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Effectiveness of Magnetic Abrasive Finishing Process over Buffing Process for surface finish of Brass component

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ABSTRACT- Magnetic Abrasive Finishing (MAF) Process is one of Non-Conventional Processes in which a mixture of non-ferromagnetic abrasives and ferromagnetic iron particles is used to do finishing operation with the aid of magnetic force. The trapped iron particles and abrasives is called Flexible Magnetic Abrasive Brush (FMAB), which when given relative motion against a metal surface, polishes that surface. The major studies concerning MAF have been done regarding the behaviors of the process under the effect of various parameters like working gap, mesh number of abrasives, speed of relative motion etc. but limited study on effectiveness of MAF over existing conventional Processes such as buffing. This paper has aim of development of Magnetic Abrasive Finishing Process & evaluate for surface finish of Brass material keeping in view the performance of buffing process, The results indicates that MAF has capability to get required surface finish with low speed over buffing with competitive machining time

Keywords: Magnetic abrasive finishing, Buffing, Surface Finish, Flexible Magnetic Abrasive Brush, MAF, Iron particles

1. INTRODUCTION

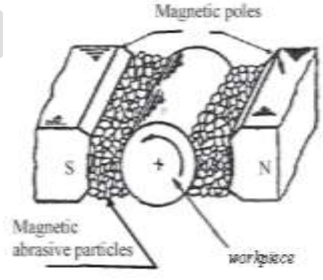
1.1 Conventional Finishing Process (Buffing)

These processes use multipoint cutting edges in the form of abrasives, which may or may not be bonded, to perform cutting action. Buffing is one of the most common, technically buffing uses a loose abrasive applied to the work wheel known as mops are either made from cotton or wool cloth using medium to hard pressure. Buffing may be done by hand or grinder or specialized equipment to convert rough surface into a smooth one

1.2 Non-Conventional Finishing Process (MAF)

A magnetic abrasive finishing process is defined as a process by which material is removed, in such a way that the surface finishing and deburring is performed with the presence of a magnetic field in the machining zone. The working gap between the work piece and the magnet pole is filled with magnetic Abrasive particles (MAP), composed of ferromagnetic particles and abrasive powder which is prepared by sintering process. The magnetic abrasive particles attract each other along the lines of magnetic force and form a flexible magnetic abrasive brush (FMAB) between the work piece and the magnetic pole and behaves like a multi-point cutting tool.

In external finishing of cylindrical surface, the cylindrical work piece rotates between the magnetic poles, with the MAP filled in both the gaps on either side (Fig 1.1). Whereas in internal finishing of cylindrical surface, the work piece rotates between the magnetic poles and the MAP (Fig. 1.2)



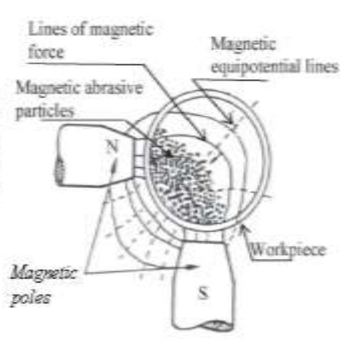


Fig-1.1External cylindrical finishing Fig 1.2.Internal cylindrical finishing

2. LITERATURE REVIEW

The effective way of changing the force/finishing pressure and rigidity of MAFB is through the change in diameter “D” of magnetic abrasive particle. Hence, ferromagnetic particles of several times the diameter of diamond abrasive “d” are mixed to form the magnetic abrasive brush. Pressure increases with increase in flux density and decreases as the clearance gap between tool & work-piece increases. Larger the particle size, poorer the finishing ut higher is the stock removal which increases linearly with finishing time [1].

The surface roughness is predicted as a function of finishing time by a model that has been derived from the removed volume of material. Thus, it is possible, from the surface-roughness model, to predict the time when existing scratches are completely removed [2]. The magnetic force acting on the magnetic abrasive, controlled by the field at the finishing area, is considered the primary influence on the abrasive behavior against the inner surface of the work-piece. [3].

