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Experimental study of process parameters for magnetic assisted AFM incorporating the drill bit helical flow effect

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Abstract
Conventional machining or finishing methods are not readily applicable to the materials like carbides, ceramics. Low material removal rate happens to be it's one serious limitation. Magneto abrasive flow machining is a hybrid machining process comprising of abrasive flow machining (AFM) & Magnetic Abrasive Finishing (MAF) .With the use of magnetic field around the work piece in abrasive flow machining, we can increase the material removal rate as well as the surface finish. To further increase the MRR drill bit can be placed in the flow medium of MAFM, and the process can be named as Drill Bit guided magneto abrasive flow machining (DBGMAFM).

1. INTRODUCTION

Manufacturing process demands approximately 15% of the total manufacturing cost for finishing operations. When the surface roughness value is less than one micron the cost of surface finishing operation again increases sharply.

1.1 Types of machining processes

The machining processes are classified into three categories on the basis of achievable accuracy viz. Conventional machining, precision machining and ultraprecision machining. Ultraprecision machining are the processes by which the highest possible dimensional accuracy is, or has been achieved at a given point of time. This is a relative definition which varies with time. It has been predicted that by 2000 AD, machining accuracies in conventional processes would reach 1 μm.

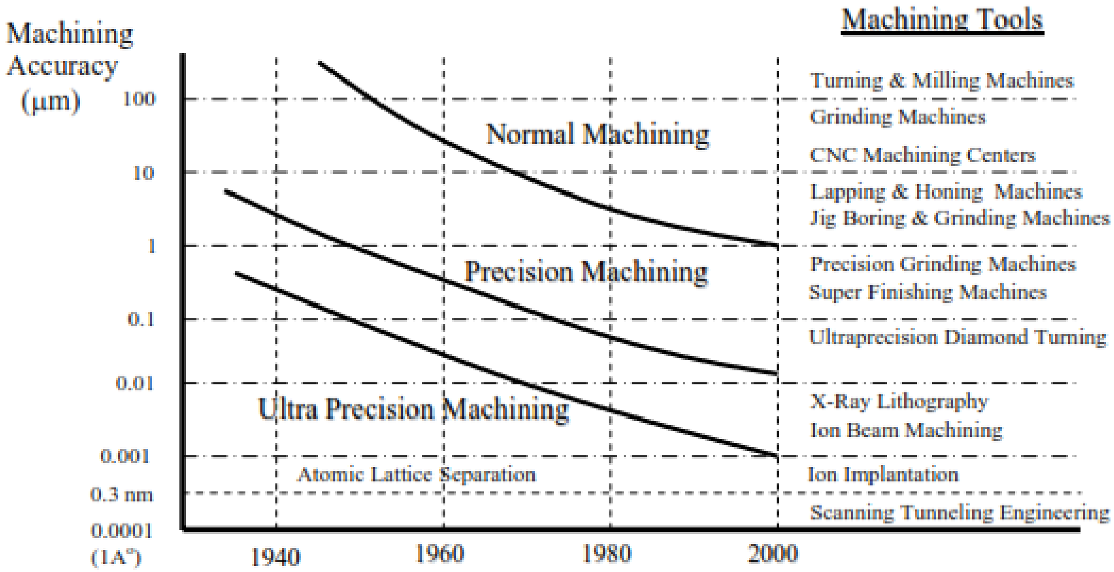

Fig. 1 Achievable Machining Accuracy [2]

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1.2 Advanced finishing processes (AFPS)

New advanced finishing processes were developed in last few decades to overcome limitations of traditional finishing processes in terms of higher tool hardness requirement and precise control of finishing forces during operation.

Comparison of surface finish obtainable by different finishing processes

S.No.	Finishing Process	Workpiece	Ra value (nm)
1.	Grinding	-	25 - 6250
2.	Honing	-	25 - 1500
3.	Lapping	-	13 - 750
4.	Abrasive Flow Machining (AFM) with SiC abrasives	Hardened steel	50
5.	Magnetic Abrasive finishing (MAF)	Stainless steel	7.6
6.	Magnetic Float Polishing (MFP) with CeO_2	Si_3N_4	4.0
7.	Magnetorheological Finishing (MRF) with CeO_2	Flat BK7 Glass	0.8
8.	Elastic Emission Machining (EEM) with ZrO_2 abrasives	Silicon	<0.5
9.	Ion Beam Machining (IBM)	Cemented carbide	0.1

1.3 Abrasive Flow Machining (AFM)

Abrasive Flow Machining (AFM) was identified in 1960s as a method to deburr, polish, and radius difficult to reach surfaces and edges by flowing an abrasive laden viscoplastic polymer over them. It uses two vertically opposed cylinders, which extrude an abrasive medium back and forth through passage formed by the workpiece and tooling. Abrasion occurs wherever the medium passes through the restrictive passages.

