Study the effects of chromium powder mixed dielectric medium for machining H13 tool steel

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Abstract: In the current examination, enhancement of chromium powder blended EDM parameters is concentrated during machining of H13 device steel. Four info parameters of powder blended EDM to be specific pinnacle current, beat on schedule, obligation cycle and powder fixation are shifted, each at three levels, to get the ideal reactions. Copper terminal of 16 mm is utilized as the apparatus. Reaction Surface Methodology is utilized to relate information and yield parameters. The variety of reactions because of variety in input parameters has been contemplated and appeared as surface plots and form plots. Results uncovers that beat on schedule, powder fixation, there should be an occurrence of Surface Roughness, beat on schedule, top current and powder focus are the huge elements influencing the Ra. Moreover, it is discovered that most extreme MRR is there when both pinnacle current and obligation cycle are expanded at the same time. Least TWR is gotten when current is at its low level (10 Amp). If there should be an occurrence of surface harshness, least estimation of Ra is acquired when beat on schedule and pinnacle current at the same time are at low levels (100µsec and10 amp) while powder focus and obligation cycle are at their transitional levels (10g/l and 6%). Attractive quality Method is utilized to advance the info parameters to get ideal estimations of reactions. Ideal arrangement that has been found for the current investigation is 16.1250 mm3/min MRR, 0.3161 mm3/min TWR and 7.6987 µm Ra with top current 20 ampere, obligation cycle 5.0909%, beat on time 200 µsec and powder convergence of 11.667 g/l.

1.0 Introduction

In PMEDM (Powder blended EDM), a reasonable powder like silicon, titanium and vanadium so on blended with the dielectric fluid. Because of the current the powder particles get empowered and quickened and conveyors and advance breakdown the hole and furthermore improve the flash between the electrode and workpiece.

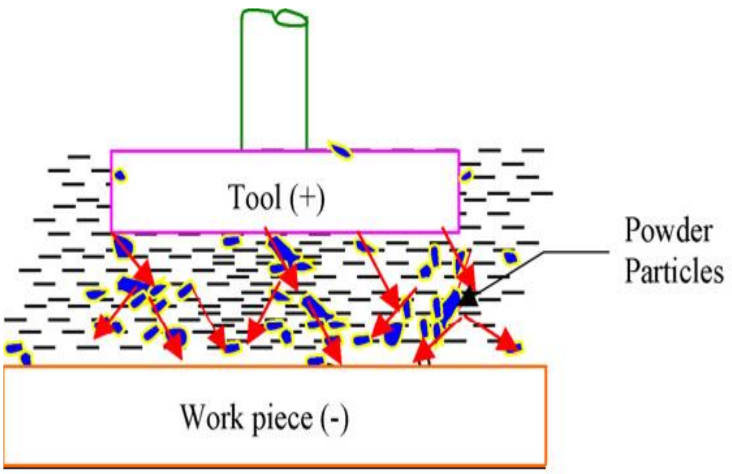

Fig 1.4 Working Principle of PMEDM [30]

Particles of powder shaped the chain structure and orchestrate themselves current. It causes the hole between terminal and workpiece, henceforth protecting quality of dielectric fluid gets decreased then lead-to simple short-circuiting thus early flash in the hole happens. It brings about the arrangement of releases under the cathode zone. Because of this, quicker starting causes the quicker disintegration from workpiece thus material removal rate increased. Expansion of powder-in-dielectric fluid amplify plasma-which makes the electric dicharge thickness decline and consequently uniform disintegration happens on the workpiece prompting better-surface completion alongside high MRR.

2.0 Literature Review

Some literature has been reviewed to find some gaps in EDM process and to find out the effect of different input parameters on MRR, TWR and Surface roughness in EDM process. Some papers are discussed below to get an idea:

Pecas et al., [1] studied the effect of silicon powder concentration on the surface roughness of AISI H13 steel. Peak current, polarity, duty cycle, flushing pressure and powder concentration were-taken as input parameters. This method was used to design the experiment. It was found that surface roughness decreases with increase in the powder concentration of silicon powder and negative polarity of the tool electrode and increases with increase in current, duty cycle and flushing pressure.