With increase in working gap, the percentage improvement in surface roughness increases initially, reaches a maximum value and then it starts decreasing [4]. Removal of burrs in large surfaces with drilled holes using MAF shown that this method can be applied both for ferromagnetic and non-magnetic parts. This method can be improved as applied to new tasks of deburring [5].

The unbounded magnetic abrasive is a mechanical mixture of Sic -abrasive and ferromagnetic particles with a SAE30 lubricant. Iron grit and steel grit, three particle sizes were prepared for both and were used as ferromagnetic particles, each of them being mixed with 1.2 and 5.5 μm Sic abrasive, respectively. Results indicate that steel grit is more suitable for magnetic abrasive finishing because of its superior hardness and the polyhedron shape [6]. Important parameters influencing the surface quality generated during the MAF were identified as: (i) voltage (DC) applied to the electromagnet, (ii) working gap, (iii) rotational speed of the magnet, and (iv) abrasive size (mesh number). [7].

Efficient finishing of magnesium alloy is possible by the process. The volume removed per unit time of magnesium alloy is larger than that of other materials such as brass and stainless, that is, high-efficiency finishing could be achieved. Micro-burr of magnesium alloy could be removed easily in a short time by the use of MAF [8].

MAF process creates micro scratches having width less than 0.5 μm on the finished surface by the shearing of the peaks resulting in circular lays formed by the rotation of the FMAB. It shows that the finished surface has fine scratches which are farther distant apart resulting in smoothened surface. But these fine scratches would also disappear by using higher mesh number (finer abrasive particles) [9]. A new technique was developed to compare the performance of the magnetic abrasive powders and to find the powder that is appropriate for finishing and deburring of drilled holes placed on a plane steel surface [10]
In addition to deburring, efficiency influence to surface roughness is analyzed. To improve the surface roughness and purity, volume of powder, height of gap, inductor rotational frequency, feed velocity and the method of coolant supply are analyzed and proved that the continuous flow of coolant and the Fe powder without abrasive is effective for deburring and surface quality. [11]

3. EXPERIMENTAL SET-UP

3.1 Buffing Process Equipment

Machine setup for the experiments is considered from the Buffing section of Industry. The main equipment used in the process is buffing machine. The tool used with machine is cylindrical fine abrasive laden cloth buff wheel. The work piece (Brass) is held by operator in hands and force it against the rotating buffing wheel whose speed is 3500 r.p.m. All the inspection is done by the operator visually. The additional data of buffing machine is given in Table no 1.1

Table: 1.1-Data regarding Buffing Equipment

Type of Motor	3 phase A.C
Type of tool	Buff Wheel
Dia of wheel	12 inches

Material of wheel	Cotton cloth
Speed of wheel	3500 r.p.m

3.2 Magnetic Abrasive Finishing

Fundamental requirements of the experimental set-up are:

A. Magnetization unit
B. Electromagnet
C. *Rotary Motion Unit*
D. Magnetic Abrasives
E. Specimen & Material

A. Magnetization Unit

Basic purpose of magnetization unit is to generate magnetic field to assist the finishing process. Main parts of magnetization unit are –

- D.C. Power supply
- Electromagnet

A variable DC supply is needed to changes the magnetic field strength. It ranges from 1 ampere to 15 amp and a very low voltage (0 to 220V) The diode is used to convert AC to DC supply with the help of bridge rectifier, which can supply a current up to 10 amp without any damage. Capacitor is used at outlet to get pure DC.

B. Electromagnet

As per literature survey, the magnetic field should vary with the help of variable D.C supply from 2KG to 12 KG between the clearance of electromagnet pole and work piece for best performance. Area of magnetic core is proximately 1200 mm^2 and the diameter of magnetic core is 36.65 mm and length is 24.7cm. Yoke is prepared from mild steel, which is suitably ground to adjust with platform. The detail is given in Table no 3.2 and figures no 1.3

TABLE 1.2 Dimensions of Electromagnet

Maximum Flux Density	12KG
Diameter of magnetic core	3.69cm
Cross-sectional Area of Magnetic Core	10.70cm2
Cross section of core	1200mm2
Material of core (pipe)	Aluminum
Thickness of core (pipe)	1.2mm
Diameter of core (pipe)	36.9mm
Length of Core (Pipe)	24.7cm
Material of Core ends	Bakelite
Coil turns (each side):	1800