1.4 Surface Formation in AFM

Fig.3 depicts scratches of the abrasive grains at different stages of the scratching process. The scratch of the cutting edge in abrasive flow machining is characterized by a continuous scratch on the surface. Alongside cutting processes, elastic and elasto-plastic forming processes take place on the surface. Based on this observation it could be asserted, that due to the sum of the properties of the medium, the abrasive grains come into action on the material as quasi bound cutting edges.

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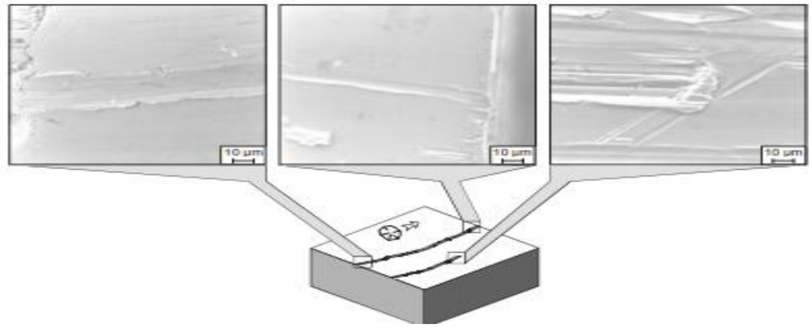

Fig.4. Surface formation during abrasive flow machining

1.5 Magnetic Abrasive Finishing (MAF)

Magnetic abrasive finishing (MAF) presents a low cost option that facilitates surface as well as edge finishing by a composite of ferromagnetic grains and fine abrasive particles. In MAF, a strong magnetic field applied on conglomerate of abrasive particles bonded with iron particles, called magnetic abrasive powder (MAP) generates the necessary pressure for material removal.

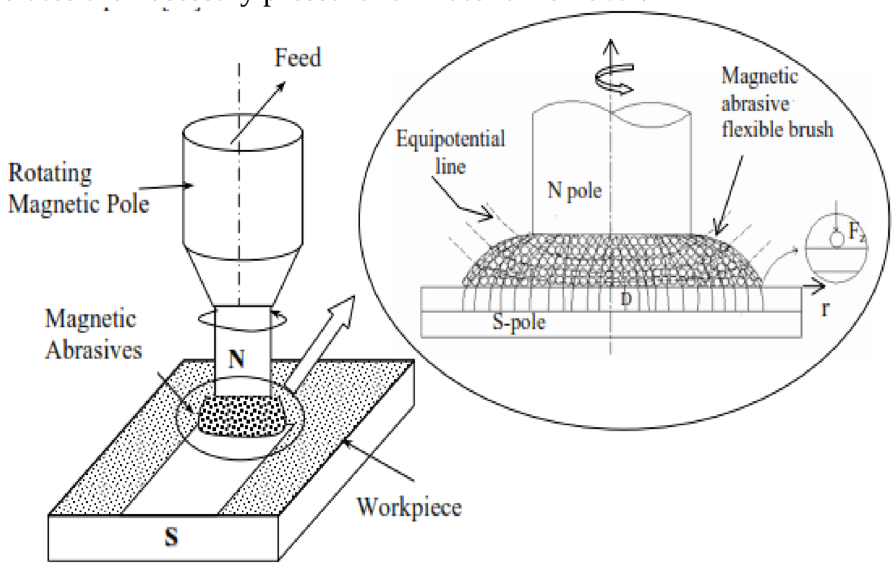

Fig.5 Rotating magnetic pole and magnetic abrasives

2. LITERATURE SURVEY

2.1 Introduction

The literature review is the main part to understand what the important information needs are. From this, it is easy to determine the research will be implemented and the related theory that has been used in previous related research. This can be done through internet, journal, thesis and reference books in this research, information needs are related to Abrasive Flow Machining, Magneto Abrasive Flow Machining and Drill Bit Guided Abrasive Flow Machining.

