Reducing Downtime of Repairing for Taper Roller Bearing by Magnetic Abrasive Finishing (MAF) Process

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***Abstract*—Bearings are one of the most important and critical component in the wide variety of machines. Most of the bearings are failed before completing their theoretical life due to the wear, corrosion, contamination, fatigue etc. The cost and time involved in repairing the bearings is very high. In the present work, Magnetic abrasive finishing (MAF) process is developed to reduce the turnaround time of repairing the taper roller bearing. The finishing time varies according to the level of damage of the bearing surface. The surface of the bearing has complex configuration (curved and conical) thus MAF is best suited due to the self-adaptability of the flexible magnetic abrasive brush (FMAB).Permanent magnets are used to hold the FMAB. The experiments performed using the magnetic abrasive powder (MAP) consisting of abrasives (boron carbide (B_4C) and diamond), iron powder, de-ionized water and glycerin in appropriate composition. The aim of the present study is to evaluate the impact of vol. % of diamond abrasives, number of magnets and strength of magnets in nano-finishing of taper roller bearings. The experiments were designed as two level full factorial. The basic principle of material removal is three body abrasive wear. It was found that addition of diamond abrasives in the MAP greatly improved not only the finishing rate but % change in surface finish also. The best finish achieved is (Ra=) 36.5 nm from initial (Ra=) 271.5 nm without any surface damage within 24 min. It is concluded that by implementing the present process a highly finished surface of taper roller bearing can be achieved within a short time span depending upon the initial condition of the bearing surface.**

***Index Terms*—Flexible magnetic abrasive brush (FMAB), magnetic abrasive finishing (MAF), magnetic abrasive powder (MAP), turnaround time (TAT).**

I. Introduction

Repairing of components is essential for smooth functioning of the product in a long run. The time involved in repairing a component is very critical. The reduction in downtime is the major task in many of the big organization. Increased downtime incurred high cost due to loss of productivity, loss of sale and above all customer dissatisfaction. Especially in aircraft industries the cost of downtime is very high. The parts which are exposed to high temperature, speed and pressure require a high level of finishing. MAF is one of the advanced finishing process which can finish any metallic (magnetic or non-magnetic) surface up to nano level [1]. A mixture of abrasive particles, ferromagnetic powder and some binding media are mixed homogeneously which is known as magnetic abrasive powder (MAP). As the MAP brought near to tool, it is attracted by the magnets attached to the tool and forms a flexible magnetic abrasive brush (FMAB). In the FMAB many small abrasive particles acts as a tool. When FMAB is mildly pressed against the surface to be finished and a relative motion is imparted the abrasive particles wear out the material in the form of very small chips [2].

Shinmura et al. [2] explored basic principle of MAF process. They used different sizes of diamond coated cast iron balls to finish the fine ceramic bars and concluded that as the size of diamond abrasive increases the material removal rate increases.

Samuels et al. [3] investigated the effect and type of diamond abrasives on material removal rates in polishing of annealed brass. They found that the maximum material removal rate is obtained with a 2-4 µm abrasive grade. They recommended polycrystalline diamond over mono crystalline for higher material removal on hard materials (hardness more than 50 HV).

The effect of amount of lubrication used in MAP is studied and it is found that an optimum amount of lubricant affects the abrasive contact against the surface to be finished and results in better surface finish and form accuracy [4].

The antifriction bearing are generally made of steel (AISI 52100) and Mulik et al. [5] conducted experiments on this material having hardness value of 61 HRC and achieved surface roughness of the order of 51nm within 120s. They concluded that mesh size of abrasive and rpm of electromagnet are significant process parameters.

The study of abrasive wear on Ni based coated alloy using the full factorial based design is done. The statistical model was design to investigate effect of various factors on abrasive wear. It was concluded that abrasive grain size has the greatest effect [6].

Patent No.US 4306386 is developed to finish the large size magnetic work pieces. A set of electromagnets are used to generate the magnetic field and ferromagnetic abrasive powder is used as a brush. The combined magnetic effect of the external field and the article (magnetized by the external field) results in the strong ferromagnetic abrasive brush. The process is energy and time saving. Patent No.US 4800682 developed a grinder especially a high precision grinder for a bearing ring. Ball-bearing ring having a curved race is finished using a high precision grinder. The grinder has exteriorly curved surface which is given oscillation while the ring is rotated. To reduce the vibration of grinder, feed guide rods are provided. Patent No.US 5775976 showed a method and device for magnetic abrasive machining of parts. This machine is developed to increase the material removal rate by introducing vacuum between the magnetic-abrasive powder and the work piece surface to be finished. Also a fluid jet is introduced directly towards the magnetic abrasive

