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OBSREVATION AND OPTIMIZATION OF WORKING PARAMETER FOR MAGNETIC ABRSIVE FINISHING PROCESS BY USING TAGHUCHI METHOD

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ABSTRACT

This report covers a detail of project on optimization of process parametric analysis of surface finishing operation on metal, alloy using Magnetic Abrasive Finishing (MAF), Alloy based material selected as a workpiece material (Magnesium alloy Az31b) and silicon carbide with iron powder as an abrasive material for cutting workpiece material. Details of Magnetic abrasive machining had been studied and basic setup for magnetic abrasive finishing on drill machine was developed. MAF is a non-conventional finishing process in which material is removed and finishing are performed concurrently by magnetic force which forcing the flexible magnetic abrasive particles (FMAP) across the workpiece surface. The process is manageable because the machining process is controlled only by the input current to the coil of solenoid (electromagnet). The process encirclements a wide range of feasible applications from critical aerospace, ceramics and medical components to high production bulks of parts. In the present investigation on MAF process, Taguchi design of experiments is applied to find out important parameters inducing the surface quality generated. Important parameters persuading the surface quality generated during the MAF are identified as: (i) **voltage** (DC) applied to the electromagnet, (ii) **working gap**, (iii) **rotational speed of the workpiece**, and (iv) **abrasive particle size. MAF** setup is designed for finishing workpieces and it is mounted on drill machine.

Keywords: *magnetic abrasive finishing, surface roughness, metal alloy (MagnesiumAz31b), abrasive particle, input parameter.*

Principle of Magnetic Abrasive Finishing

MAF process depends upon the two main things such as magnetic field and magnetic abrasive if we concern about magnetic field, we found two ways, such as permanent magnet and electromagnet. Both ways produce magnetic field. Using magnetic abrasive (silicon carbide, aluminum oxide, diamond etc.) with mixing the iron powder, sometime added steel greets in fixed portion, by weight or by part. when electric field giving to the setup the magnetic field induced and mixed (abrasive +iron powder) abrasive attracts the pole side and work as the flexible brushes. When we provided the working gap between electromagnet-pole and the mixed abrasive can finishing the surface, providing material or workpiece. Axial vibration is important things to provide a better surface finish neither abrasive make a ring towards the workpiece and other parameter giving great impact to surface finishing and material removal in micro level.

In MAF, there are two types of force act, first the cutting force (machining pressure) can be controlled by the input current to the electromagnets and other force applied by the brush. In MAF operation, workpiece take a place between the two Pole of magnets. The air gap between the magnet and the workpiece, is filled with magnetic abrasive particles, which of maid up of iron powder and abrasive powder and sometimes steel greet. abrasive particle used as unbounded, loosely bounded, or bounded. Bounded MAPs are arranged by mixing of ferromagnetic powder and abrasive powder with a high pressure and temperature with the help of inert gas so that shield from atmosphere. Loosely bounded MAPs are arranged by mechanical mixing of abrasive powder and ferromagnetic powder and with a small quantity of lubricant to give some binding strength between the abrasive and ferromagnetic particles. Unbounded MAPs are normally mixture of ferromagnetic and abrasive particles without any lubricant

The MAF process done by the magnetic field and the flexible brushes which also done by the magnetic field because abrasive particle magnetizes and work like as flexible brushes and vibration get a better surface finish.

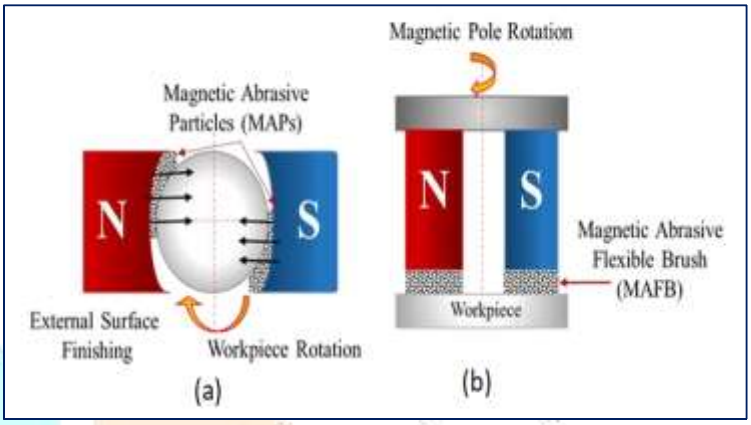

Figure 1: Examples of existing MAF methods, (a): Fixed magnetic source with rotated work piece (b): Rotated magnetic source with fixed work piece.