Klocke et al., [2] directed an examination to consider the impact of aluminum powder blended dielectric on surface unpleasantness of Inconel 718 combination utilizing tungsten cathode. Extremity, voltage, powder fixation and heartbeat term were taken as information parameters. Reaction Surface strategy was utilized as the plan system. It was discovered that powder focus and heartbeat span has the noteworthy impact on a superficial level unpleasantness. Increment in powder fixation brought about bringing down the surface unpleasantness and the other way around. Then again, low surface unpleasantness was found at low heartbeat length.

Wu et al., [5] studied that by adding Al powder in the dielectric fluid can result in obtaining the electric discharge distribution effect. Electrostatic forces among the powder particles make the powder to concentrate at one point in the dielectric. Hence, to separate the powder homogeneously in the dielectric, a surfactant can be used. In the study, effects of adding-powder and surfactant in the dielectric on the work piece (SKD steel) after EDM is investigated. With 0.1g/l and 0.25g/l of powder and surfactant respectively, a best distribution effect is found. Positive polarity, gap voltage 90 V, surfactant concentration 0.25g/l, discharge current 0.3 A, pulse duration time 1.5 μs were required for optimum surface roughness. There is 60% improvement in the surface roughness as compared with the surface roughness of the surface machined with no powder in the dielectric.

Dhar and Purohit [7] studied the effect of pulse on time, current and open voltage on the MRR and TWR during EDM with Al–4Cu–6Si alloy–10 wt. % SiC composites. Experiment was performed on PS LEADER ZINC EDM machine using cylindrical type brass electrode of 30 mm diameter. Three level factorial designs were used to analyze the results. In order to establish the relationship among the machining parameters, a second order non linear mathematical model was developed. ANOVA was used to check the significant of the model. It was found that MRR and TWR increase significantly with increases in current.

Kansal et al., [8] studied EDM of AISI D2 die steel by mixing silicon powder in the dielectric fluid of EDM. Cu-electrode of 25 mm was used as the EDM tool. Six parameters namely peak current, pulse on time, pulse off time, concentration of powder, gain and flushing pressure were considered as input parameters and MRR as output. Taguchi method was used as the design technique. All the input parameters except flushing pressure have the significant effect on the MRR according to ANOVA analysis. Peak current and powder concentration were most effective parameters in causing material removal. Levels of the parameters that produce optimum MRR were Peak current (16 A), powder concentration (4g/l), pulse on time (100micro sec), pulse off time (15 micro sec) and gain (1mm/sec).

3.0 Objectives:

The objectives of this experimentation are given below:

a) Machining of H13 steel which is very difficult to machine due to high toughness and hardness.
b) Effects of various process parameters namely on MRR.

4.0 Experimentation:

For this experimentation, various tools and machines were used to get various observations and results.

4.1 EDM Machine

In this experimentation, we have conducted trails on ELEKTRAPLUS PS 35 die sinking Electrical Discharge Machine available at Gaurav Machine Tools Pvt ltd Chandigarh. The pictorial view of the machine is shown in fig 1.

Fig 1 EDM used for experimentation

EDM machine shown in fig 1 can vary the peak current from 0.5 to 50 ampere. It has two settings for dielectric fluid i.e 0 and 1. Pulse on time can be varied from 2 to 440 µsec. Pulse off time has the range from 0 to 200 µsec. Spark voltage can be varied from 0 to 15 volt. Fluid Pressure can be varied from 0 to 30 kg/cm^2. Some other specifications of EDM machine are shown in the following table.

4.2 Setup of Powder Mixed in Dielectric fluid

For carrying out the experiment by mixing the powder in the dielectric following points should be considered:

a) Entry of the powder to the main tank and filter unit of the machine should be prevented.

b) To prevent the settling of the powder at the bottom of the tank, proper stirring to the powder should be provided.

c) Proper electrical conductivity between the tool and the workpiece should be maintained.