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powder to increase the pressure exerted on the work piece surface thus increasing the rate of removal. Patent No.US 5931718 presented magnetic float polishing processes. This invention is related to the surface finish of advance ceramic materials using magnetic float polishing and followed by chemo-mechanical polishing. The work piece used is Si_3N_4 balls which is finished in various stages using the B_4C, SiC and CeO_2 abrasives. The first two are used for magnetic float polishing while CeO_2 is used in chemo-mechanical polishing to remove the SiO_2 layer formed during the magnetic float polishing process. The best possible surface roughness value measured as Ra < 4.0 nm. The total finishing time is around 16-20 hrs. as compared to several weeks by conventional processes. According to Patent No.US 6146245 a flat surface is super finished, which is held between two permanent magnets located opposite and spaced from one another, by the relative motion of one of the magnet and work piece. The gap between the work piece and magnets is filled with magnetic abrasive slurry containing different abrasives in water or oil base. In this experiment silicon wafers are used as a work piece.

As discussed in the above literature survey the work piece used were not real life products. However, in the present work efforts have been made to reduce the downtime of repairing of taper roller bearing (considering no major pin holes). Taper roller bearing assembly is one of the most critical components which fitted in the root of the propeller of the aircraft (AVRO). All the surfaces are complex in nature and are different from one another. The hardness of the bearing surfaces was measured as 63 HRC.

II. Experimental Set–Up

The schematic of experimental setup with vibrational attachment is shown in Fig.1. The major components of setup are radial drilling machine, tool holder, taper tool, work piece fixture, oscilloscope.

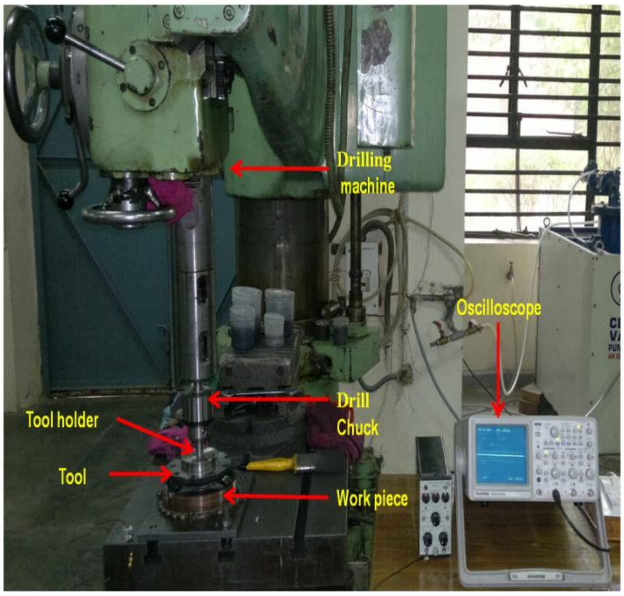


Fig. 1. Experimental set-up (With vibrational attachment).

A. Magnetic Abrasive Powder (MAP)

The composition and properties of Magnetic abrasive powder (MAP) used for finishing is shown in Table I.

TABLE I: Composition and Properties of MAP Constituents

Magnetic abrasives (Loosely bonded)	Vol. %	Density (g/cm^3)
Ferromagnetic powder (Fe)	30%	7.80
Diamond	20%	3.53
Boron carbide (B_4C)	20%	2.52
Glycerin	20%	1.26
De-Ionized water	10%	1.00

The mixture is made homogeneous by mixing with a rotating blade attached to a motor. All the solid powders (diamond, Fe and boron carbide) were mixed first and then the liquids (glycerin and de-ionized water) to avoid the formation of lump. The quantity of the each ingredient is calculated on the basis of volume required in formation of FMAB and the gap between work surface and FMAB.

B. Tools

Two types of tools are investigated in the present experiments, one with nine magnets and other with eighteen magnets. These permanent disc magnets (Nd-Fe-B) of size 12X 6 X 6 mm were inserted with the help of epoxy adhesives in the tool made of aluminum. Comparisons of two different magnetic strength magnets (0.35 tesla and 0.50 tesla) were studied and the results are formulated in the design of experiments with full factorial design.

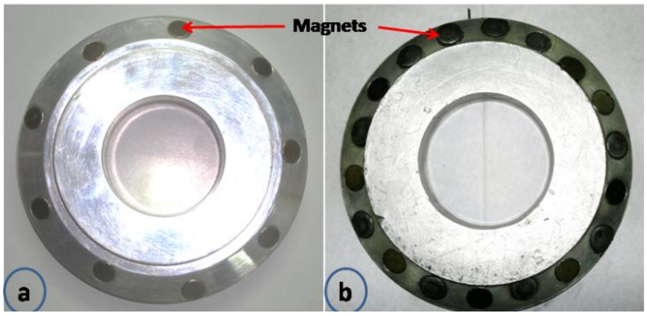


Fig. 2. Arrangement of magnets in the taper tool
(a) Tool with nine magnets (b) Tool with 18 magnets.