Impact of process parameter on Surface Roughness and Material removed rate:

Surface finish and materials removal rate is most important function of any machining process. In the case of MAF surface finish is desirable rather than the material removal because its finishing process. For assembly purpose dimension accuracy and surface quality play a very important role. Keeping all the requirement researcher mainly focused on improvement of surface quality. **Yoon et al (2)** Investigated the surface roughness of STS 304 improved by 50.9%, 70.6 %, 63.6% and 75.5% respectively. Because they using magnetic pole arrangement such as 4(four) different magnetic pole arrangement which include N single, N-S 90°C, N-S 180V and N-S-N arrangement.**Imet al.(3)**Investigated the surface roughness and removed weight using STS 304 bar and they found improved surface roughness when used and they used different grain size (1,3 and 9µm).When we focus on the removal rate the best result found when 3 µm diamond abrasive particle used.

Wu and Zau et at. (4) Investigated on the SUS304 stainless steel pulsating low frequency alternating magnetic field roughness improved from 240.24µm to 4.38 µm and other parameter help for the improving the result such as magnetic pole. Rotational speed and grinding the help for better surface finish and higher removal rate.In the MAF process surface finish and material removal rate of the workpiece, increased when the working gap magnetic abrasive flexible brushes getting stronger and giving large amount of material removal due to deeper cuts. **Jain etall(5)** Investigated the surface finish and material removal rate according to the working gap total material removed in 300s/linear distance travelled by the w/p 300s.In the term of surface finished up to 4µm is minimum in the 0.5mm of working gap. **Jain et al. (5)-(2)**Investigated on the stainless steel cylindrical workpiece mounted on a lathe machine tool using iron powder 300 mesh size (51.4µm) and abrasive powder Al_2O_3 of 600 mesh size 25.7µm, and lubricant used sero spin-12 oil and find the better surface finish with working gap 0.4-0.7mm height in the 0.5mm. **Singh et al(6)-(1)**They were analysis, when they apply the Taguchi design of experiments and found the working gap ,voltage and the most important factor of surface finishing followed by the rotational speed and different mesh size number in order to achieved better surface finish and material removal .**Givi et al (7)** Investigated on the Aluminium plate for finishing and effect of other parameters such as working gap, rotational speed, pole number and arrangement of cycle. they found the working gap has important effect on the surface finish for higher working gap decrease surface roughness and lower working gap giving higher surface finish and using methodology (ANOVA) technique.

Rotational speed and axial vibration is one of the most important parameters because chips were generated during finishing and chips removed from the work piece causing relative motion between magnetic abrasive and the work piece and without axial vibration magnetic abrasive making a grove on the work piece due to centrifugal force generated and abrasive particle moving in a form of ring. **Im et at (3)-(2)** Investigated the surface STS-304 stainless steel bar (fie3 150mm) and the rotational speed 30,000 rpm with 0 Hz and 12 Hz of vibration In the case of 0 Hz vibration they found surface roughness improved much more in initial condition but after some time it gone worse, approximately 60 second of processing. In the case of 12 Hz vibration the surface roughness improved till 30second of processing after that it will remain same, approximately.

In the magnetic abrasive finishing process the setup used as a generally electromagnet **fox et al (8)** Investigated that when they provided various flux density they found variation of surface finishing they found when they increase the flux density (0.17Tto .37Tesla) result was improve in the form of surface finish up to the saturation level . **Galsokav et al (9)** studied the lubricant in magnetic abrasive finishing they provide cooling effect and it take a important role because cutting fluid react chemical for mechanically weak compound. sometimes lubricant giving penetration fluid with good wetting property give better surface finish 5 to 10% solutions of Emuls01 E2 (soluble oil) **Fox et al (7)-(2)**investigated the effect of lubricant and found during operation solid lubricant give to the abrasive brushes more flexible so that ability to produce better surface finish.