4.3 Preparation of Workpieces for Experimentation

A H13 steel plate of dimension 105 mm × 105 mm × 15 mm is taken. As there are 31 experiments have to be performed therefore 31 rectangular pieces are cut from the available plate with the help of power hacksaw. After performing grinding operation for finishing, the rectangular pieces of dimension 28 mm × 20 mm ×10 mm become ready for carrying the experiments. The pictorial view of the final rectangular pieces is shown below

Fig 2 Specimens for experimentation

The chemical composition of the H13 steel is shown in table 4.2. This composition is according to the catalogue of the Sehgal die steel company Ludhiana from where material has been bought.

4.4 Weighing the Specimen

Before performing the experiments, the weight of all specimens was measured using electronic balance (SONIC) model HBP2000N. After EDM operation, again the weight of specimen was measured. This was done to calculate the material removal rate (MRR). In the same manner, weight of copper electrode before and after each experiment was measured in order to find out the tool wear rate (TWR).

4.5 Surface Roughness Measurement

Surface roughness is an important output parameter in the present study. Profilometer, model M4Pi Germany available in the metrology lab of Thapar University Patiala, was used to measure the surface roughness of the specimens. This equipment uses the stylus method of measurement and can measure the surface roughness up-to 100 µm. In this study, surface roughness was measured at two different positions with the tracing length of 4 mm and average of the values at these two positions was taken as final reading for analysis the result.

5.0 Results and discussion

5.1 Response Surface Methodology

In the present study, Response Surface Methodology (RSM) is used to design the experiments. RSM is implemented with the help of MINITAB 16 software. For designing the experimental matrix, four parameters selected. Each parameter has three levels in which they are varied. MRR, TWR and Ra are considered as output parameters (desired responses) which will judge the performance of Powder mixed EDM when the values of input parameters will be varied in different levels.

As RSM is used to design the experimental matrix with the help of MINITAB 16 software, therefore there will be total 31 experiments as there are four input parameters are taken in an experiment. Type of design used in the present study is CCD. The worksheet of this step is shown below:

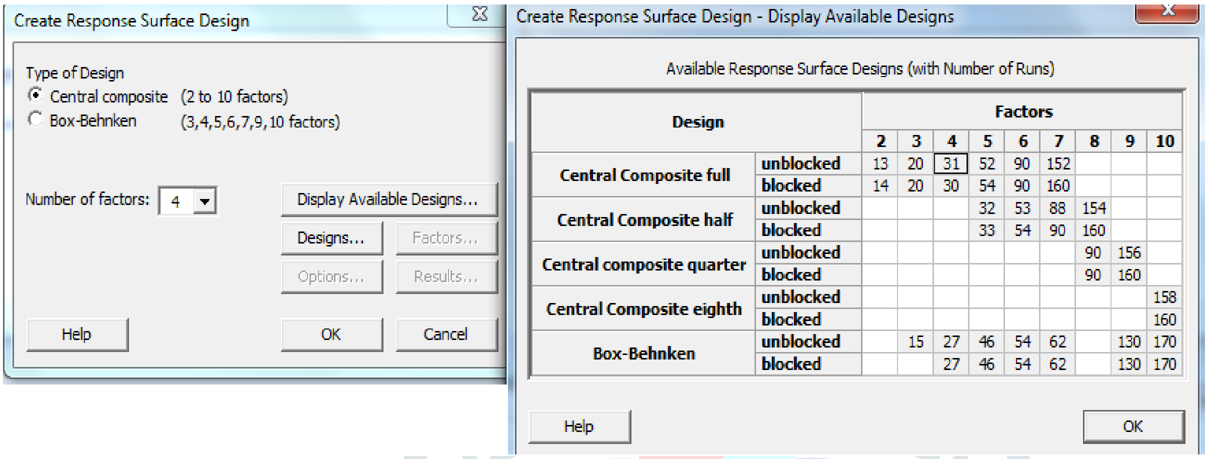

Fig 5 DOE by RSM using MINITAB

5.2 Input Parameters and their Levels

Among the four input parameters, the levels of three input parameters namely Peak-current, Pulse-on-Time and Duty cycle are taken according to the range of the machine while the levels of the fourth parameter which is powder concentration are selected on the basis of literature review. Input parameters with their levels are listed in the following table:

Table 1 Input Parameters with Levels

Parameter	Code	Level 1	Level 2	Level 3
Peak current (Amp)	A	10	15	20
Duty Cycle %	B	4	6	8
Pulse on Time (µs)	C	100	150	200
Powder Concentration (g/I)	D	5	10	15

Above mentioned parameters are the parameters which are varied to get the best result of MRR, TWR and Ra. Apart from these parameters, there are some parameters which remain constant throughout the experiment. These parameters along with their values are given in table 5.2.