2.2 Previous research

Number of research papers and studies have been conducted on Abrasive Flow Machining and Magneto Abrasive Flow Machining. Number of reviews have been taken and analysed below to complete the present study.

[**1**]**Sunil Jha and V. K. Jain** in their technical paper "Nano-Finishing Techniques" various conventional and non-conventional finishing processes are discussed in detail and the various process parameters and their effect on the response variables is studied. Traditional Finishing Processes such as grinding, lapping, honing , and the advanced finishing processes such as magnetic field assisted finishing processes

Magnetic Abrasive Finishing (MAF), Magnetic Float Polishing (MFP), Magnetorheological Finishing (MRF), and Magnetorheological Abrasive Flow Finishing (MRAFF). Chemo Mechanical polishing are discussed in detail.

[2]**Szulczynski, Hubert; Uhlmann, Eckarti** in their study on "material removal mechanisms in AFM" they studied the material removal mechanism in the AFM and the effect of the grain size on the surface formation is studied. Surface formation during scratching with the abrasive medium with the specification D100-20S(200)-NX(3) at these settings was described. The images were shown the depicting th surface machined with an additive for deburring. In single acting, the grains generate very thin scratches. During multiple scratching too, mainly thin scratches were generated on the surface of the work piece.

[3]**Berhanu Girma, Suhas S. Joshi, and M. V. G. S. Raghuram** in their research paper "An Experimental analysis of Magnetic Abrasive Finishing on plane surfaces" the effect of various parameters such as Grain Size of MAP, Size-Ratio, Feed Rate, Current on the response variables MRR and Surface Roughness is studied and the optimum level of these parameters is suggested for the maximum MRR and best surface finish. Graphical relationship between the independent variable and the response variables for MAF is also shown .In this research paper the study was done for the plane surface an extension of the work which was done earlier for cylindrical surfaces. Various differences between the two are also highlighted.

[4]**Kamble et. al.** in their research paper titled "Use of Magneto Abrasive Flow Machining to improve MRR and Surface finish" the hybrid machining process formed by combination of two non –conventional machining processes AFM and MAF is proposed and it is shown that the MRR and the Surface Finish are both improved as compared to individual processes. Problems of Low finishing rate, Low MRR, Bad surface texture, Uneconomical are removed to a certain extent.the effect of the process variables such as Magnetic flux density, Number of cycles, Extrusion pressure, Viscosity of the medium, Grain size and concentration of the abrasive, Work piece material, Flow volume of the medium, and Reduction ratio on the response variables MRR and Surface Finish are studied. Graphs of Effect of Magnetic Flux Density and Medium Flow Rate on MMR, Effect of Number of Cycles and Magnetic Flux Density on MRR, Effect of Medium Flow Rate and Number of Cycles on MRR are drawn.

[5]**Singh and Walia (20120** in their research paper titled "Study the Effects of Centrifugal Force on Abrasive Flow Machining Process" In this paper they discussed centrifugal force as a technique for productivity enhancement in terms of surface roughness (Ra). A rotating Centrifugal Force Generating (CFG) rod was used inside the cylindrical work piece, which provides the centrifugal force to the abrasive particles normal to the axis of workpiece. The effect of the key parameters on the performance of process was studied. The result showed that the process parameter number of cycles has the highest contribution towards the response characteristic and is 54% for the percentage improvement in ΔRa. As the number of cycles increases from 2 to 6, the percentage improvement in ΔRa is maximum at the second level of 4. Lesser number of cycles led to better surface finish.

[6]**Jose Cherian, Dr Jeoju M Issac** in their research paper titled "Effect of Process Variables in Abrasive Flow Machining" the effect of various independent variables on the response variables MRR and Surface Roughness in AFM is studied. The results highlighted that the average percent reduction in surface roughness can be increased by keeping the extrusion pressure, grain mesh number and Abrasive concentration at high levels, while the average force ratio can be increased by keeping extrusion pressure and abrasive concentration at high level and grain mesh number at low level.

Also from experiments it was clear that when the force ratio is maximum the percentage reduction in surface roughness is also maximum. The correlation coefficient between average percent

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reduction in surface roughness and average force ratio is higher as compared to correlations of average percentage reduction in surface roughness with average axial and radial forces.