C. Selection of Abrasives

Various experiments are conducted to select the appropriate abrasive for reducing cycle time of repairing of bearing assembly. The process parameters adopted during the experiments are summarized in Table II.

TABLE II: Process parameters during selection of abrasives

Sl.no.	Parameter	Value
1	Fe powder	65% (by vol.)
2	Abrasive	15% (by vol.)
3	Glycerin	10% (by vol.)
4	De-ionized water	10% (by vol.)
5	Working gap	1.5 mm
6	Time of finishing	60 min
7	Magnets used in tool	Nine magnets (0.35 tesla)

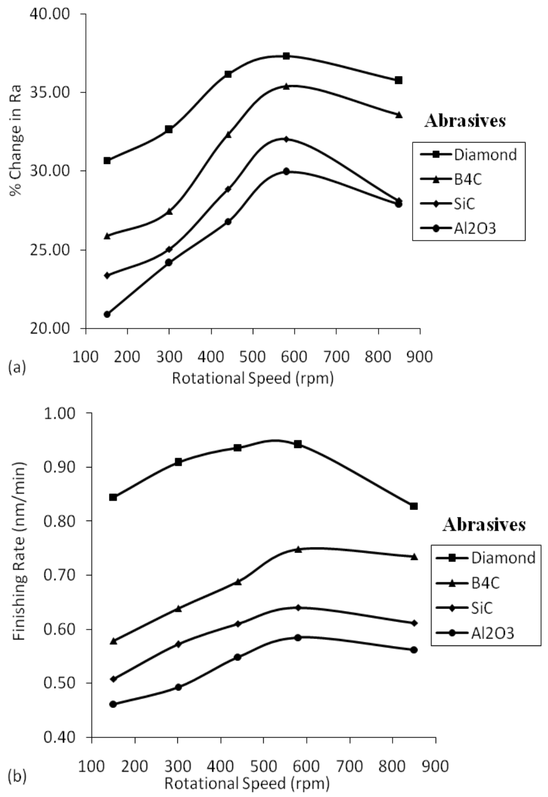


Fig. 3. Selection of abrasive on the basis of (a) % Change in Ra and (b) Finishing rate.

From Fig.3 it is evident that % change in Ra and finishing rate are maximum for diamond abrasives followed by Boron carbide (B_4C), Silicon carbide (SiC) and Alumina (Al_2O_3). The responses have maxima at rotational speed of 580 rpm. The selection of diamond abrasive is based on the above results.

D. *Process Parameters*

The process parameters which kept constant during the study of % change in Ra and finishing rate are shown in Table III. These values are evaluated with earlier results obtained using response surface methodology with a tool having nine magnets of strength 0.35 tesla, and without diamond abrasive. The main aim of the present experiments was exploring the methods of improvement in the earlier design of experiments to reduce the cycle time of repairing of taper roller bearing.

TABLE III: CONSTANT PROCESS PARAMETERS DURING THE EXPERIMENTS

Sl.no.	Parameter	Value
1	Boron carbide (B_4C) abrasive size	400 mesh (37.5 μm)
2	Diamond abrasive size	5000 mesh (2-4 μm)
3	Ferromagnetic particles size	300 mesh (50 μm)
4	Working gap	1.5 mm
5	Rotational speed	580 rpm

III. EXPERIMENTAL PROCEDURE

A. *Full Factorial Design*

In the present study the experiments are factor based thus a two level full factorial design is adopted [7]. Three independent factors (Strength of magnets, No. of magnets, and vol. % of diamond abrasive) are chosen to study their effect on % change in Ra and finishing rate. The factors and their levels are summarized in Table IV.

TABLE IV: LEVELS OF THE PROCESS PARAMETERS

Factor	Low level (-)	High level (+)
(A) Strength of magnets (Tesla)	0.35	0.50
(B) No. of magnets	9	18
(C) Vol. % of diamond	10	20

This is a two-level, three factor design, called a 2^3 factorial design, which produces 8 runs. It includes all seven of the effects which can evaluate (in addition to the overall mean) with the eight runs (three main effects (MEs), three 2-factor interactions (2FI) and one 3-factor interaction (3FI)). Eight experiments (Table V) have been conducted based on the factorial design. Table V gives summary of the responses (% change in Ra and finishing rate) obtained under different finishing conditions.% change in Ra is calculated as (Δ Ra/ initial Ra) * 100, where Δ Ra = initial Ra – final Ra. Here, Ra is center line average surface roughness measured in μm. Finishing rate is calculated as (Δ Ra/ finishing time in min)*1000. It is expressed in nm/min.