Table 2 Constant Parameters

Workpiece material	H13 die steel
Diameter of copper electrode	15 mm
Pressure	0.6 kg/cm^2
Peak voltage	120 volt DC
Machining-time	8 minutes
Gap	3 mm
Pulse off time	180 µseconds
Polarity	Straight

Each run is performed by keeping these above parameters constant at their values given in the table 2.

5.3 Responses Variables

In this study, three responses namely MRR, TWR and Ra are selected for evaluating the performance of Powder mixed EDM. Therefore, it is necessary to evaluate the values of MRR, TWR and Ra.

1. **Evaluation-of-MRR**: The material removal rate is

   MRR=$(Wjb - Wja) \times 1000/(t \times \rho,)$ mm^3/min. (5.1)

   Wjb=Weight of the workpiece before machining in grams.

   Wja= Weight of the workpiece after machining in grams.

   $\rho,$ = Density of H13 steel= 7.80gm/cm^3.

   t= Machining time = 8 min.

Fig 3 (a) Workpiece after machining

Fig 3 (b) Workpiece before machining

Fig 4 Copper electrode used for machining

5.4 Results for Material Removal Rate

Table 3 represents the ANOVA table for material removal rate which is as follow:

Table 3 ANOVA table for MRR

Source	DF	Adj SS	Adj MS	F ratio	P value
Model	14	674.118	48.151	56.81	0.0001
Linear	4	618.235	154.559	182.90	0.0001
A	1	428.409	428.409	506.96	0.0001
B	1	166.920	166.920	197.53	0.0001
C	1	5.315	5.315	6.29	0.0231
D	1	17.592	17.592	20.82	0.0001
Square	4	23.036	5.759	6.81	0.0021
A*A	1	6.413	6.413	7.59	0.0141
B*B	1	0.002	0.002	0.00	0.9581
C*C	1	0.144	0.144	0.14	0.7181
D*D	1	0.006	0.006	0.01	0.9321
Interaction	6	32.847	5.474	6.48	0.0011
A*B	1	20.122	20.122	23.81	0.0001
A*C	1	8.312	8.312	9.84	0.0061
A*D	1	1.852	1.852	2.19	0.1581
B*C	1	0.645	0.645	0.76	0.3951
B*D	1	0.057	0.057	0.07	0.798
C*D	1	1.860	1.860	2.20	0.1571
Residual Error	16	13.521	0.845		
Lack of fit	10	6.972	0.697	0.64	0.7471
Pure Error	6	6.549	1.092		
Total	30	687.639			

With the help of MINITAB 16 in RSM, a mathematical equation between the MRR and given input factors has been generated as below

MRR = 20.32 - 2.152 A - 0.31 B - 0.0832 C - 0.215 D + 0.0629 A*A - 0.008 B*B

+ 0.000084 C*C + 0.0020 D*D + 0.1121 A*B + 0.002883 A*C + 0.01361 A*D

+ 0.00201 B*C - 0.0060 B*D + 0.001364 C*D (5.3)

The above equation in terms of coded factors can be used to make the predictions about the MRR for given levels of each factor.

Furthermore, in order to study the effect of individual parameter on the response, main effect plots are generated. When the mean response changes across the levels of a factor, then the main effect occurs. The main effects plot for MRR is shown below in fig 5.4. From the main effects plot it is found that MRR increases almost linearly with increase in current (A). It may be due to the fact that pulse energy increases with increase in current which further increases the rate of heat energy in the discharge channel and hence results in increasing the rate of melting of workpiece at the portion where discharge occurs which enhances the MRR. With increasing the Duty cycle (B), MRR increases continuously because percentage of pulse on time duration relative to total cycle increases which increases the energy density on workpiece and hence the MRR.

