Studies in Magnetic Abrasive Finishing of Internal Surface of Stainless Steel Tubes Using Pole Rotation System

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Abstract: **Magnetic Abrasive Finishing (MAF) is a renowned polishing technique widely used for operations requiring ultra finishing operations such as finishing of PCB's, balls, rollers, shafts, complex work pieces. This paper analyses the effect of MAF on the SS 307 tubes by using pole rotation system on aluminium based sintered magnetic abrasives. Input parameters have been selected on the basis of literature review and preliminary investigation. Experimentation have been carried out by varying the input parameters such as working gap, rotational speed of poles, size of magnetic abrasive particles (MAP's), Abrasive weight and keeping the other parameters fixed like machining time, lubricant type and quantity.**

Keywords: ***MAF, MAP, PISF, sintered magnetic abrasives, SS 307, surface finish***

1. INTRODUCTION

MAF is popular for utilizing controlled magnetic force having small magnitudes which is almost impossible in the conventional machining processes. The material removal is done with the help of magnetic abrasives.
Shinmura et al. (1985) conducted an experimental study on plane work and found that the surface roughness value decreases with increasing finishing time up to a certain limit of time beyond which no further improvement was noticed. Adding machining fluid (such as stearic acid, straight oil type of grinding fluid) to unbounded MAPs has shown remarkable effects on stock removal and surface roughness.
Shinmura et al. (1992) utilized iterations through uniformly mixing the diamond abrasives with iron to form diamond magnetic abrasives. They concluded that finishing efficiency increased with diamond magnetic abrasives with increase of speed of tool. Results showed that machining depth increases with increase of mixing weight percentage of iron particles.
Takeo Shinmura et al. (1994) prepared new type of abrasive material to study the magnetic abrasive machining of ceramics. They mixed small size diamond magnetic abrasives with large size ferromagnetic particles.

It was found that in the plane finishing, the magnetic force on the surface and rigidity of magnetic abrasive brush are most influenced by the diameter of the magnetic abrasives. He also showed that the use of ferromagnetic particles mixed with diamond magnetic abrasives not only improves the finishing efficiency but also multiplies the magnetic field density.

Kremen et al.(1999) performed experiments on ceramic cylindrical parts and silicon wafers using different grain size of magnetic abrasives to study their effect on material removal rate and surface roughness. their result showed variation of grain size has no effect on surface finish obtained in both cases. But material removal rate increase with increase of size of the diamond grain size of magnetic abrasives.
Dhirendra et al. (2005) analyzed microscopic changes in the surface texture resulting from the MAF process to distinguish the behaviour of abrasive particles during finishing. The observed surface texture indicated that the process creates micro scratches having width less than 0.5µm on the finished surface. Moreover, the surface is finished by the shearing of peaks resulting in circular lays formed by the rotation of the flexible abrasive magnetic brush (FMAB).
Jae-Seob Kwak (2009) improved the magnetic flux density in magnetic abrasive polishing process for non ferrous materials. To increase the flux density he installed a permanent magnet at the opposite side of the work piece. He concluded that the optimal conditions for the MAF of the magnesium alloy were an applied current of 2.0A, working gap of 1mm rotational speed of 800rpm and the amount of powder (Fe + boron nitride powder) of 0.7 g.
Singh et al. (2012) utilized mechanical alloying followed by heat treatment to prepare magnetic abrasives. The MAF is used effectively to remove tool marks, burrs and plastic deformation.
Shukla et al. (2013) stated that current and machining gap are most influencing factor. For optimization response genetic algorithm is used. Equations of response parameters are given by RSM. Sum of energies is depicted by a formula.
Yamaguchi et al. (2014) established relationships between surface conditions of AlTiN-coated round tools, cutting forces, and wear and their characteristics were clarified by milling of Ti-6Al-4V alloys.
Choopani et al. (2016) found that the magnetic force on the abrasive particles and strength of magnetic brush depends upon the type, shape and size of abrasive particle.
Saraeian et al. (2016) derived results which indicated that the parameters of working gap, rotational speed, and abrasive particle size influence the surface roughness from the most to the least respectively.

2. EXPERIMENTATION

The magnetic abrasive finishing process for the current experimentation is used for finishing internal surface of cylindrical work pieces using a magnetic pole system. Magnetic abrasives introduced in the work piece are conglomerated at the finishing zone by a magnetic field, generating the finishing force against the contact surface of the work piece. These particles join each other to form a flexible magnetic abrasive brush (FMAB) which pushes against the work piece surface and develops finishing pressure. The tangential force developed by FMAB is the major cutting force responsible for micro chipping. During the finishing operation rotary motion is given to the magnets and the work piece is stationary.