TABLE V: EXPERIMENTAL DESIGN WITH FULL FACTORIAL (2^3)

Std. Order	Variables			Response			
	(A)	(B)	(C)	Initial R_a (nm)	Final R_a (nm)	% change in R_a	Finishing Rate (nm/min)
1	0.35	9	10	653.7	86.8	86.71	12.60
2	0.50	9	10	361.0	47.3	86.90	13.07
3	0.35	18	10	637.9	76.5	88.00	14.04
4	0.50	18	10	551.3	59.0	89.30	15.38
5	0.35	9	20	637.2	81.8	87.23	13.22
6	0.50	9	20	590.9	64.6	89.08	15.04
7	0.35	18	20	585.1	69.7	88.09	14.32
8	0.50	18	20	500.1	46.5	90.71	18.14

B. *Analysis of Variance (ANOVA)*

The experimental results (Table V) were analyzed using Design Expert software and the analysis of variance (ANOVA) for % change in Ra and finishing rate are presented in Table VI and Table VII respectively. The model p - value ('Prob> F') is 0.0365 for % change in Ra and 0.021 for finishing rate both being less than 0.05 (significance level, α for 95 % confidence interval) implies that models are significant. It has been observed that no. of magnets have the major impact followed by strength of magnets and vol. % of diamond on % change in Ra and finishing rate.

TABLE VI: ANOVA FOR% CHANGE IN Ra

Source	F Value	p-value Prob> F	Percent Contribution
Model	26.68	0.0365	Significant
A	45.67	0.0212	34.20
B	*49.10*	*0.0198*	*36.80*
C	22.68	0.0414	17.00
AB	4.54	0.1667	3.40
AC	11.42	0.0775	8.60

TABLE VII: ANOVA FOR FINISHING RATE

Source	F Value	p-value Prob> F	Percent Contribution
Model	46.86	0.021	Significant
A	75.03	0.0131	32.02
B	*85.44*	*0.0115*	*36.47*
C	42.85	0.0226	18.29
AB	11.14	0.0793	4.75
AC	19.83	0.0469	8.46

C. Effect of Vibration

During the experiments, it is observed that the rotary motion of the tool is generating the marks on the work piece surface which is not desirable. To overcome this, some experiments were conducted on the cone surfaces by imparting vibration to the work piece surface. The amount of vibration is measured with the help of sensors and oscilloscope. The amplitude of vibration is measured in all the three axes.

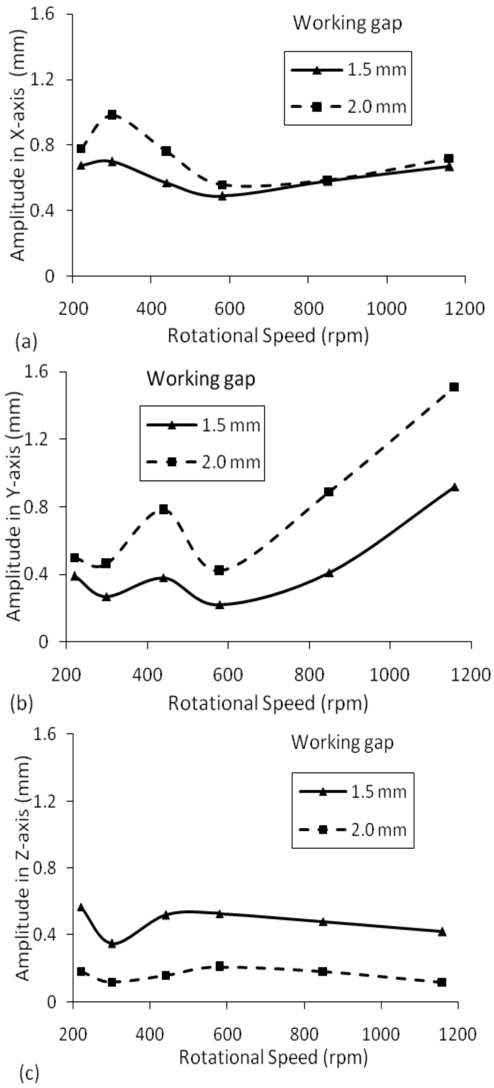


Fig. 4. Plot between rotational speed and amplitude of vibration in (a) X-axis (b) Y-axis and (c) Z-axis at varying working gap.

The plot between the amplitude of vibration and rotational speed at varying working gap is shown in Fig.4. It is found that X-axis and Y- axis vibration is more effective (at low rotational speed and high working gap) up to certain maxima and finally it increases rapidly as the rotational speed increases. The vertical Z-axis (Fig.4(c)) vibration is more effective at low working gap which continues to be maximum at the optimum condition. By setting these vibration conditions the experiments were conducted to study the effects of vibration on % change in surface roughness and finishing rate.