Material of coil wire:	Enameled copper (17SWG)
Current Range of wire	0- 5 Ampere
Voltage range of wire	0-3 volts
Diameter of Wire	1.7mm (17 gauge)
Angel between two poles:	180 degree

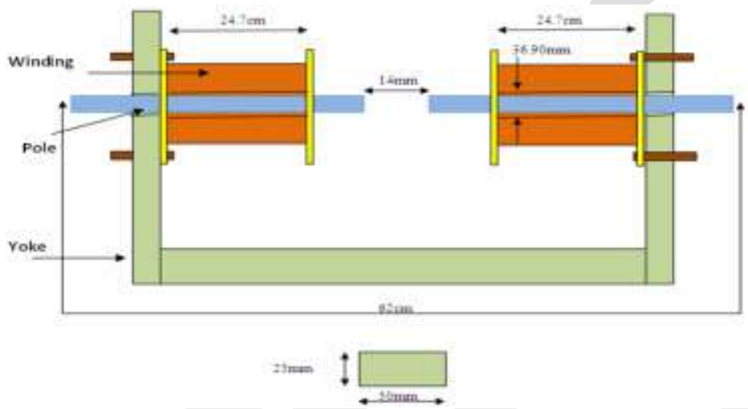


Fig 1.3- Detail Diagram of MAF Setup for external cylindrical finishing

C. Rotary Motion Unit

Variable D.C motor is used to rotate the work piece in between two poles. Motor has 3- jaws chuck to hold the job to get the relative motion between work piece and FMAB.

D. Magnetic Abrasives

In the present work sintered magnetic abrasives are used. The mixture of iron particles and Al2O3 is sintered and heat treated. After that the solid mass is crushed to get required size of abrasives. From the literature survey, it was found that 60-100 grit size is most suitable size of magnetic abrasive for finishing brass material. Grit Size 60 was selected for experimentation.

E. Specimen & Material

One of the tap cap of Brass being manufactured by industry has been used as the specimen for the present work. Cap has one handle that is used to move manually as shown in figure no 1.4

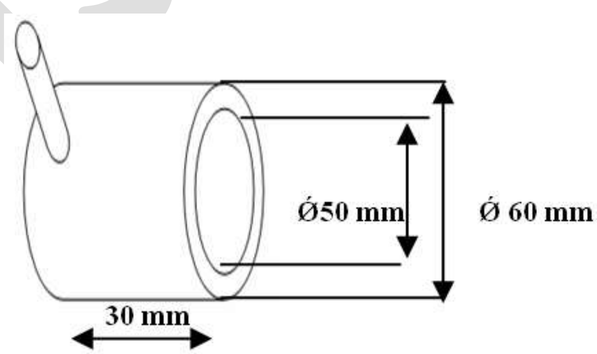


Fig 1.4 Detail of Tap cup

Brass is common for household building materials such as lock sets and door hinges, made from a combination of copper and zinc with other alloys often added for strength and/or additional corrosion resistance. (Yellow Brass has a ratio of roughly 70% Copper and 30% Zinc). The relatively low melting point of 1560 to 1725 °F makes it good for both casting and machining.

4. EXPERIMENTAL PROCEDURE

4.1. Buffing Process

In the first set of present experimental work, around 30 components were taken to observe the performance parameters and response parameters such as surface finish after fine grinding process. Ten work pieces with small variation in surface finish are selected for further buffing process. In the industry, buffing is done by operator manually so there were variations in the accuracy. Measurements about surface finish and weight were taken after buffing. Further variation in values is considered as final acceptable range. The other observations related to buffing machine setup is given table no 4.1

Table: 1.3- Additional Data for Buffing

Cost of machine	Rs 50,000/-
Cost of Tool	Rs 1200/-
Life of Tool	2 days
Speed of Tool	3500 r.pm
Working Environment	Pollutant, unhealthy
Noise Level	High

4.2. Magnetic Abrasive Finishing Process (MAF)

The experiments were conduct according to following steps-

Twenty work pieces were taken from the industry which was ground by surface grinder to give all the work pieces almost same initial recommended surface roughness value.