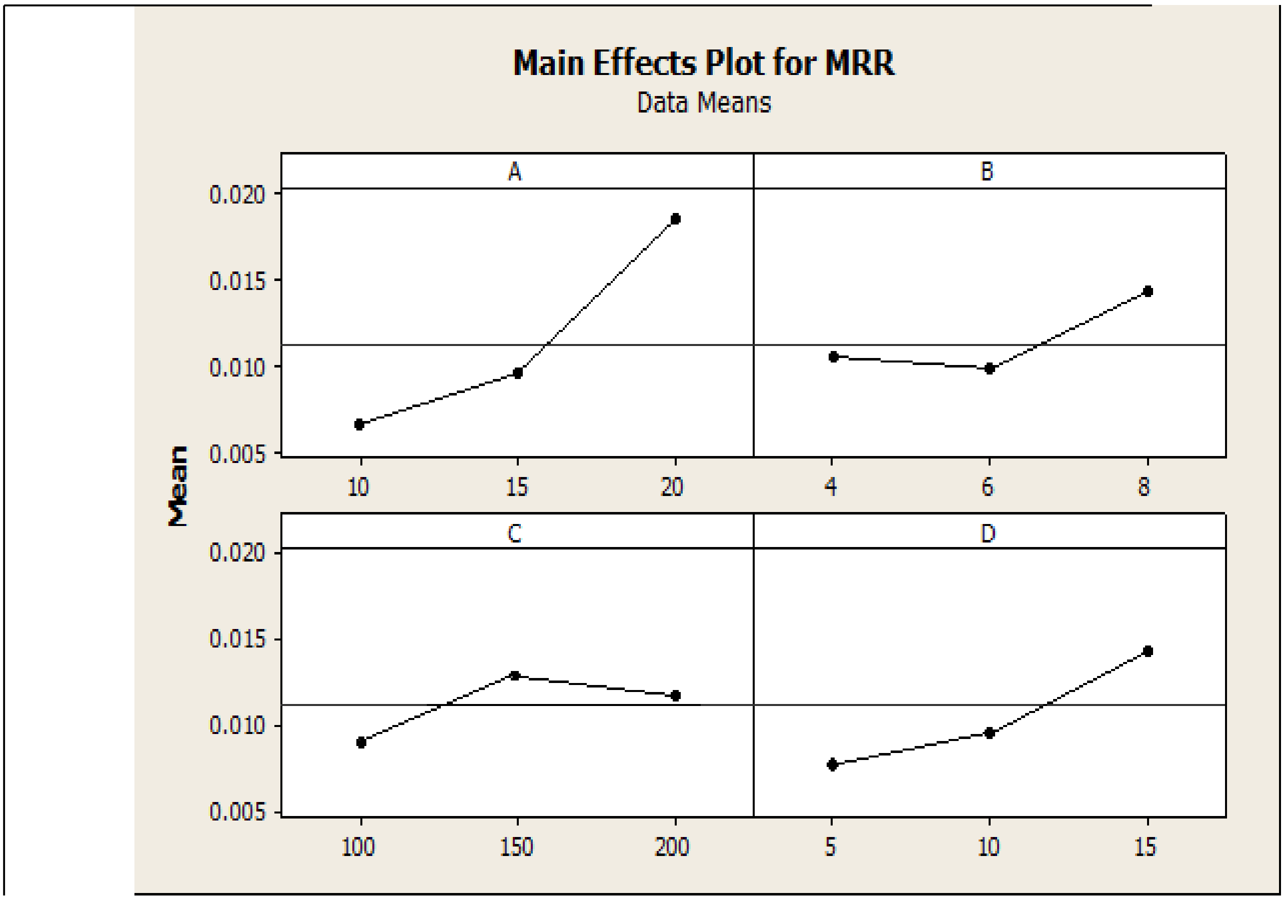

Fig 5 Main effects plot for MRR

It can be seen the main effect plot that MRR increases when the value of pulse on time (C) changes from 100 µseconds to 150 µseconds and then decreases as the value of pulse on time increases from 150 µseconds to 200 µseconds. This may be due to the fact that short pulse duration causes less vaporization on the workpiece surface, whereas longer pulse durations make the machining process unstable due to increased possibility of short circuiting. Also increasing the powder concentration (D) in the dielectric increases the MRR as on increasing the powder concentration, the breakdown strength of the dielectric fluid starts decreasing.