Since the magnitude of machining force caused by the magnetic field is controllable, a mirror like surface finish (R_a value in the range of nano-meter) is obtained.

2.1 Preparation of magnetic abrasive using sintering

Sintered Magnetic abrasives were prepared in following 4 steps:

- Uniformly mixing of aluminium oxides and iron powder
- Preparation of compacts
- Sintering of compacts
- Crushing and sieving of crushed sintered Compacts to prepare magnetic abrasives

2.2 Response Variable:

The response variables chosen for the present research is surface roughness. The initial surface roughness is not identical for all the work pieces (it varied between 1.70 µm to 1.90 µm R_a). A ratio of decrease of surface roughness to the initial roughness is considered as the response variable during this experimentation. It is called percentage improvement in surface finish and is given by

$$PISF(\mu m) = \frac{\text{Initial Surface Roughness - Final Surface Roughness}}{\text{Initial Surface Roughness}} \times 100$$

2.3 Independent Variables:

Selection of independent variables is mainly governed by the findings from literature and earlier experimentation.

2.3.1 Magnetic Gap:

The magnetic force generates finishing pressure on the work piece surface during MAF. Depending upon the limitation of set up the machining gap and size of work piece selected, the gap is selected in the range of 0.5 to 2.5 mm.

2.3.2 Rotational speed:

The poles are rotated to obtain surface finish. Material removal increases with rotational speed and after some value of speed jumbling of abrasives starts which decreases surface finish. In the present study five levels ranging from 100 to 300 rpm were selected for poles of the permanent magnet as it is clear from the initial experimentation that the abrasives start rolling over the surface due to higher value of tangential force.

2.3.3 Size of MAP:

It refers to the size of Sintered Magnetic abrasive prepared for the experimentation. It is understood that smaller MAP grains tend to give better surface finish, whereas the larger grains apply excessive force on the work piece and tend to deteriorate the surface finish. In the present experimentation, MAP grains with intermediate size were chosen so that the five levels of grain size of MAP lie between 60µm–450 µm.

2.3.4 Percentage of iron in magnetic abrasives:

In most of the cases iron percentage is varied from 60 to 90% of the abrasive volume. So in the present study the sintered magnetic abrasives were prepared by varying iron percentage from 75 to 95 % of the abrasive volume.

2.3.5 Constant Parameters:

Machining Time of 2 Hrs, Percentage of abrasive used in MAP: 20% by weight, Quantity of Lubricant was 1ml for 5 gm wt. of MAPs and SUS 307 stainless steel work piece having dimensions

3. RESULTS AND DISCUSSION

Initially the R_a values of work pieces were measured. The sintered magnetic abrasive powder, which is prepared just before each test by adding the lubricant, was placed in the stainless steel tube mounted in the magnetic chuck. After experiment, cleaning the specimen with ethanol, its surface finished was measured using a Mitutoyo surface roughness tester having a least count of 0.001µm (cut off length = 0.8mm).

The experiment was designed on the basis of Response Surface Methodology (RSM) using Central Composite Design (CCD). The practical deployment of CCD often arises through the sequential experimentation. In the present CCD, the total number of experimental runs came out to be 30. So to complete the entire experimentation 30 experiments were performed in random order. The 3D graphs were plotted with the help of software showing the composite effects of two input parameters on the response parameter.

The 3D plot (Fig. 1) shows the effect of simultaneous variation of Rotational Speed and Working Gap on PISF. At minimum rotational speeds, with the decrease in working gap the PISF increases noticeably. When at maximum rotational speeds, the PISF increases sharply with decrease in the working gap. The PISF increases slightly with increase in rotational speed when the gap is kept at minimum value. When the gap is maximum, the PISF decreases by 5 % with increase in the rotational speed.

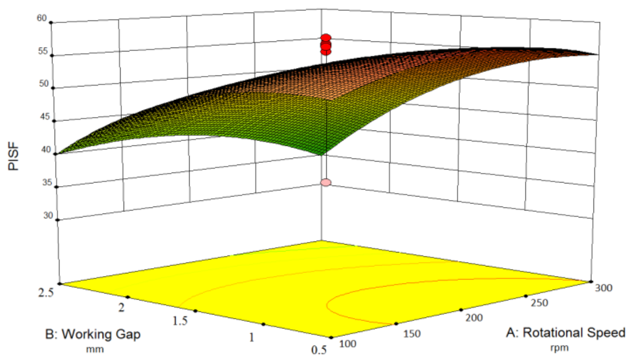

Fig. 1 Interaction effects of Rotational Speed (A) and Working Gap (B)

Fig. 2 shows the relationship between the rotational speed and magnetic abrasive particles size. As the size of MAP's increase by keeping the rotational speed at maximum value, the PISF increases pointedly. As the MAP's size decreases at minimum rotational speed, the PISF increases acutely. The PISF increases steadily when the size of MAP's is kept minimum by decreasing the rotational speed. Using the maximum MAP's size, by increasing the rotational speed the PISF increases abruptly.