Effect of temperature: Rajneesh Kumar Singh et-at all- study on surface micro finishing of Aluminum 6060 using MAF process, in this process low heat generated and free from thermal stress such as 9°C rise in temperature was achieved using Buckingham π method to achieve it and find average error 7.31 %. They were using drill machine setup for MAF to rotate a magnetic field using K type thermocouple and stationery the workpiece

Advantages of MAF

(i) This process can be used on flat surfaces with a good surface quality of the order of nanometers and to efficiently produce products mirror-like surface.
(ii) like the inner and outer surfaces of tube-type work pieces.
(iii) Setup does not depend of work piece material; like used for all types of material it can efficiently finish stainless steel, brass, coated carbide, ceramics, andsilicon.
(iv) The finishing tool never need of dressing.
(v) This method can be done by both ferromagnetic materials as well as non-ferromagnetic materials.
(vi) Itdamagestothe surface to be finishedcanbeminimized because of uses verylowforces and unbounded abrasive.
(vii) Material surface is free from thermal defect.
(viii) Using MAF, improvement in wear resistance, physical and mechanical property.

Limitations of MAF

(i) Selection of hard material giving low MRR and low efficiency.
(ii) It is too difficult for mass production because of low removal rate.
(iii) It is not suitable for some ordinary process where other conventional process easily performs.
(iv) Process cost is high.
(v) It taken too much time to perform.

Experimental setup

MAF setup is the combination of electromagnet, drill machine, auto transformer, ac to dc convertor, and abrasive particle with iron particle, machine oil, workpiece material.

The electromagnet mounted on drill machine, consists a MS road with 2flange, slip ring with carbon brush in order to provide dc supply, in between flange 18-gauge copper wire wrapping almost 900 turn, so that it makes an electromagnet. Autotransformer is a type of transformer which have single core, having two winding such as primary and secondary but wrapping in single core in to tapping. In this transformer top of the place having nob which control the turns of the secondary winding, by using that we control the drill machine speed. the auto transformer principle is based on self-induction. Ac to Dc convertor convert the Ac to dc supply, it can also control the voltage and current. the convertor comes to required specification .it can fix the voltage and current during the load. Using different mesh size of Silicon carbide as an abrasive particle like 400,500,600 with iron particle 100 mesh size mixing with 5% machine oil.

In this experiment magnesium alloy Az31b of size 250 mm ×250 mm × 3 mm plate is chosen for conducting the experiment because Magnesium Az31b plate are easy to machine and very light weight ,when magnesium is alloyed with other metal such as zinc silicon and iron magnesium alloys are derived .the density of material is 1.77g/cm3. It is flammable so extreme care should be taken while performance the process. A lubricant is used to perform machining process. Plate in AZ31B find application in medium strength service at temperatures below 150°C. Diverse uses including aerospace, aircraft, concrete tools, 3C (cell phone / camera / computer), speaker cones and textile machinery can all benefit from light weight

AZ31B is non-magnetic and has high electrical and thermal conductivity filling the requirements for RFI and EMI shielding in the electronics and computer industries. Superplastic forming of AZ31B sheet at elevated temperatures allows production of a wide variety of intricate parts for automotive uses. Monocoque construction utilizing formed sheet can be adapted to many commercial applications.

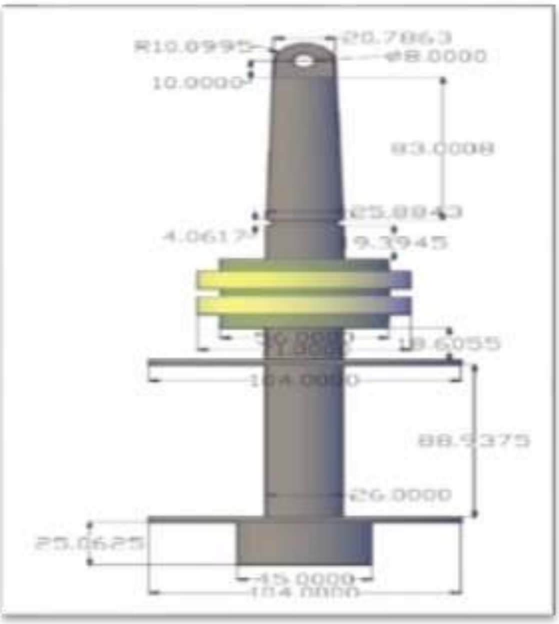

Figure 2 Model of electromagnet tool (All dimension in mm)

Brush formation

Figure 3 Brush formation

The complete setup consists such many things like as,

1- Electromagnet tool.
2- Auto transformer.
3- Ac to Dc convertor.
4- Drill machine.