3. DEVELOPED EXPERIMENTAL SETUP

In our setup we have placed a drill bit inside the workpiece while the abrasive fluid is passed through the workpiece while the machining cycle. The images for which has been displayed below:-

Fig. 6 set up

3.1 **Machining setup**

The machining stup is an assembled two way AFM machine with following given specifications.

Type of Press- 2 Pillar type fabricated Design of capacity- 25 + 25 Ton and stroke length 96 mm

Hydraulic cylinder Bore dia – 2 No.130mm

Hydraulic cylinder Stroke- 90 mm
Working Pressure-210 kg/Cm^2
Maximum Pressure in the Cylinder – 35 MPa
Stroke Length of Piston - 300mm

3.2 Fixture Design

The work fixture was made of poly propylene , a non-magnetic material. It is specially designed to accommodate magnet poles such that the maximum magnetic pull occurs near the inner surface of the work piece.

Fig. 7 permanent magnets

3.3 Magnetic Setup

For creating magnetic pull at the inner surface of the workpiece permanent magnets of cylindrical shape hacing dimensions of 10x10 are used. The magnetic strength of one single piece is 400 gauss (approx.)

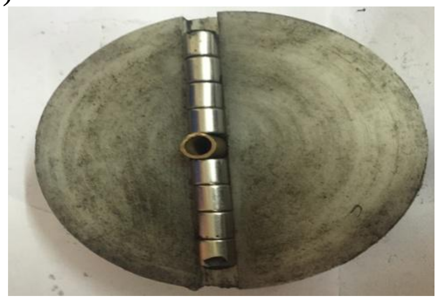

Fig.8 magnetic fixture

3.4 Drill bit attachment for centrifugal force

For creating centrifugal force inside the workpiece a drill bit of dia.4mm is used and is modified to erect it accurately inside the workpiece.

Fig.9 Drill bit attachment

3.5 Polymer Preparation

For preparation of polymer a vessel was taken and then 1 litre of dimethyl silicon oil is poured into it. 60 gram boric acid was then added. The color changed to light yellow. Then 10 gram lewis acid(FeCl3.6H2O)is added into it. It changed to yellow color. Stirring is done till all the particles are properly mixed. After that it was heated in a vessel and stirring is done continuously. When when the mixtures starts boiling and becomes viscous,10 gram NH4CO3 is added into it and stirring is done continuously till it becomes very viscous and non sticky type. Then it is allowed to cool .The polymer is hence prepared.

3.6 Preparation of gel

For making gel a vessel is taken and then half kg of hydrocarbon (toluene)oil is added into it. Then it is mixed with 30 gram aluminium stearate .It turned into white color. Proper stirring is done till the particles are properly dissolved. Then heating is done for 20 to 25 minute and stirring is done continuously till it became a thick gel .It was allowed to cool. Hence the gel is prepared.

3.7 Preparation of media

We took 300 gram of polymer and 80 gram of gel and then it was mixed by hand complete. Then we added 200 gram of ferric oxide and 180 gm of silicon carbide into it. It was mixed until homogeneous solution is obtained. The media was hence prepared.

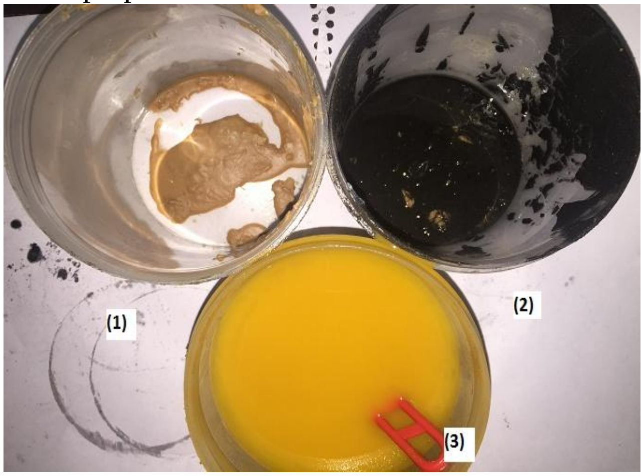

Fig. 10 (1) Hydrocarbon Gel (2) Abrasive Media (3) Polymer

4. Experimental Design and Analysis

4.1 Experimental Design

The experiments were designed to study the effect of some of the DBGMAFM parameters on response characteristics of DBGMAFM process. Taguchi parametric design methodology was adopted. The experiments were conducted using appropriate orthogonal array (OA). An L9 (a standard 3-level OA) having 8= (9-1) degree of freedom was selected for the present analysis. The selected number of process parameters and their levels are given in the table:

