A Review on Magnetic Abrasive Finishing process for Flat surfaces

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Abstract: Magnetic Abrasive Finishing (MAF) is a super finishing process having capability to produce precision finish in nano-meter level. The MAF process can be used for finishing of both magnetic and Non Magnetic materials. In this process a Flexible Magnetic Abrasive Brush (FMAB) is developed using electro magnet and other attachments to finish machine the targeted work piece. The literature reveals that the concept of mechanism of Surface finish (SR) and material removal rate (MRR) in MAF is limited to few materials only. However, phenomena involved in these mechanism needs to be investigated well in order to improve the process. In this paper, the concept of mechanism of Surface finish in MAF is reviewed till date; scopes for further research have been identified and discussed. Possible future efforts to enhance Surface Finish in MAF are also discussed.

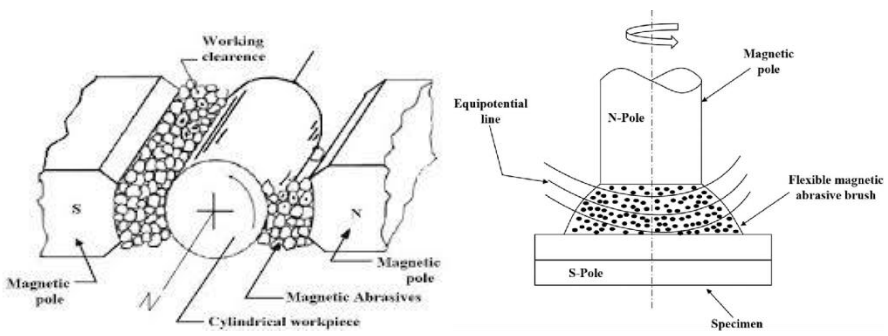
Keywords: MAF, FMAB, SR, MRR

1. Introduction

The surface finish of a component plays a significant role in its quality for cases requiring precision fits or application of cyclic loading. The rapid progress in the semiconductor, optical, electronic, atomic energy, aerospace component industry, etc., increased the significance of the quality of surface finish and integrity [1]. These advancements lead to a greater demand for fine surface finishing capabilities in a varied range of industrial applications as the finishing operation is a vital and costly segment of the whole production process. Due to the rapid advancements in the field of materials, the materials having properties like high hardness, toughness, high strength to weight ratio and fragility have now become popular in industries. Extraordinary features make them demanding for different industrial applications. Finishing of such materials by conventional finishing processes is the principal challenge for the manufacturing industry [2].

2. Magnetic Abrasive Finishing (MAF)

The traditional finishing processes like grinding, honing and lapping create micro/nano burrs, subsurface dam- age and residual stresses. They are also unable to finish the fragile materials like glass. Achieving the surface roughness values of the order of nanometer by conventional finishing processes is an onerous and an uneconomical proposition. In the last few decades, developments have taken place for fine finishing of these materials. The application of flexible abrasive process with the use of gentle forces is an effective solution to the problem of obtaining a nano level surface finish. In some flexible abrasive finishing process, abrasive particles are supported by a carrier, whose properties are controlled by an external magnetic field. These include magnetic abrasive finishing (MAF), magnetic float polishing (MFP) and magneto rheological finishing (MRF). MAF uses magnetic force in the finishing zone to allow the flexible abrasive particles to shear off the material in the form of microchips.



(a) (b)

Fig 1. (a)MAF for Cylindrical Surfaces and (b) Flat surfaces

3. Analysis of Process Parameters

The impact of various input parameters on process characteristics namely R_a and MRR of MAM during machining of different engineering materials has been analyzed using the experiment and are discussed below:

- *Influence of Voltage on R_a and MRR.* With the increment in voltage supplied to the electromagnet, the R_a and MRR rate are also increases [10]. It creates much line of magnetic force so there is increase in magnetic flux density on the working zone. With the decrement of working area the strength and contact area of FMAB with workpiece increase. By that there is increment in R_a.