Figure 4 complete setup (MAF)

Result analysis

In this thesis ,work, multi-characteristics response optimization model based on Taguchi is used to optimize process parameters, such as working gap, voltage ,abrasive mesh size and weight, and other multiple performance characteristics, namely, surface roughness (Ra) in magnesium az31b. Design of experiments with optimum setting is most suitable Taguchi approach which involves using orthogonal arrays to organize the parameters affecting the process and the levelsat L9 algorithm.

Selection of control factor and level

There are four process parameter with three level such as voltage, working gap,abrasive mesh number. the process parameter and the level are finalized by literature survey or book, these process parameter and level use in workpiece magnesium Az31b shown in the table.

Table 1 Control Factors and Levels

Factors /Levels	**Voltage V(v)**	**WORKING GAP**	**ABRASIVE WEIGHT Wa**	**ABRASIVE MESH NO.**
1	15	1	15	400
2	18	1.5	20	500
3	21	2	25	600

The current (1.5 amp), iron mesh size (100), and time of finishing 30 minuet fix during experiment. done 9 experiments ,the finishing workpiece is as.

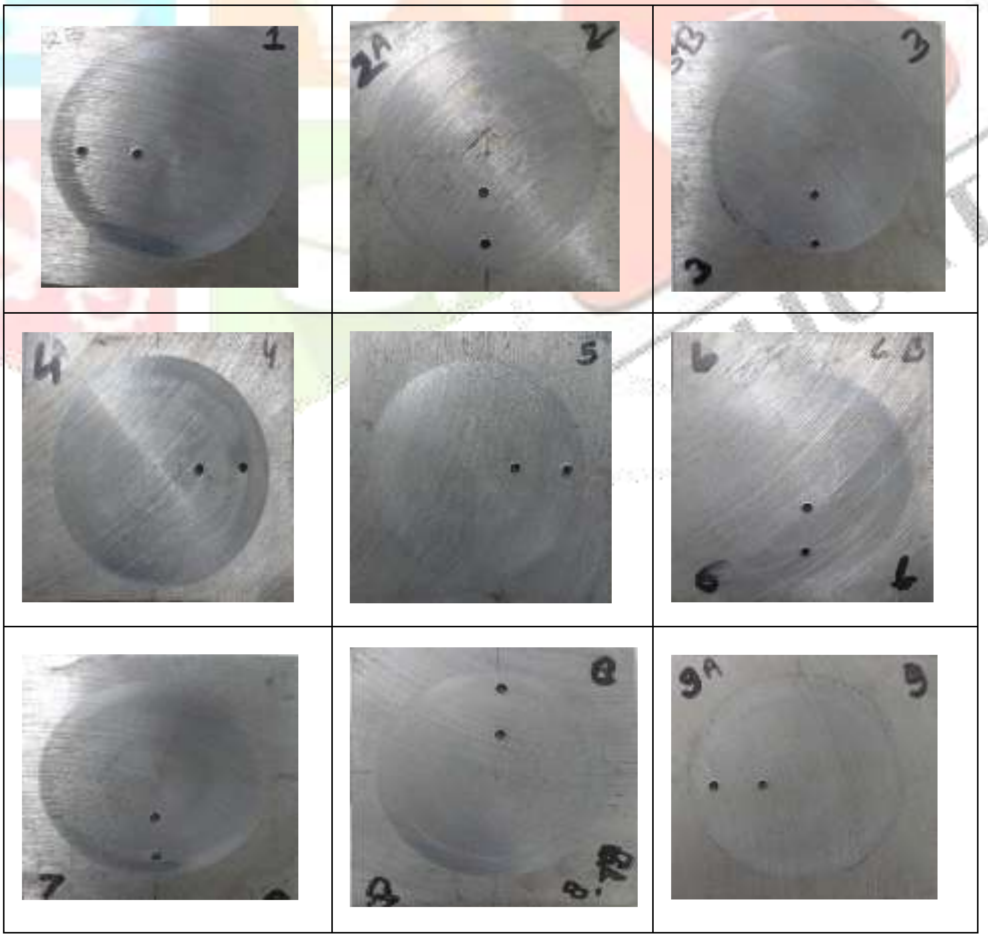

Figure 5 workpiece after finishing

After setting the machining parameter on the MAF setup, experiment has been performed at nine times according to **T**aguchi orthogonal array. All machining data such as response and intermediate data recorded into the table no. 2

Table 2 Observation table on the basis of experimental data.

Sl. No	Wt.B	Wt. A	Voltage	Iron100Wt.	Silica Mesh no/Wt.		Working Gap	S.R. B. Avg	S.R.A. Avg	MRR	S.F.A
1	20.68	20.64	15	8	400	1.5	1	2.41	0.64	0.04	1.77
2	19.89	19.88	15	7.5	500	2	1.5	2.22	1.29	0.01	0.93
3	19.88	19.87	15	7	600	2.5	2	2.26	1	0.01	1.26
4	21.03	21.02	18	7.5	600	2	1	2.08	0.67	0.01	1.41
5	19.84	19.8	18	7	400	2.5	1.5	2.3	1.24	0.04	1.06
6	21.02	21	18	8	500	1.5	2	2.66	1.26	0.02	1.4
7	21.28	21.24	21	7	500	2.5	1	2.39	1.36	0.04	1.03
8	20.03	20.01	21	8	600	1.5	1.5	2.34	1.28	0.02	1.06