Table 1. Process Parameters and their values at different levels

Process Parameters	Unit	Level 1	Level 2	Level 3
Pressure	Bar	10	20	30
No. of Cycles	Number	2	4	6
Magnetic field intensity	Intensity	Low	medium	High

Design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not. However, in statistics, these terms are usually used for controlled. A properly planned and executed experiment is of the utmost importance for deriving clear and accurate conclusions from the experimental observations.

Table 2. Experimental Readings For Taguchi's Analysis

Reading No.	Workpiece No.	Initial Wt. (gms)	Final Wt. (gms)	MRR (gms)	Initial Roughness(µm)	Final Roughness(µm)	%Improvement
1 (111)	03	4.1330	4.1270	0.0086	1.96	1.34	31.63
2 (122)	10	3.7544	3.7517	0.0027	1.84	1.84	00.00
3 (133)	02	3.9416	3.94004	0.0016	1.24	1.20	03.20
4 (212)	17	4.0536	4.0511	0.0025	2.06	1.78	13.60
5 (223)	05	3.8632	3.8613	0.0019	1.58	1.36	13.92
6 (231)	07	4.1568	4.1495	0.0073	1.72	1.34	28.35
7 (313)	04	3.8311	3.8287	0.0024	1.60	1.32	17.50
8 (321)	15	4.1314	4.1295	0.0019	1.76	1.28	27.27
9 (332)	12	3.9176	3.9151	0.0025	1.92	1.64	14.58

