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Effect of Various Parameters on Finishing of Inner Surfaces of Brass Tubes Using Magnetic Abrasive by RSM: A Study

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***Abstract* - With the increase of technology and the demand of industry the surface finish requirements are also increasing. Conventional technologies like grinding and lapping etc. fail to finish some pieces such as pipes, complex shape tubes consisting of straight and bent sections up to desired accuracy. Magnetic Abrasive Finishing (MAF) is one of the advanced finishing methods, proposed to produce highly finished surfaces of brass340 pipes. In this research work the process, finishing characteristics and the principle of magnetic abrasive finishing of pipes using sintered magnetic abrasives are described. The sintered based of Al2O3 magnetic abrasives with iron particle of size 106 µm were used in this work. The Statistically designed experiments based on Taguchi methods show that weight of abrasive, Revolutions per minute (rpm), finishing time and type of lubricant which have significant effect on the surface roughness obtained. The effects of lubricants on surface finish are also analyzed in this work by using different types of lubricants. It is noticed that the surface finish was affected by the change of type of lubricant and the internal surface finish of pipes were analyzed in terms of percent improvement in surface finish (PISF) and using Response Surface Methodology (RSM). The obtained maximum PISF was 60% by using toothpaste as a lubricant and minimum surface roughness was 0.126 µm Ra. The improvement in surface finish was further validated using R-Ray Diffraction (XRD) technique.**
***Keywords:* Magnetic Abrasive Finishing, Sintered Magnetic Abrasives, Surface Roughness, Lubricant, RSM.**

I. INTRODUCTION

Advanced technology of industries requires very ultraclean and smooth finished surfaces for their complex and critical applications. In modern time, finished surfaces are in very high demand with the development of manufacturing technology, in a wide range of industrial applications such as vacuum tubes, Liquid piping systems, high purity gas tubes, sanitary tubes and Pharmaceutical industries require finished Inner surface to prevent and minimization of the Contamination of gas and liquid in the pipes or tubes. A new finishing process called Magnetic Abrasive finishing has been developed for above types of application areas where a precise control of surface finish and various characteristics are required. Magnetic abrasive finishing is a non-conventional machining process which came to the surface in 1938 in a patent by Harry P. Coats. The MAF process related to surface and edge finishing by means of magnetic abrasive brush formed in a magnetic field. The MAF having various advantages such as; it can be applied to create efficiently good surface quality of the order of few nanometer finishes on internal and external surfaces of long pipes or tubes and also for flat surfaces, which may be difficult to be finished by other traditional finishing methods. Also this method can be used for non-ferromagnetic materials such as stainless steel and brass [1, 2]. In addition of MAF possesses many attractive advantages such as self-adaptability, self-Sharpening, controllability, and the finishing tool require neither compensation nor dressing. Harish kumar et.al [3] presents a work on magnetic abrasive finishing; they describe the various results obtained by various research scholars based on their experiences and experimentations in MAF field. MAF is successfully used for finishing of internal as well as external and complicated design of pipes and flat surfaces. In magnetic abrasive finishing process the magnetic force is affected by the composition of magnetic abrasives, material of the job, shape and size of work, gap between pole and work, shape and size of magnetic pole etc. H. Yamaguchi et.al [4] in his research examines the applicability of magnetic abrasive finishing to the internal finishing of large–sized bent tubes produced by high frequency induction bending.

A. Magnetic Abrasive Finishing

In MAF process the material is removed in such a way that surface finishing and deburring are performed simultaneously due to magnetic field produced in the finishing zone. The controlled magnetic force is used to finish surface in this method. In this process, a cutting tool that consists of abrasives and iron particles is flexible in nature as shown in Fig. 1. The gentle/flexible finishing conditions and low level of controlled force are required to minimize the surface damage.

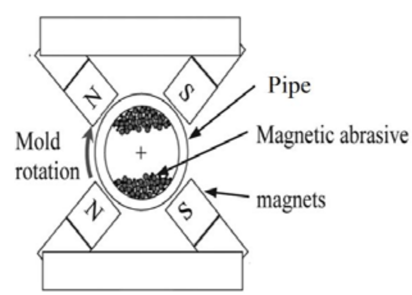

Fig.1 Schematic diagram of magnetic abrasive finishing

B. Response Surface Methodology (RSM)

Response surface methodology (RSM) is a collection of statistical and mathematical techniques for empirical model building. During series of tests, called runs, in which changes are made in the input control variables in order to identify the reasons for changes in the output response. This method was introduced by G.E.P. Box and K.B. Wilson in 1951. The basic approach of RSM is an easy way to estimate the first degree of polynomial model is to use a factorial experiment. This is sufficient to find which input variables have an impact on the response variable(s) of interest. The application of RSM to design optimization is aimed at reducing the cost of expensive analysis methods (e.g. finite element method or CFD analysis) and their associated numerical noise. In this research work the RSM technique is used for analysis of independent parameter on the PISF and plotting the 3D-Graph of the results. Also it is used for analysis the interaction between the input variable and effect on PISF. For design of experiments the Taguchi method was used in this research work.