TABLE VIII: CONSTANT PARAMETERS DURING INVESTIGATION OF EFFECT OF VIBRATION ON MAF

Parameter	value
Working gap	1.5 mm
Finishing time	15 min
Abrasive	B_4C (Boron Carbide)
vol. % of abrasive	0.15
vol. % of iron powder	0.65
vol. % of de-ionized water	0.1
vol. % of glycerin	0.1

From Fig.5 it is clear that initially % change in surface finish and finishing rate are increased (towards maxima) up to a certain rotational speed and afterwards decreases. It is due to the fact that at higher speeds, however the vibration is more but the magnetic flux density, which holds the magnetic abrasive powder decreases which results in poor surface finish and finishing rate. The circular marks generated by rotation of tool are marginally removed by imparting the vibration to the work piece. The parameters which were constant during the experiments are tabulated in Table VIII and the data used to plot these graphs is shown in Table IX. It was found that % change in Ra and finishing rate both increased at rotational speed of 580 rpm and at 0.53 mm axial vibration. The above vibration is not controlled and is originated by loosening the bolts which hold the cone surface to the work piece fixture.

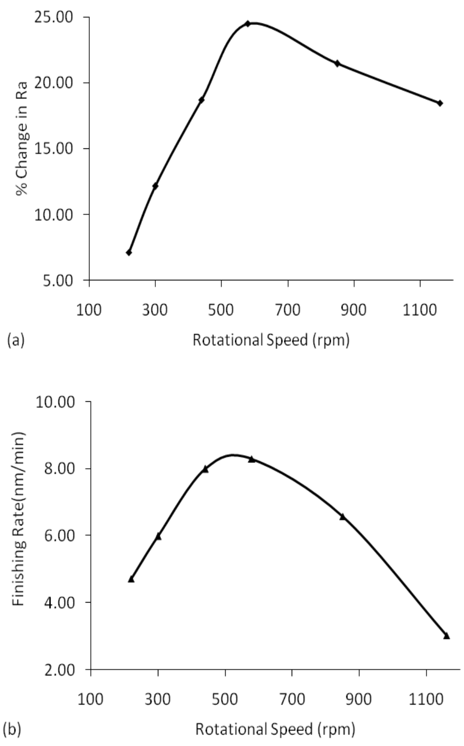


Fig. 5. Effect of vibration on (a) % Change in Ra (b) finishing rate at different rotational speeds

TABLE IX: EFFECT OF VIBRATION ON % CHANGE IN RA AND FINISHING RATE

Sl. no.	Rotational speed (RPM)	Amplitude (mm)	Frequency (Hz)	Initial Ra (nm)	Final Ra (nm)	% Change in Ra	Finishing Rate (nm/min)
1	220	0.68	3.73	990.1	919.3	7.15	4.72
2	300	0.70	5.00	740.1	650.2	12.15	5.99
3	440	0.57	7.24	640.7	520.8	18.71	7.99
4	*580*	*0.49*	*9.43*	*508.5*	*384.0*	*24.48*	*8.30*
5	850	0.58	13.8	460.8	362.0	21.44	6.59
6	1160	0.67	19.2	246.7	201.2	18.44	3.03

IV. RESULTS AND DISCUSSION

The effects of various ingredients on the % change in Ra and finishing rate are studied and modeled using the response surface methodology. Using these model equations, the parametric analysis has been carried out and the results are discussed as follows.

A. Regression Equations

The regression equations for % change in Ra and finishing rate are as below.

$$\% \text{ Change in Ra} = 90.47 - 14.37A - 0.12B - 0.32C + 0.67AB + 0.99AC \quad (R^2 = 0.9852) \tag{1}$$

$$\text{Finishing Rate} = 18.34 - 21.08A - 0.23B - 0.40C + 1.06AB + 1.27AC \quad (R^2 = 0.9915) \tag{2}$$

The value of R^2 in both the cases is above 98% and shows significant correlation. Therefore, the equations (1) and (2) may be considered as predictive model of % change in Ra and finishing rate for MAF process.

B. Effect of Interactions on % Change in Ra

The effect of interactions among the factors such as strength of magnets, no. of magnets, and vol. % of diamond on % change in surface finish was analyzed. Fig.6 (a) shows the effect of simultaneous variation of Strength of magnets (A) and No. of magnets (B) on % change in Ra. At low level of strength of magnets as no. of magnets increases the % change in Ra increases also at high level of strength of magnets the % change in Ra improves better. The same results are shown in Fig.6 (b) for simultaneous variation of Strength of magnets (A) and vol. % of diamond (C). Increased no. of magnets and strength of magnets enhanced the holding capacity and quantity of FMAB and more no. of abrasives particles are available to remove the material thus improves the surface finish.