1. After the grinding process, the work pieces were manually cleaned by acetone to remove the foreign particles from the work surface. Initial surface roughness values were measured. Surface finish was measured by using ‘Citizen cy 510 surf analyzer’ (least count up to 0.001µm).

2. To conduct the surface finish experiments, after the grinding, the work piece was mounted on the MAF machine chuck. The work piece was made perpendicular to the electromagnet pole to maintain proper gap between them.
3. On supplying current to the electromagnet, it gets energized and the Magnetic Abrasive Particles (MAPs) fill between the electromagnet and work piece. The MAPs get aligned along the magnetic lines of forces making Flexible Magnetic abrasive Brush (FMAB). By giving rotation to the work piece, this FMAB behave like multi cutting tool and performs the actual finishing operation on cylindrical portion with length of 30 mm on job.

4. After completing the finishing operation, work piece was again cleaned and final surface roughness.

4.2.1 Selection of parameters for experimentation

The following three effective parameters has been taken for conduct of experiment on MAF

1. Current
2. Machining Time
3. Circumferential speed of work piece.

The ranges of the values of the variable parameters selected from available literature and on the basis of capabilities of experimental setup shows the range of variables and values of constant parameter respectively constant in Table 1.4 & 1.5

Table 1.4 Variable parameters and their ranges

Parameter	**Range of Values**
Current	2 Amp to 10 Amp
Machining Time	1 mins to 3 mins
Circumferential Speed of Work Piece	200 rpm to 1500 rpm

Table 1.5 Fixed parameters and their value

Parameter	**Value**
Gap	1. mm
Grit size	60#
Abrasives used in MAP	Sintered (Al2O3+ Iron)
Work-piece	Cylindrical Brass
Percent of oil in MAP	2 %

Response Surface Methodology (RSM) was used to conduct & analyses the experimental work that can be used for either process improvement or determination of optimal conditions of various industrial processes in no of possible experimental situations to represent independent factors in quantitative form.

4.2.2 Response Characteristics

The effect of selected process parameters was studied on the following response characteristic of MAF process:

Percentage Improvement in Surface Roughness (∆ Ra)

The surface roughness before and after the machining operation was measured with Mitutoyo Roughness tester and calculated with the formula given below:-

$$\Delta Ra = \frac{(\text{Initial roughness} - \text{final roughness}) \times 100}{\text{Initial roughness}}$$

5. OBSERVATIONS

5.1 Buffing

Surface Finish and metal removal were measured on ten work pieces and recorded in Table 1.6. The speed of Buffing was fixed 3500 r.p.m. The operator was asked to do buffing as per his judicious judgment. The operator took time to the prevailing practice. There was 15 % variation of buffing time for ten specimens. Max & Min time taken by the operator was 2.43 mins & 2.00 mins respectively. The max % age improvement in Ra is 86% with machining time 2.34 mins. Surface finish varies from **0.2µm –to- 0.6µm**. The decision about the rejection of the work piece is taken by visual inspection.

Table 1.6: Observations for Surface Finish (Ra)

Ex. No	Buffing Time (mins)	Surface finish before Buffing (µm)	Surface finish After Buffing (µm)	% Age Imp (Ra)

1	2.02	1.0	0.23	77%
2	2.00	1.5	0.32	78%
3	2.30	1.1	0.22	80%
4	2.34	1.2	0.34	86%
5	2.5	1.2	0.21	82%
6	2.1	1.5	0.63	60%
7	2.4	1.2	0.45	62.5%
8	2.32	1.5	0.5	68%
9	2.33	1.3	0.3	76%
10	2.43	1.3	0.2	84%

It is observed that the selection criteria of product in the industry after buffing depend upon the surface finish. So the range of Recommended surface finish under which the work piece get approval is **0.2 µm-to- 0.6 µm** at the speed of 3500 r.pm.