II. PRINCIPLES OF INTERNAL FINISHING

In MAF process the mixture of magnetic abrasives and iron particles introduced into the pipe at the finishing zone by a magnetic field force, the magnetic field generates finishing force against the inner surface of the tube. The combination of iron particles and abrasives join each other along the lines of magnetic force due to dipole–dipole interaction and form a Flexible Magnetic Abrasive Brush (FMAB) which pushes against the internal surface of work piece and develops required finishing pressure. This pressure originates micro indentations in the work piece surface.

In MAF, the FMAB generates two types of forces which are responsible for removing material from surface:

a. Normal magnetic force responsible for packing the magnetic abrasive particles and providing micro indentations into the work piece.
b. Tangential cutting force responsible for micro chipping due to rotation of the FMAB.

III. EXPERIMENTAL SETUP

The MAF experimental set up is shown in Fig. 2.The major components of experimental setup are lathe machine, electromagnet, variac for variable A.C. supply and abrasive powder (Sintered Al2O3 + Fe). The cylindrical work piece i.e. brass pipe was held in the chuck attached to lathe machine and abrasives were packed in the pipe. With the help of electro magnet the magnetic field was generate. The variable A.C. supply used to increase or decrease the magnetic field strength during experimentation. The space between electromagnet and work piece is kept constant. The magnetic field strength also depends upon percentage of weight of the magnetic particles present in the magnetic abrasive powder. The size of the work piece is also taken into consideration while designing the experiments. The main objective of the experimental design is to remove the material from the inner surface of pipe with the rotational motion to the cylindrical work piece and kept stationary FMAB. The rotational motion to the work piece is provided by lathe machine and magnetic abrasive particles kept stationary through the magnetic flux density inside the work piece. In this work Al_2O_3 based sintered magnetic abrasives were used as magnetic abrasives.

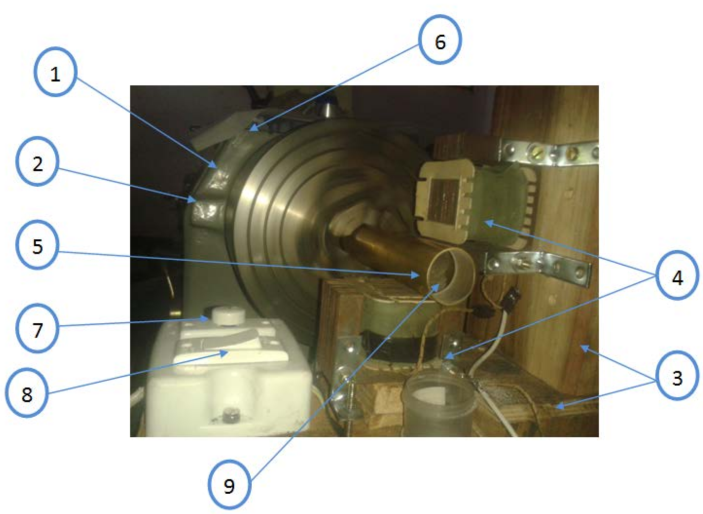

Fig.2 MAF experimental set up (1) Lathe machine, (2) 4–Jaw chuck, (3) Base of Electromagnets (4) Electromagnets (5)Work piece (6)Gear Box (7) Variac (8) On/Off switch (9) Magnetic Abrasive Brush

A. Why Lathe Machine is used

In this research, the horizontal lathe machine is used to perform the experiments. The MAF setup was mounted on the cross slide of the lathe machine. Replacement of tool post with MAF set up as shown in Fig. 3. For surface finishing of work piece the four different types of speeds used 250 rpm, 400rpm, 550 rpm and 700rpm. To run the experiment on particular speed, simply change the gear of lathe machine.

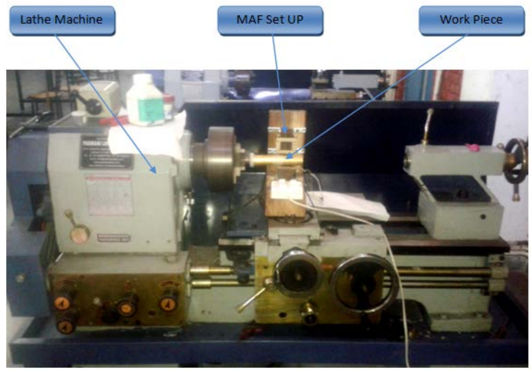

Fig.3 MAF set up mounted on Lathe machine

a) Lathe machine has a rigid and heavy bed, which help to reduce the vibrations. These vibrations affect the Magnetic Flux Density which results poor surface finish.
b) Internal finishing of long pipes can be done with help of lathe machine.
c) MAF is mounted on cross slide which is very easy to adjust for different diameters of pipes.