In this study, surface plots and contour plots have been also generated by RSM in MINITAB 16. These plots show how the response (MRR) is related to the combined effect of two input parameters in one time.

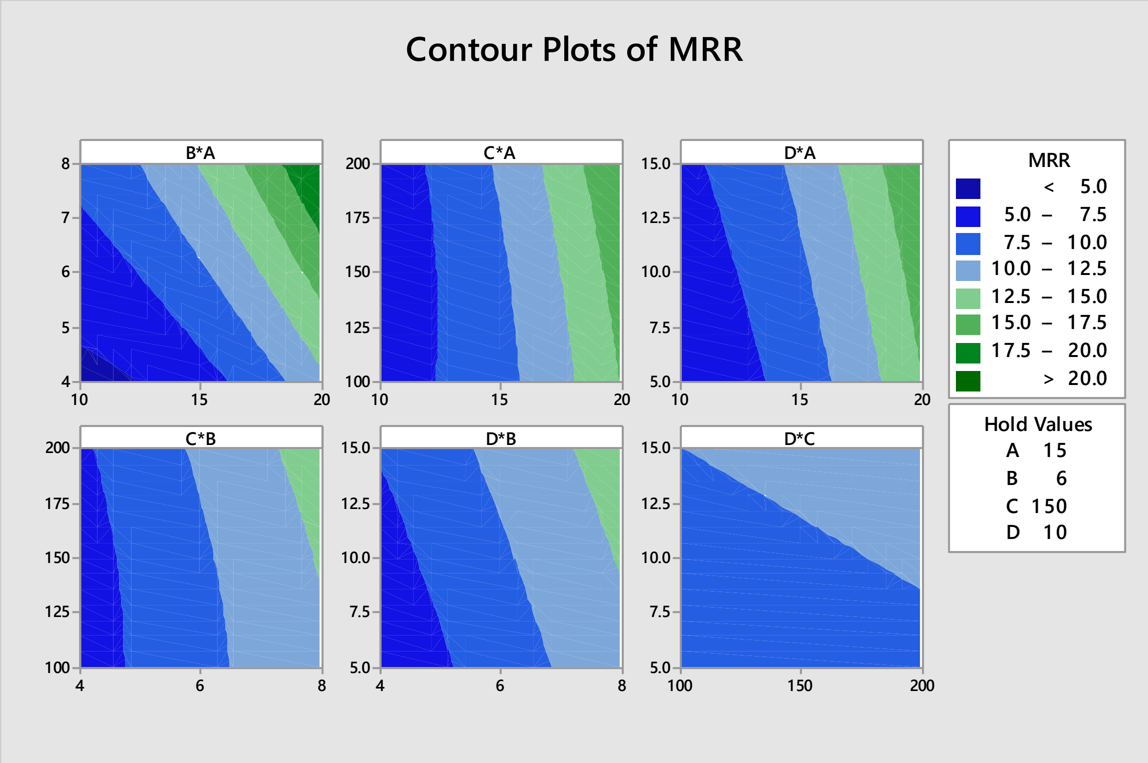

Fig 6 Surface plot and Contour plot for MRR

From the surface plots and contour-plots for-MRR, it is clear that maximum values of all input parameters namely Peak-current, Duty-cycle, Pulse-on-time and Powder concentration result in high MRR. These plots also indicate that maximum material removal rate of more than 20mm^3/min occurs at 20 amp of current and 8% of duty cycle holding the values of pulse-on-time and powder concentration at 150µsec and 10 g/l respectively. For determining whether the model meets the assumptions of the analysis, residual plots are plotted for MRR with MINITAB 16 in RSM. These plots indicate whether the residuals are normally distributed, outliers exist in the data. It also indicates whether the variance is constant or nonlinear relationship exists in the data. The residual plots for MRR are shown below in fig 5.6