- *Influence of Mesh Size of Abrasive Particles on R_a and MRR.* With the increment in abrasive particles size there is decrease in surface finish [10, 32, 33]. With the decrease in abrasive particle size, there is increase in a contact area of workpiece with abrasive particles size. So, much surface got sheared off so that there is increase in surface finish but it is not

- possible to larger abrasive particle size because in FMAB it is hard to trap between abrasive particles size. Thereby, it impact in finishing, result on improper R_a and MRR.

- *Influence of Rotational Speed of Electromagnet on R_a and MRR.* Surface roughness and MRR increase which guide to the better surface finishing due to increment of Rotational speed [10, 18]. Furthermore Rotational speed supply additional energy to abrasive to penetrate workpiece, thereby there is better R_a and MRR. But there is decrement in surface roughness with increment in rotational speed. Increment of centrifugal force is corresponding to the increment of rotational speed. The mixtures of MAP is cast away from the machining zone with increment of force, thereby magnetic flux density decrease in the machining zone as well as there is available of less MAP used for the shearing with the surface of workpiece. So, there is reduction in R_a with more increase in rotational speed of electromagnet.

- *Influence of Magnetic Flux Density on R_a and MRR* There are improvement in R_a and MRR of workpiece, when there is increase in magnetic flux density [34-35]. R_a and MRR are increased due to the increment in flux density of magnetic; thereby increase in tangential finishing force which is the crucial cutting force required for smoothening of surface by removing materials as microchips. Magnetic flux density and different parameters should be used according to the properties of operating workpiece materials.

Influence of Working Gap on R_a and MRR. Due to decrement of working zone percentage of R_a and MRR increases [20, 26, 35]. But with the increment of working zone, surface finish is decreased because magnetic field generated is minimum so that ferromagnetic particle is weakly magnetized therefore it produce lesser amount of pressure force in FMAB during workpiece boundary by that abrasive particle size doesn't have exact indentation with large working zone. So, R_a and MRR are decreased.

4. Discussion

MAF is one of the finest surfaces finishing unconventional machining process for all types of engineering materials and it is suitable for the surface finishing with high accuracy and efficiency. It is always not necessary that there should be significant contribution of input parameters on output parameters like surface finish and MRR. Some of the parameters are significant as compared to others. In this section, different authors' contribution for Magnetic abrasive finishing of flat surfaces has been summarized in the Table 1.

Table 1: Summarized MAF process for Flat surfaces

Authors	Year	Work Material	Abrasives Used	Input Parameters	Observations
D K Singh et al	2004	SUS 304	SIC	Voltage:7.5-11.5 V Working gap:1.25-1.75mm,Rotational speed:90-180 rpm, Grain size: 400-1200(mesh number), Time :20 min	1.a high level of voltage (11.5 V), a low level of working gap (1.25 mm), a high level of rotational speed (180 rpm), and a high level of grain mesh number are desirable for improving ?Ra 2. forces increase with increase in voltage and decrease in working gap.
Shaohui Yin and Takeo Shinmur	2004	Magnesium alloy AZ31B, Stainless steel SUS304, Brass C2680	WA magnetic abrasive	Vibration of workpiece Amplitude:1 mm, frequency: 6 Hz, Feed speed of workpiece: 17 mm/min, Magnetic flux Density:0.8 T Working gap:2mm	The removal volume per unit time of magnesium alloys is larger than that of the brass and stainless steel.
Berhanu Girma et al.	2006	NA	Al_2O_3	MAP gain size: 180–210mm; size-ratio: 1.5–2.0; and current: 3.0–3.5A. The feed rate:0.01–0.045mm/rev.	The surface finish was found to improve significantly with an increase in the grain size, relative size of abrasive particles and iron particles, feed rate and current.
V K Jain et al.	2007	Alloy steel	SiC	Flux density:0.2-0.3 T,Working gap:1.5 -2 mm, Size of the abrasive grain: 5µm	1.Flux density, working gap and size of magnetic abrasive particle have significant effects on surface roughness.
Hitomi Yamagu	2014	**Ti-6Al-4V alloys**		Magnetic particles: Steel grit (700 mm mean diameter)	1.The MAF-processed surface improves