5.2 Magnetic Abrasive Finishing

Observations for Surface Finish are obtained for standard combination of process parameters by using RSM analyzed by the Design expert v. 8 software. By putting the range values of the process parameters namely current, speed of work piece and machining time, we obtained the combinations of three parameters shown in Table no 1.7

Table 1.7: Observations for Surface Finish (Ra)

Exp No	Current (Amp)	Machining Time (mins)	Speed (r.p.m)	Surface Finish Before	Surface Finish After	ΔRa
1	3.62	1.41	463.51	1.0	0.7	30%
2	8.38	1.41	463.51	1.5	0.5	66%
3	3.62	2.59	463.51	1.1	0.4	63%
4	8.38	2.59	1236.49	1.2	0.7	41%
5	3.62	1.41	1236.49	1.2	0.7	41%
6	8.38	1.41	1236.49	1.6	0.3	80%
7	3.62	2.59	1236.49	1.2	0.5	58%
8	8.38	2.59	1236.49	1.6	0.2	87%
9	2.00	2.00	850.00	1.3	1.0	23%
10	10.00	2.00	850.00	1.3	0.6	54%
11	6.00	2.00	850.00	1.5	1.0	33%
12	6.00	3.00	850.00	1.3	1.0	23%
13	6.00	2.00	1500.00	1.2	0.9	25%

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14	6.00	2.00	850.00	1.6	0.7	56%
15	6.00	2.00	850.00	1.5	1.0	33%
16	6.00	2.00	850.00	1.3	0.8	38%
17	6.00	2.00	850.00	1.4	0.9	35%
18	6.00	2.00	850.00	1.2	0.8	33%
19	6.00	2.00	850.00	1.4	1.0	28%
20	6.00	2.00	850.00	1.4	0.9	35%

It is observed that the max %age improvement in **Ra is 87 %** with machining time 3.00 minutes at the speed of **1236 rpm. Experiment no 2,6,10** shows that the surface finish within the recommended range, obtained at the speed 463 **rpm, 850 rpm and 1226 rpm** with **max 80 % improvement** Ra with same or less time as compared to buffing process

6. RESULTS & DISCUSSIONS

6.1 Effective Analysis of Process Parameter on Response

All the three individual parameters current, speed of work piece, machining time in MAF have significant effect on the surface roughness as shown from three dimensional views shown in fig 7.1. I it can be seen that as the current increases (from 3.62 amp to 8.38 amp) resulting increase in the %age improvement in surface roughness (ΔRa). In case of Machining Time, as the time increases (from 1 minutes to 3 minutes), the %age improvement in surface roughness (ΔRa) increases. Machining time and current have higher contribution to ΔRa. Due to high current, rigid brush of abrasives that is why more surface finish. Optimization of MAF setup can be done by controlling these effective process parameters for specific application

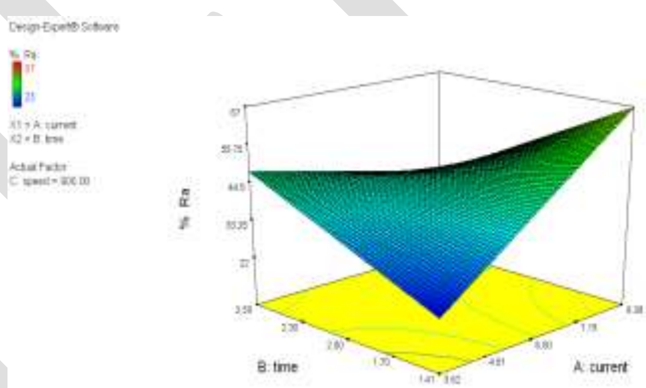

Fig: - 1.4 Comparison of required rotational speed for Buffing & MAF to get Ra ((0.2 µm-to- 0.6 µm)

7. COMPARITIVE EVALUATION FOR SURFACE FINISH

7.1 Rotational Speed

It is observed that the range of Recommended surface finish under which the work piece get approval for electroplating is **0.2 µm-to- 0.6 µm** at the speed of 3500 r.pm. Experiments on MAF were conducted to get same recommended surface finish value. As per the experiment no 2,6,10 from the table no: 6.2, It is observed that the surface finish within recommended range can be obtained with low speed of work piece (463rpm).