9	20.05	20.03	21	7.5	400	2	2	2.15	1.45	0.02	0.7

Design of Experiment and collected Response values:

There are L9 orthogonal arrays used for the experimental run in this experiment 3 control factor and 3 level are chosen so $(3^4)=81$ data are shows in below table for each control factor and level combinations. And response values such the Material removal rate and the Surface roughness are measured with the help of weighing machine and surface roughness tester within simultaneously.

Table

Table 3 L9 Orthogonal arrays with measured MRR and Ra

Exp. Run	**Control Factor**			**Response parameter**		
	Voltage V(v)	**Working gap**	**ABRASIVE WEIGHT Wa**	**ABRASIVE MESH NO.**	**Surface finish(μm)**	**MRR**
1	15	1	15	400	1.77	0.04
2	15	1.5	20	500	0.93	0.01
3	15	2	25	600	1.26	0.01
4	18	1	20	600	1.41	0.01
5	18	1.5	25	400	1.06	0.04
6	18	2	15	500	1.4	0.02
7	21	1	25	500	1.03	0.04
8	21	1.5	15	600	1.06	0.02
9	21	2	20	400	0.7	0.02

After the Experimental run when MRR and surface roughness found, perform the analysis of result by analytically and as well as the graphicaly. For the statistical analysis by using a design expert software as the MINITAB 17 saftwere. But before this, calculate the S/N ratio for both such as the MRR and the SR, after S/N ratio calculation making a Response table for the MRR (Larger is better) and the Surface roughness (Smaller is better) then the plot graph between control factors and S/N ratio, And control factors/mean of the means. Which are shows the main effect plot for the MRR and SR.

S/N Ratio calculation For Material removal rate (MRR)

By using Taguchi methodology obtained the Signal to noise ratio. Here signal represents the desired values as the mean and the noise represents the undesired values as the standard deviation. So the signal to noise ratio represents the amount of variation which are present in the performance characteristics. Presently the desirable objective is to be optimize the response value as the Material removal rate. So here Larger-the-better type signal to noise ratio is gives the optimum result.