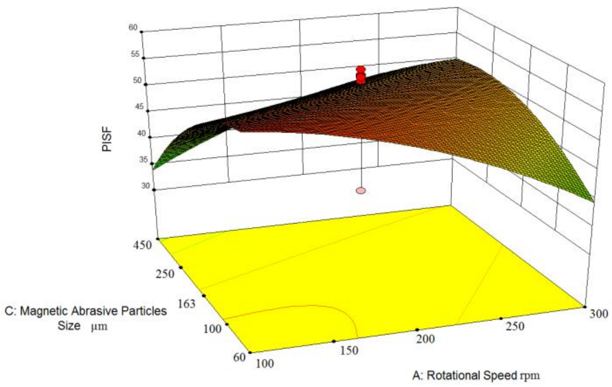

Fig. 2 Interaction effects of Rotational Speed (A) and MAP Size (C)

Fig. 3 shows the relationship between the rotational speed and abrasive weight. At lowest rotational speed, by decreasing the abrasive weight, the PISF increases while approaching the mid value of abrasive weight and then decreases afterwards. At higher rotational speeds, upon decreasing the abrasive weight, the PISF increases slightly.

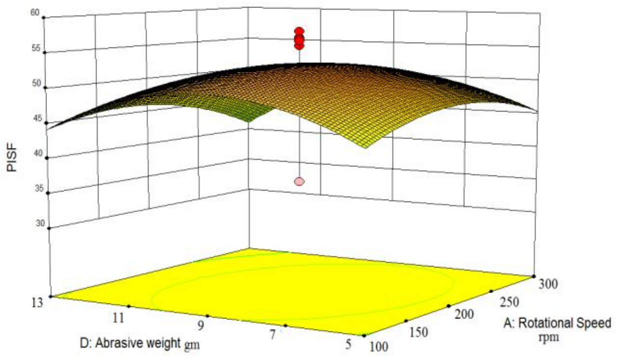

Fig. 3 Interaction effects of Rotational Speed (A) and Abrasive Weight (D)

As the rotational speed decreases by utilizing maximum abrasive weight, the PISF increases minutely. By using minimum abrasive weight, the PISF increases till midpoint value of the rotational speed and decreases afterwards.

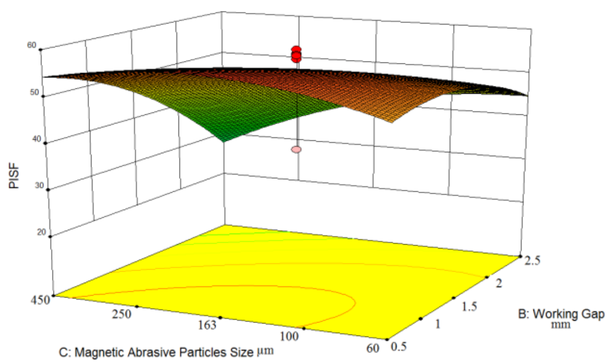

Fig. 4 Interaction effects of Working Gap (B) and MAP Size (C)

Fig. 4 shows interaction effect of working gap and magnetic abrasive particles size. With decrease in working gap by using maximum particle size the PISF increases abruptly. By using minimum particle size and decreasing the working gap, the PISF increases slightly. At minimum gap, the PISF increases minutely by increasing the abrasive particle size. At maximum working gap, by decreasing the particle size, the PISF increases sharply.

Fig. 5 shows the interaction effects of working gap (B) and abrasive weight (D) on the PISF. The PISF increases sharply with decrease in the gap by using abrasive weight as 13gm. When the gap is maximum, the PISF increases noticeably as the abrasive weight decreases. When the gap is minimum, the PISF increases gradually as the weight increases. By using minimum abrasive weight, the PISF increases till midpoint value of the working gap and decreases afterwards.

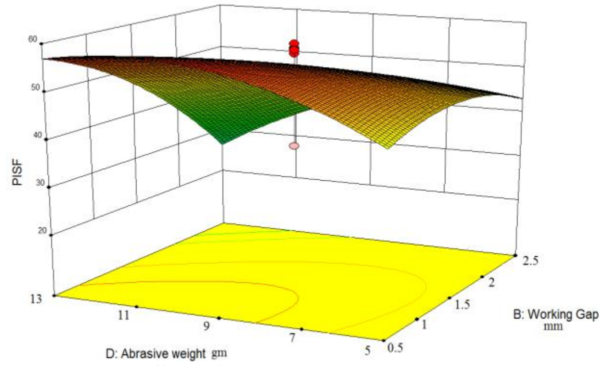

Fig. 5 Interaction effects of Working Gap (B) and Abrasive Weight (D)

