to these factors but only the significant factor would be chosen. This factor will be chosen from the ANOVA table.

Level	A	B	C	D	E	F
1	3.27	7.37	5.16	5.03	5.09	4.73
2	5.47	4.97	5.06	5.08	4.97	4.48
3	6.49	2.90	5.01	5.13	5.17	5.97
Delta	**3.21**	**4.46**	**0.15**	**0.10**	**0.14**	**1.48**
Rank	**2**	**1**	**5**	**6**	**4**	**3**

Table 9. Response Table for Signal to Noise Ratios (Larger is better)

Level	A	B	C	D	E	F
1	1.5	2.368	1.842	1.794	1.889	1.805
2	1.925	1.803	1.848	1.889	1.842	1.737
3	2.166	1.42	1.901	1.909	1.86	2.048
Delta	**0.665**	**0.949**	**0.059**	**0.115**	**0.048**	**0.311**
Rank	**2**	**1**	**5**	**4**	**6**	**3**

Table 10. Response Table for Means



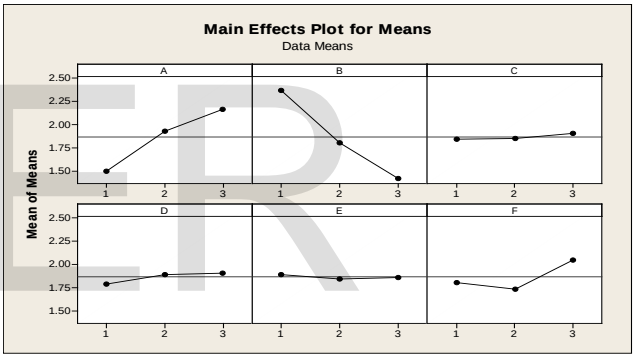


Figure10. Main Effect Plot for S/N ratio and MEAN

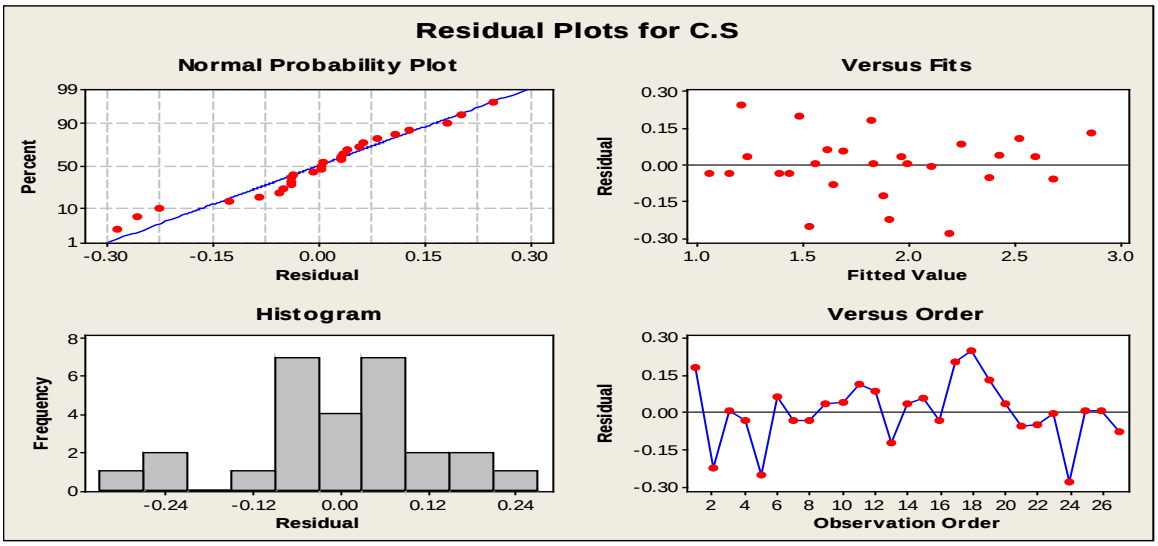


Figure11. Residual Plot for Die Width

Confirmation experiment is conducted for the cutting speed, die width and for surface roughness. The experimental value obtained at the optimal setting of parameter is:

Cutting speed = 3.00 mm/min

Die width = 12.08 mm

Surface roughness = 3.12 µm.

Material Removal rate= 60mm/min

CONCLUSION:-

On the basis of above studied experiments, it can be safely concluding that:-

- Material removal rate increases with increase the Pulse ON time and Pulse OFF time.
- Die width is best at Wire tension, wire feed and pulse on time.
- Surface Roughness is mostly affected by Pulse ON time.
- Cutting Speed is affected by Pulse OFF time

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