4.2 Taguchi Analysis: Material Removal versus Pressure, Number of Cycle, Magnetic Field Strength

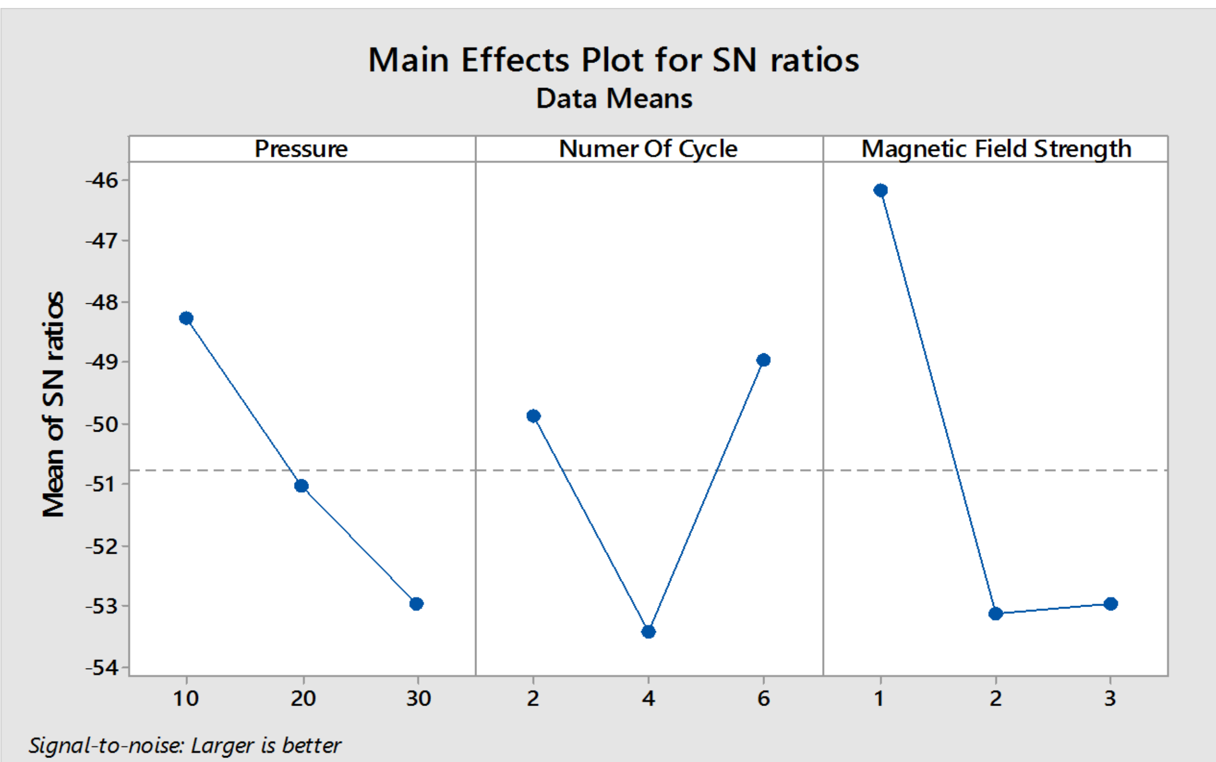

Table 3.Response Table for Signal to Noise Ratios

LEVEL	PRESSURE	NO. OF CYCLES	MAGNETIC FIELD INTENSITY
1.	-48.24	-49.87	-46.16
2.	-51.03	-53.41	-53.11
3.	-52.95	-48.94	-52.95
DELTA	4.71	4.47	6.95
RANK	2	3	1

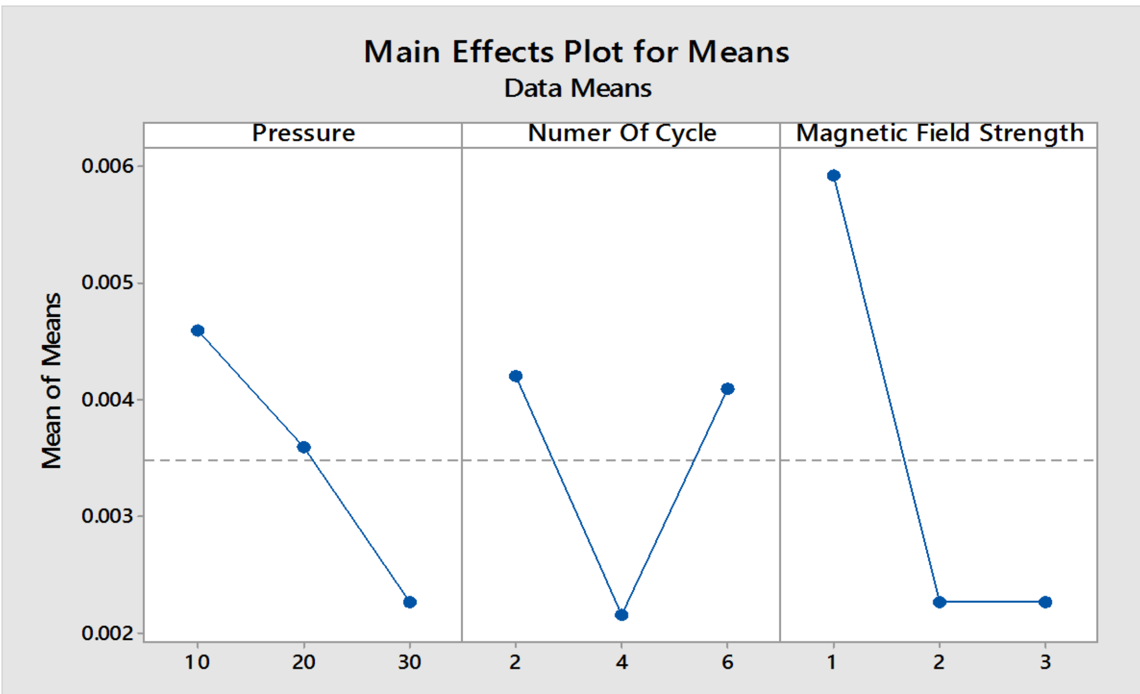

Table 4. Response Table for Means

LEVEL	PRESSURE	NO. OF CYCLES	MAGNETIC FIELD INTENSITY
1.	0.004600	0.004200	0.005933
2.	0.003600	0.002167	0.002267
3.	0.002267	0.004100	0.002267
DELTA	0.002333	0.004100	0.003667
RANK	2	3	1

5. CONCLUSION

The effect of magnetic field is the most dominant among the variables. The rank of magnetic field is 1 in both the response tables. For optimum results ie. MRR the choice of variables should be as pressure = 10 bar , no. of cycles = 6 and magnetic field strength = low**.** As the rank of variables in both the response tables is same. Therefore the above readings have acceptable accuracy.

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