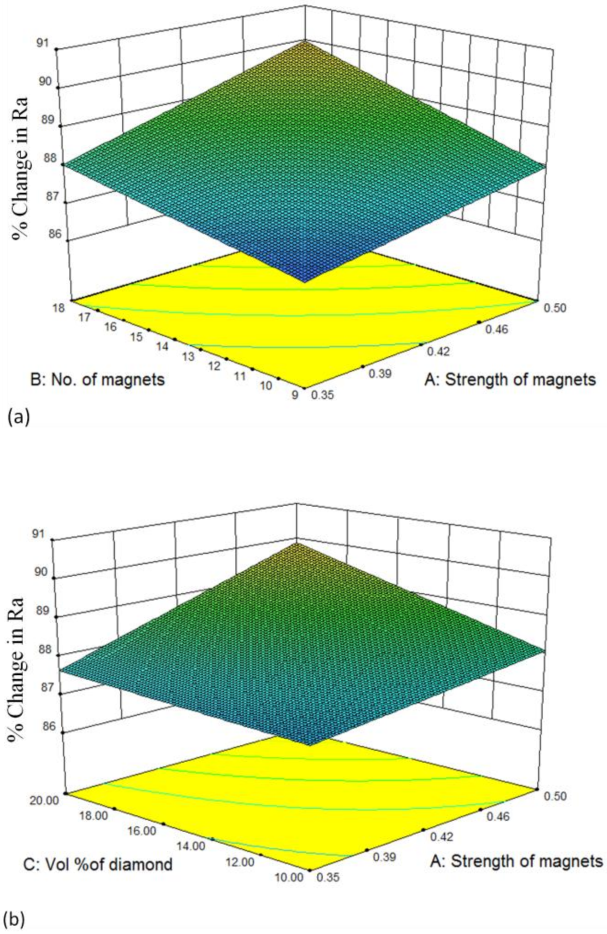


Fig. 6. Effect of interaction between (a) Strength of magnets (A) & No. of magnets (B) and (b) Strength of magnets (A) & vol. % of diamond (C) on % Change in Ra

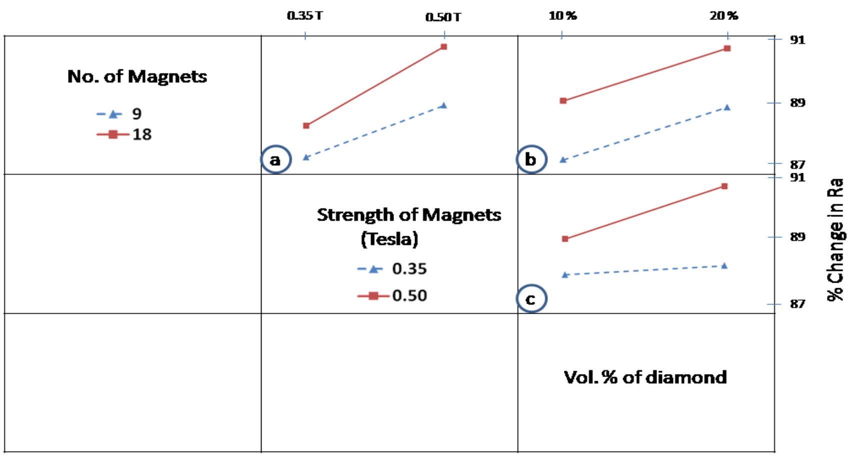
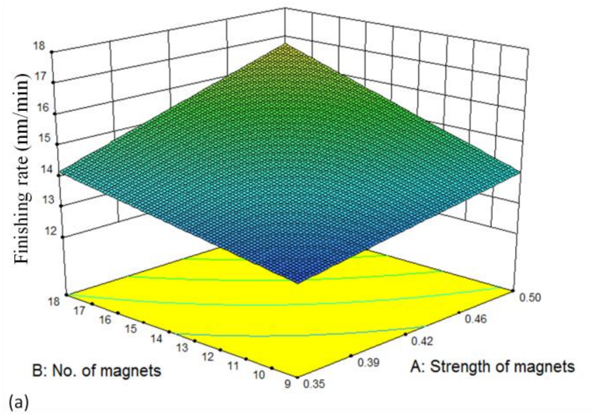


Fig. 7. Two level main effects and their interactions on % Change in Ra.

The two-level effects and interaction of each two factors on % change in Ra are shown in Fig.7. It is clear from Fig.7 (a) and (b) that % change in Ra is more using eighteen magnets as compare to nine magnets for increased strength of magnets and increased vol. % of diamond powder. Fig.7 (c) revealed that as the vol. % of diamond powder increase % change in Ra increases for high strength of magnets.

C. Effect of Interactions on Finishing Rate

The effect of interactions among the factors strength of magnets (A), no. of magnets (B), and vol. % of diamond (C) on finishing rate was analyzed. Fig. 8(a) shows the effect of simultaneous variation of Strength of magnets (A) and No. of magnets (B) on finishing rate. At low level of strength of magnets as no. of magnets increases the finishing rate increases also at high level of strength of magnets the finishing rate improves better. The same results are shown in Fig. 8(b) for simultaneous variation of Strength of magnets (A) and vol. % of diamond (C). Finishing rate increased by adding more vol. % of diamond abrasives. However after a certain limit the addition of diamond abrasives will not add any value addition to the process since at higher rpm the diamond particles will spilled out due to poor hold ability of FMAB.