85% reduction in speed is possible to get same level of finish on the component. So MAF has capability to get required surface finish with low speed over buffing for less than 2 minutes machining time as shown by Figure no 1.5

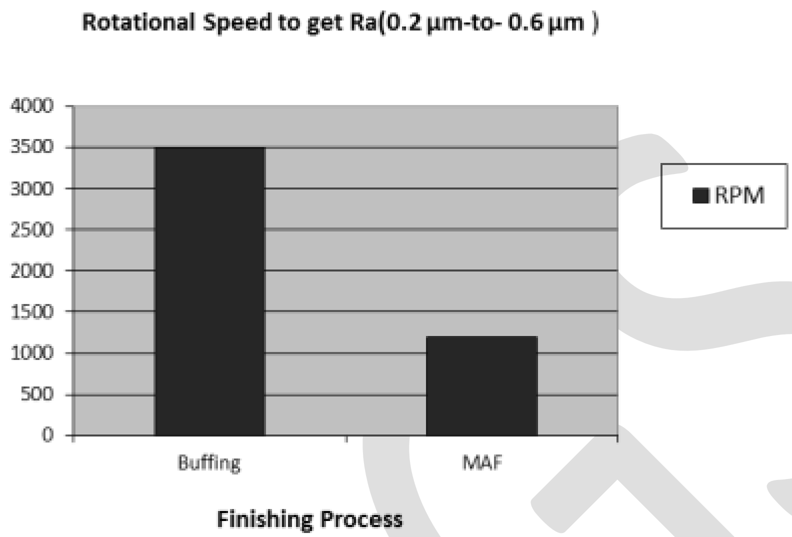

Fig: - 1.5 Comparison of required rotational speed for Buffing & MAF to get Ra ((0.2 µm-to- 0.6 µm)

7.2 Machining Time

From the table no 6.2, It can be seen that to get required surface finish, operator takes machining time from 2 min to 2.5 min at the speed of 3500 r.pm. Experiments on MAF were conducted to get same recommended surface finish value. As per the experiment no 2,6,10 from the table no: 5.2. It is observed that the surface finish within recommended value can be obtained with almost same machining time as taken during buffing, This factor shows the production rate capability of MAF same as Buffing. as shown in figure no 1.6 From table no:-1.7, it observed that 12 experiments out of 20 experiments , produce the surface finish close to recommended value , when machining time is not consider as mandatory factor to maintain.

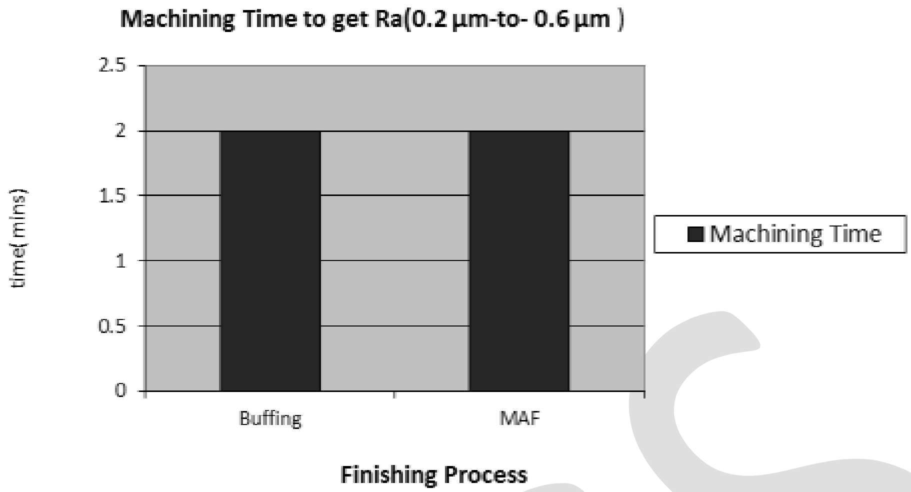

Fig: - 1.6 Comparison of Machining time for Buffing & MAF to get Ra ((0.2 µm-to- 0.6 µm)

CONCLUSIONS

Experimental results indicate that MAF is better than buffing as regards to reduction of operating speed of the motor in MAF for same required surface finish range (**0.2 µm-to- 0.6 µm)**

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