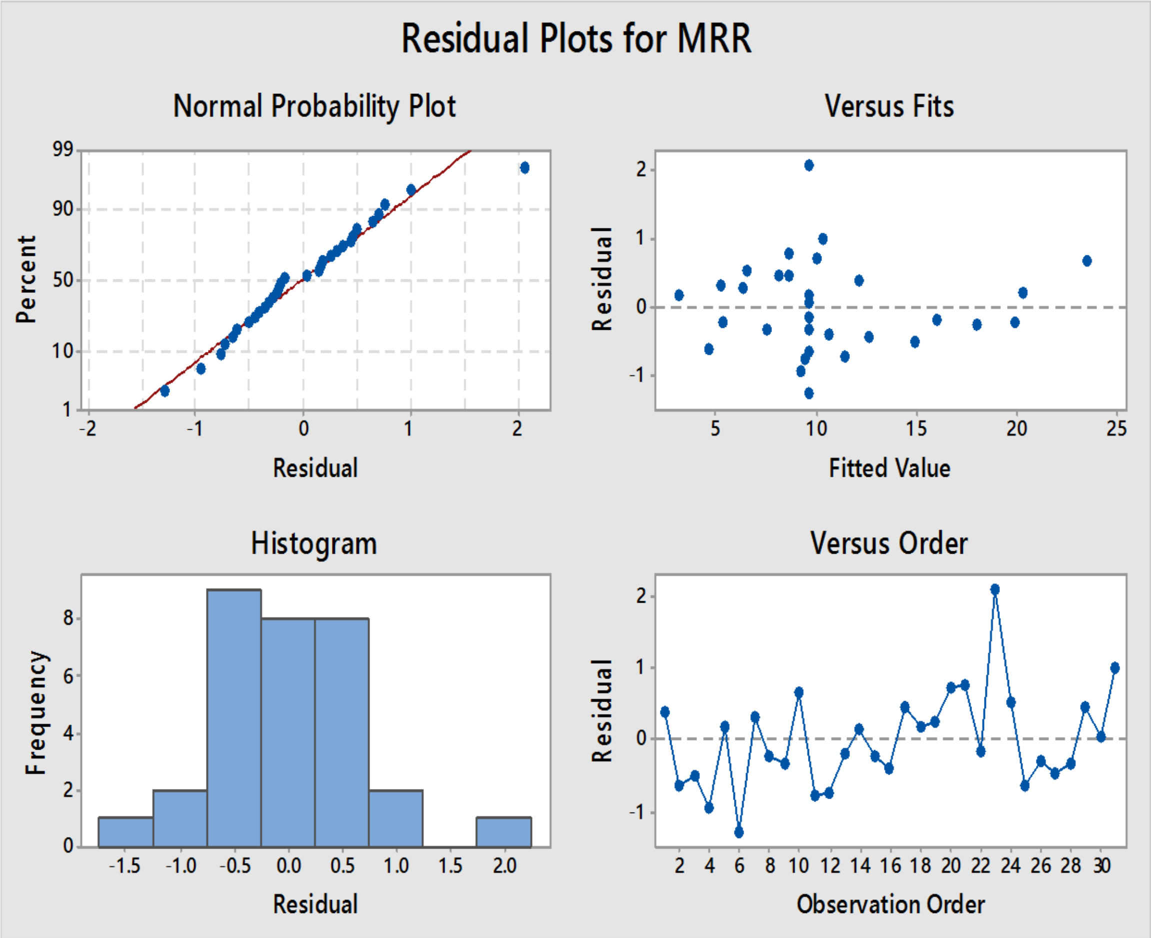

Fig 7 Residual Plots for MRR

Plot indicates that the data are normal distributed as the points make the straight line. As there is no recognizable pattern in the residual versus fitted value plot, therefore nonlinear relationship exists in the data. Histogram indicates that the data are not skewed and variance is constant.

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