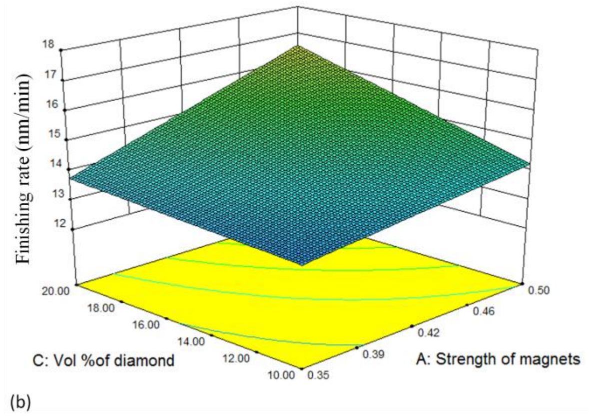


Fig. 8. Effect of interaction between (a) Strength of magnets (A) & No. of magnets (B) and (b) Strength of magnets (A) & Vol. % of diamond (C) on finishing rate

The two-level effects and interaction of each two factors on finishing rate are shown in Fig.9. It is observed from Fig.9 (a) and (b) that finishing rate is more using eighteen magnets as compare to nine magnets for increased strength of magnets and increased vol. % of diamond powder. Fig.9 (c) revealed that as the vol. % of diamond powder increase finishing rate increases for high strength of magnets.

D. Surface Roughness Profile

Fig. 10 shows the surface roughness profiles of initial and final surface obtained by MAF process for the same work piece and at the same location. The best surface finish achieved after finishing by MAF process is 36.5 nm within 24 min. The surface roughness (Ra) is measured in Surf test machine at nine places of the work piece surface with the help of deep groove stylus. Special rotatory vice is used to hold the work piece surface since the surface of the work piece is taper. The measurement is taken before and after finishing at the same points.

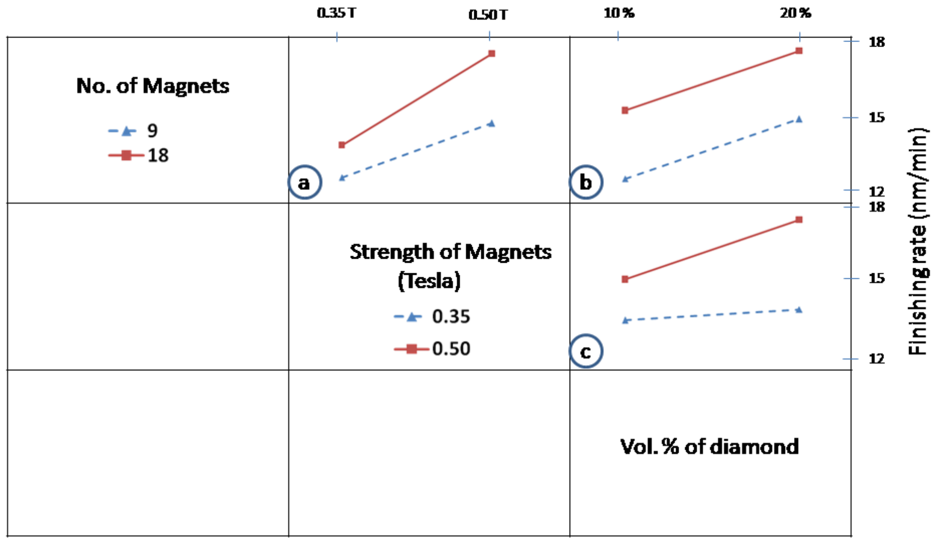


Fig. 9. Two level main effects and their interactions on finishing rate

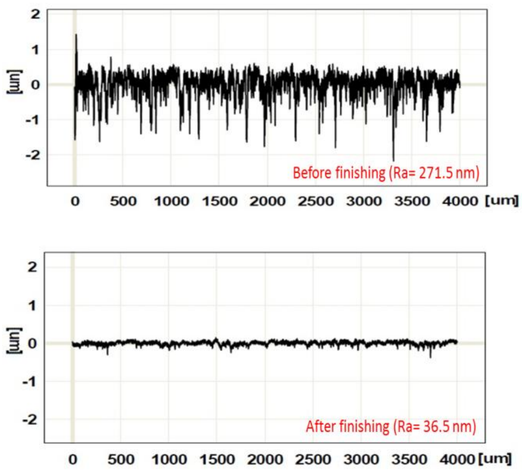


Fig. 10. Surface profiles before and after finishing

V. Conclusion

Based on the experimental data the following conclusions are made:

- The present experimental work has been focused on reducing the cycle time of finishing of taper roller bearing. Earlier the finishing time is observed as 6-20 hrs. depending on the level of damage of the bearing surface. By implementing the methods and processes described in this paper the authors were able to achieve the finishing as low as (Ra=) 36.5 nm from initial (Ra=) 271.5nm without any surface damage within 24 min.
- Mixing of diamond abrasives in a particular amount to the MAP enhanced the finishing rate as well as surface finish.
- The impact of vibration in all the three directions was observed and it was found that introducing a small amount of vibration in the axial (vertical) direction can reduce the occurrence of circular marks.
- By increasing the no. of permanent magnets the finishing rate increases as more no. of magnets are available to hold the MAP.
- As the strength of magnets increases the finishing rate and surface finish increases.