Table 4. Taguchi orthogonal arrays design for S/N ratio: MRR

Exp. Run	Voltage V(v)	Working gap	ABRASIVE WEIGHT Wa	ABRASIVE MESH NO.	Surface finish(μm)	S/N Ratio
1	15	1	15	400	1.77	4.95947
2	15	1.5	20	500	0.93	-0.63034
3	15	2	25	600	1.26	2.00741
4	18	1	20	600	1.41	2.98438
5	18	1.5	25	400	1.06	0.50612
6	18	2	15	500	1.4	2.92256
7	21	1	25	500	1.03	0.25674
8	21	1.5	15	600	1.06	-33.9794
9	21	2	20	400	0.7	-33.9794

Table 5 Effect of Control factor on SF

Level	VOLTAGE	WORKING GAP	WEIGHT	ABRASIVE MESH SIZE
1	0.55487	1.56138	-0.09174	-0.40646
2	-0.13245	-2.07481	-0.65355	-2.29666
3	-2.68078	-1.74492	-1.51307	0.44477
Delta	3.23565	3.63618	1.42133	2.74143
Rank	2	1	4	3

Main Effcet Plot For S/N Ratio: SR

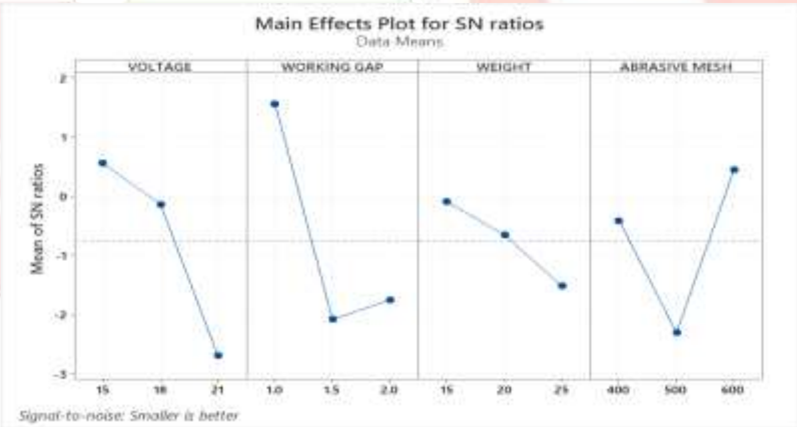

Figure 6 Main Effcet Plot For S/N Ratio: SR

Table 6 Response Table for Means:

Level	VOLTAGE	WORKING GAP	WEIGHT	ABRASIVE MESH
1	0.9767	0.8900	1.0600	1.1100
2	1.0567	1.2700	1.1367	1.3033
3	1.3633	1.2367	1.2000	0.9833
Delta	0.3867	0.3800	0.1400	0.3200
Rank	1	2	4	3

Main Effcet Plot For Means

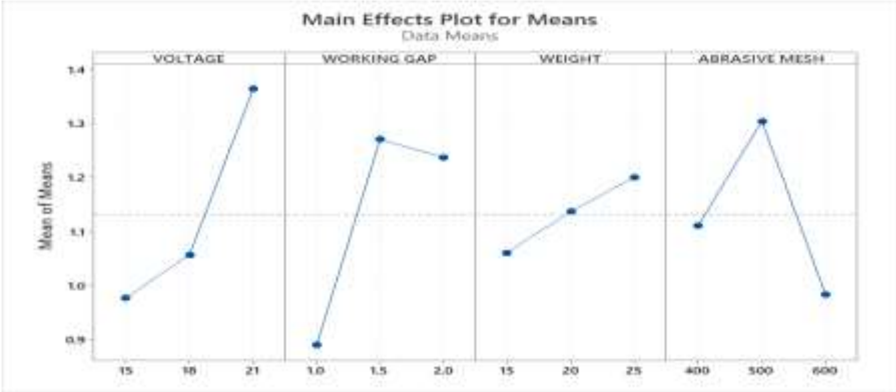

Figure 7 Main Effcet Plot For Means

Effect of Control factor on MRR (Larger is better)

Table 7 Response Table for Signal to Noise Ratios

Level	VOLTAGE	WORKING GAP	WEIGHT	ABRASIVE MESH
1	-35.99	-31.97	-31.97	-29.97
2	-33.98	-33.98	-37.99	-33.98
3	-31.97	-35.99	-31.97	-37.99
Delta	4.01	4.01	6.02	8.03
Rank	3.5	3.5	2	1