chi et al.			Diamond	Iron particles (44–105 mm diameter) 0.5 g total), Abrasive:40g, Spindle speed:600 rpm, Working gap:2 mm,	tribological properties, 2.MAF-processed tools had tool lives of up to 1.5 times as long as untreated tools.
Prateek Kalaa and Pulak M. Pandey	2014	**Copper alloys**	Al_2O_3	Upper disk working gap:1.5-2.5 mm, Lower dusk working gap:1.5-2.5 mm,Percentage of abrasive:10-30% Rotational speed:200-400 rpm	1.normal finishing forces is affected most significantly by lower and upper working gap 2.finishing torque is effected mostly by the lower working gap and rotational speed of the magnetic disk
Prateek Kala and Pulak M. Pandey	2015	**Copper alloy (C61400) and Stainless steel (SS 202)**	Al_2O_3	Working gap :1-3 mm, Percentage of abrasive :10-40 %wt, Abrasive mesh number:400-1200 Feed :1-5mm/min, Rotational speed :100-600 rpm.	1for hard materials higher magnetic flux density and thus higher finishing forces like at 1 mm working gap, 18% abrasive weight percentage, and 436 rpm. 2.lower magnetic flux density and thus lower finishing forces like at 2.3 mm working gap, 36% abrasive weight percentage, and 467 rotational speed
Vahdati and Mehrdad Rasouli,	2016	Aluminium alloy	Al_2O_3	Abrasive Powder wt:0.35-1.75 g, Working gap:0.5-2.5mm,Feed rate: 10-50 mm/min, Electromagnet speed:100-2100 rpm.	Optimum parameters are gap size of 0.5 mm, feed rate of 10 mm/min, rotational speed of 2100 rpm, and powder amount of 1.75 g.
Ahmad et al.	2017	Stainless Steel 202 to	Al_2O_3	Voltage:6-18 V, Rotational Speed:60-120 rpm, Abrasive size:90-300 µm	Abrasive size of 150 µm and Voltage has greater significance abrasives particles on machining performances.

Pei-Ying Wu and Hitomi Yamaguchi	2018	316L material from	Al_2O_3	Working gap:2mm, Magnet speed: 600 rpm,Feed:1 mm/s, No of passes:50	The surfaces made using MAF were dominated by valleys. In particular, the surface made by the magnetic abrasive showed higher skewness and lower kurtosis than the one made by the conventional abrasive.
Naveen, K. et al	2018	Stainless steel 304	Diamond	Magnet speed:200-600 rpm,Feed:75-225 mm/min, Gap:1-2 mm	optimized process parameters are speed 600RPM, feed 75mm/min and gap of 1mm

5.Conclusions

1. Batter analysis of all forces acting during magnetic abrasive process gives us better understanding of dynamics of process and good control over finishing process. Process is in batter control when indentation force (normal to work piece surface) is accurately measured, and gives the finishing scale up to few Nano- meters.

2. From past researches, it can be concluded that any other movement to work piece table like ultrasonic vibration as in UAMAF will provide batter results over conventional MAF process.

3. MAF process is feasible for finishing of cutting tool tips and extended surfaces. 4. Newly developed DDMAF process overcomes the difficulties in finishing of paramagnetic and diamagnetic material on conventional MAF process.

5. By using various optimization techniques and analysis of process variables, efficiency of magnetic abrasive finishing process can be increased.

6. Till date, very little attention has been given on development of flexible magnetic abrasive brush for finishing of external and internal surfaces of both flat and cylindrical surfaces.

7. It is concluded that, a high level of voltage, a small working gap, higher rotational speed, and a higher mesh number of grains are desirable process parameters for improving surface finish.

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