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References

[1] V. K. Jain, "Magnetic field assisted abrasive based micro/nano-finishing," *Journal of Materials Processing Technology*, vol. 209, Issue 20, pp. 6022-6038, Nov. 2009.

[2] T. Shinmura, K. Takazawa, E. Hatano, M. Matsunaga, "Study on magnetic abrasive finishing ," *Annals of CIRP*, vol. 39, Issue 1 , pp. 325-328, Jan. 1990.

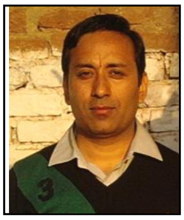
[3] L. E. Samuels, B. Wallace, "Effects of type and size of Diamond abrasives on Material removal rates in Metallographic Polishing ," *Metallography*, vol. 17, Issue 1, pp. 19-41, Feb. 1984.

[4] H. Yamaguchi, T. Shinmura, "Internal finishing process for alumina ceramic components by a magnetic field assisted finishing process ," *Precision Engineering*, vol. 28, Issue 2 , pp. 135-142, April 2004.

[5] R. S. Mulik and P. M. Pandey, "Magnetic abrasive finishing of hardened AISI 52100 steel," *IJAMT*, vol. 55, no. 5-8, pp. 501-515, 2011.

[6] J. E. Fernandez, M. D. R. Fernandez, R. V. Diaz, and R. T. G. Navarroette, "Abrasive wear analysis using factorial experiment design," presented at the 14th International Conference on Wear of Materials, vol. 255, Issue 1-6, pp. 38-43, Aug. - Sept. 2003.

[7] D. C. Montgomery, *Design and analysis of experiments*, 5th ed. New York, U.S.A.: Wiley, 2001.



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Vijay K. Jain passed his B. E. (Mechanical) from Vikram University Ujjain in 1970, and M. E. (Production) from University of Roorkee in the year 1973. He did his Ph.D. from University of Roorkee in Mechanical Engineering in the year 1980. Dr. Jain has more than 38 years of teaching and research experience. He has served as a Visiting Professor at the University of Nebraska at Lincoln (USA) and University of California at Berkeley (USA).Presently he is a Professor at Indian Institute of Technology Kanpur (India). He has also served as a faculty at other Indian institutions, namely, M. R. Engineering College Jaipur, B. I. T. S. Pilani, and M. N. R. Engineering College Allahabad.

He has written Five books and Eleven chapters for different books published by international publishers. He has organized Eighteen summer/ winter/short term schools on various topics such as Micromanufacturing, Micromachining (four times), Advanced Machining Techniques (three times), Precision Engineering, Computer Integrated Manufacturing Systems, Design of Machine Tools, N. C. Machine Tools (two times), Advanced Manufacturing Technology, Tools and Die making, and Contact Program for undergraduate graduate students. He has edited the proceedings of these schools also. He has Seven Indian patents and One USA patent to his credit. Dr. Jain has brought six consultancy projects from private and public undertakings. Dr. Jain has guided Eleven Ph.D. theses and Five are under progress, Eighty One M.Tech. theses, 9 M.E. Projects and more than Thirty B.Tech./B.E. Projects while working at different universities during his carrier. Dr. Jain has around 270+ publications to his credit. He has published about 169 research papers in referred Journals, 97 in conference proceedings, 11 in popular magazines. He has delivered more than twenty six keynote lectures in different conferences / workshops / Universities.

Prof. Jain has won three gold medals two silver medals and one best paper award as recognition to his research work. The Institution of Engineers (India), Khosla Research Awards committee and All India Manufacturing Technology Design and Research conference organizing committee have given this honor to him. Dr. V. K. Jain has been appointed as a Full Editor of Two international journals and Associate Editor of three International Journals. He has also worked as a Guest-Editor for the six special issues of different International Journals and six more are under preparation. He has been opted as a member of the editorial board of twelve International Journals. He has Seven Indian patents and One USA patent to his credit. Dr. Jain has been opted as Vice-President of the National Advisory Committee of AIMTDR, India. He has served / is serving as a member of national committees like R & D Lab. accreditation committee (DST), Program Advisory committee (DST, PAC-(R & M)), Management Advisory Committee (DST, MAC), National Advisory Committee for Precision Engineering, and National Advisor Committee of AIMTDR. Dr. Jain's name has been appearing in World's Whose Who (WWW), American Biographical Institute (ABI), and Asia Pacific Biography consecutively for many years.