Main Effcet Plot For SN ratio

Figure 8 Main Effcet Plot For SN ratio

Main Effcet Plot For MRR

Level	VOLTAGE	WORKING GAP	WEIGHT	ABRASIVE MESH
1	0.02000	0.03000	0.02667	0.03333
2	0.02333	0.02333	0.01333	0.02333
3	0.02667	0.01667	0.03000	0.01333
Delta	0.00667	0.01333	0.01667	0.02000
Rank	4	3	2	1

5.8 Main Effcet Plot For Means

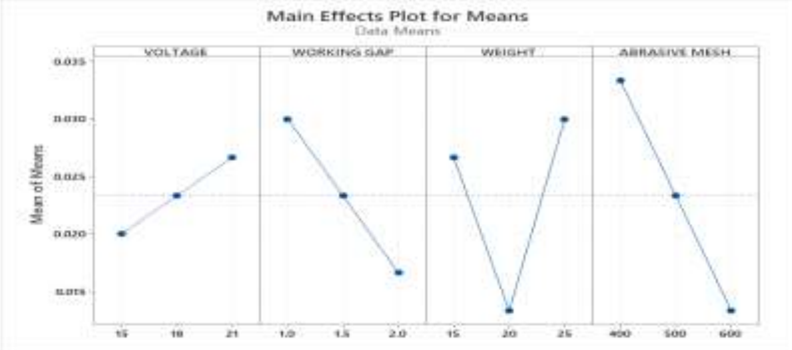

Figure 9 Main Effcet Plot For Means

Anova Table:

Table 9 Analysis of Variance surface finish

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	4	0.484300	60.54%	0.484300	0.121075	1.53	0.344
VOLTAGE	1	0.228150	28.52%	0.228150	0.228150	2.89	0.164
WORKING GAP	1	0.120417	15.05%	0.120417	0.120417	1.53	0.284
ABRASIVE MESH NUMBER	1	0.129067	16.13%	0.129067	0.129067	1.64	0.270
ABRASIVE WEIGHT	1	0.006667	0.83%	0.006667	0.006667	0.08	0.786
Error	4	0.315700	39.46%	0.315700	0.078925		
Total	8	0.800000	100.00%				

Table 10 Analysis of Variance MRR:

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	4	0.000950	67.86%	0.000950	0.000238	2.11	0.244
VOLTAGE	1	0.000067	4.76%	0.000067	0.000067	0.59	0.484
WORKING GAP	1	0.000267	19.05%	0.000267	0.000267	2.37	0.198
ABRASIVE MESH NUMBER	1	0.000017	1.19%	0.000017	0.000017	0.15	0.720
ABRASIVE WEIGHT	1	0.000600	42.86%	0.000600	0.000600	5.33	0.082
Error	4	0.000450	32.14%	0.000450	0.000112		
Total	8	0.001400	100.00%				

CONCLUSION AND FUTURE SCOPE

Experimental study in MAF process done, focus on three parameters during experiment such as voltage, working gap, mesh size affecting the surface finishing.

Effect of voltage.

If voltage increase surface finish decrease. In experiment voltage variation to 15 to 18 and average surface roughness improved in order to surface finish, and using 400 500 600 mesh size of abrasive.

Effect of working gap.

If working gap small during experiment the surface roughness improve in order to surface finish. working gap variation 1mm to 2 mm.

Effect of mesh size

If mesh size of abrasive increase surface roughness improved in order to surface finish 1.77 µm. In experiment abrasive (Si) mesh size variation 400,500,600.

Effect of temperature

In the experiment temperature rises in MAF process, If the temperature rise, abrasive particle burns and giving not better surface finishing. when using the magnesium az31b alloys as a material rise in temperature maximum 5 °C almost.

Effect of rotational speed

In the experiment the speed variation is 360-365 rpm, when we increase the rpm the flexible brushes moving outside and they make a ring in outer surface, for this reason inner surface have less abrasive contact and less finishing this area.

Future scope

In the experiment focus on three parameters, voltage working gap, abrasive size affecting the MAF process in order to achieve better surface finish. When increase the oil ratio with abrasive it giving better result in form of gel. Controlling the speed is affecting parameter for surface finish. for continuous process should be focus on draining system.

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