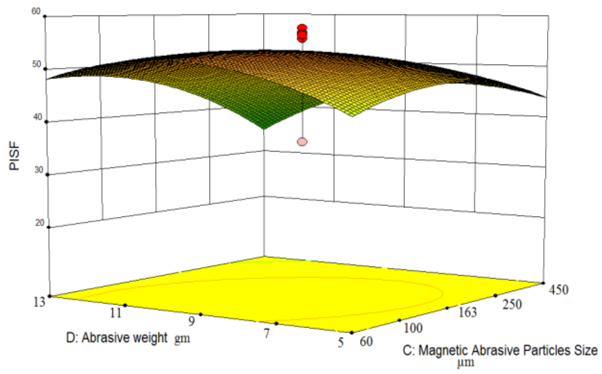

Fig. 6 Interaction effects of MAP Size (C) and Abrasive Weight (D)

Fig. 6 show 3Dgraph plots for the effects of magnetic abrasive particles size (C) and abrasive weight (D) on the PISF. It is observed that PISF decreases pointedly using large size MAP's as the abrasive weight increases. Whereas, PISF increases slightly using small size MAPs as the abrasive weight increases. Keeping minimum abrasive weight, the PISF improves using middle sized MAPs. At maximum abrasive weight value the PISF increases sharply as the MAP size decreases.

4. CONCLUSIONS

In the current research work, the machining of non-magnetic steel (SS307 grade) tubes by MAF process utilizing alumina based sintered magnetic abrasive particles was performed. The conclusions drawn are summarized as follows:

1. The working gap and size of abrasives have predominant effect on the percent improvement in surface finish.
2. The percent improvement in surface finish starts decreasing as the rotational speed of work piece increases.
3. The interaction effect of Rotational Speed (A) and MAP Size (C) had significant effect on PISF.
4. The SEM analysis shows that the tool marks are completely removed by MAF.
5. The process yielded best results at gap = 2mm, speed = 150 rpm, MAP size = 250 µm and weight = 11 gm for PISF on SS 307 grade tubes and surface finish (Ra) of about 0.16 µm.

REFERENCES

[1] Shinmura T, Takazawa K, Hatano E, “Study on magnetic abrasive process-application to plane finishing”, Bull Japan Soc Precision Engineering, vol.19, no. 4, 1985,pp.289–291.

[2] Shinmura T, Yamaguchi H, and Shinbo Y, “A New Internal Finishing Process of Nonferromagnetic Tubing by Applying a Rotating Magnetic Field”, Int’l Japan Society of Precision Engineering, vol.26, no. 4, 1992, pp.302–304.

[3] Shinmura T, Feng Hui Wang and Toshio Aizawa, “Study on a new Finishing Process of Fine Ceramics by Magnetic Abrasive Machining” , Int .J. Japan Society of precision Engineering, Vol.28 , No. 2, 1994.

[4] Kremen, G.Z, Elsayed, E.A,Feygin S and Igelshteyn L., “Material removal rate and surface roughness of Magnetic Abrasive Process” presented at 3rd international machining and grinding conference Cincinnati, Ohio, 1999.

[5] Dhirendra K. Singh, V. K Jain, V. Raghuram, R. Komanduri, “Analysis of surface texture generated by a flexible magnetic abrasive brush”, wear, vol.259, 2005, pp. 1254-1261.

[6] Kwak J.S, “Enhanced magnetic abrasive polishing of non ferrous metals utilizing a permanent magnet”, International journal of machine tools and manufacture, vol.49, 2009, pp.613-618.

[7] Shukla A., Singh D.K., “Modelling and optimization of Magnetic Abrasive Finishing Process”, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, 2(9), 2013.

[8] Yamaguchi H., Srivastava A.K., Tan M., Hashimoto F., “Magnetic Abrasive Finishing of cutting tools for high-speed machining of titanium alloys”, CIRP Journal of Manufacturing Science and Technology, 7, 2014, pp. 299–304.

[9] Choopani, Y., Razfar, M. R., Saraeian, P., & Farahnakian, M., “Experimental investigation of external surface finishing of AISI 440C stainless steel cylinders using the magnetic abrasive finishing process,” *The International Journal of Advanced Manufacturing Technology Int J Adv Manuf Technol, 83*(9-12), 2016, pp. 1811-1821.

[10] Saraeian P., Mehr H.S., Moradi B., Tavakoli H., Alrahmani O.K., “Study of Magnetic Abrasive Finishing for AISI321 stainless steel”, Materials and Manufacturing Processes. doi:10.1080/10426914. 2016.1140195, 2016.