IV. RESEARCH METHODOLOGY

According to the identified research gap certain set of objectives were set up. These objectives are accomplished with the help of the mentioned research methodology. The objectives of this research are as follows:

I. To study the effect of various input parameters on the surface finishing of brass tubes.
II. To find out the optimum parameters for internal finishing of brass pipe by using Taguchi method
III. To study the Influence of lubricant type on Percent Improvement in Surface Finish (PISF)

Al_2O_3 based sintered magnetic abrasives were used to finishing of inner surfaces of cylindrical brass pipes. The magnetic abrasives were prepared by mechanical mixture technique. In this technique Al_2O_3 and iron powder of 140 mesh size (106 μm) were used. The mixture of Al_2O_3 was prepared which was 20% weight of total mixture and iron powder which was 80% weight of total mixture with mechanical mixing method. In this method both powders are mixed with each other manually for 5-10 minutes. Duration of mixing depends upon the quantity of powders. It is noticed that during literature review [5] for better bonding between Al_2O_3 and iron powder generally light machining oil lubricant 5% - 7% of total weight was using in the mechanical mixture. But in this research work the four different types of lubricants were used for improving bonding strength between two powders.

A. Select Input Variables and Levels

In this research work three input control parameters RPM of work piece, quantity of abrasives and machining time was taken on the basis of previous research [6], because these are the major parameters which affect the results. But the fourth controlled input parameter which was taken in this research work is 'Lubricant type'. For this experimental work the various input variables and their ranges are shown in Table 1. Other experimental conditions are shown in Table 2.

Lubricant is the new parameter which was used during experimentation and in this research work lubricant is not used to reduce the friction it is only used as a binding agent for making the bond between Al_2O_3 and iron particles. It is first time that comparison of results of internal finishing of brass pipes is done on the basis of using different types of lubricants in this field. The quantity of lubricant is 5% of total weight of magnetic abrasive mixture was used. This quantity has been decided on the basis of pre experimentation. It is noticed that during experimentation when the quantity of lubricant 15% of total mixture weight was used the abrasive and iron particles were sticking with the inner surface of pipe and they were rotating with the pipe. Due to large amount of lubrication the FMAB was not generated. After performing the pre experimentation with change of amount of lubricant it was found that the weight of lubricant 5% is appropriate for 30 mm diameter of brass pipe for abrasive finishing. The detail chart of quantity of Al_2O_3, iron powder and lubricant was used in this work as shown in Table 3.

B. *Design of Experiments*

After deciding all the parameter and grit size of the iron particles for this work the Minitab-16 is used for design of experiments to reduce the number of experiments to a practical level, only a small set from all the possibilities is selected. The method of selecting a limited number of experiments which produces the most information is known as a partial fraction experiment. In this tab Taguchi technique is used to reduce the number of experiments. For this work four input control variables with four different levels were used. If the experiments were conducted by selecting the process parameters based on the findings of trial runs then the possible combination of 4 X 4 matrixes is 256 experiments would be required to perform. Taguchi method was used to design the experiment with L16() orthogonal array (16 tests, 4 variables, 4 levels), which leads to reduce the high required number of experiments to 16 effective experiments as shown in Table 4. After obtaining 16 best runs of experiment the work was performed according to the parameter levels that had been decided earlier stages on the research. The surface roughness was measuring to analyzed the finishing characteristics of magnetic abrasives, which was measured at four different points before and after finishing using a Mitutoyo surface roughness tester (SJ- 201) (cut off length = 0.8 mm). The average surface roughness Ra value 0.321 µm was obtained before finishing. During the experiments the duration of machining was controlled with the help of stop watch.

TABLE I INPUT CONTROL VARIABLES

Factors					
Levels	**S.NO.**	**Rotational Speed (RPM)**	**Lubricant Type**	**Quantity of Magnetic Abrasives (gm)**	**Machining Time (min)**
	1	250	Water	4	30
	2	400	Hydrogen Peroxide	6	40
	3	550	Tooth Paste	8	50
	4	700	Engine oil	10	60

TABLE II OTHER EXPERIMENTAL CONDITIONS

Experimental Conditions (constant)		
S.No.	**Parameter**	**Specification**
1	Work Material	Brass 340
2	Iron Particle Size	106 µm
3	Work piece - Electromagnets Gap	1 mm
4	MFD	1.2 T

The four more experiments were also performed to analyze the effect of type of lubricant on the surface roughness of brass pipe. The input control variables and the values of each level are shown in Table 5. In these four experiments rpm of work piece, quantity of abrasives and machining time were kept constant but the lubricant was changed. The constant values of all input parameters were decided on the basis of pre experimentation. The surface finish was analyzed using Response Surface Methodology (RSM). Therefore finishing characteristics in terms of PISF (Percentage Improvement in Surface Finish) were analyzed. Calculated the PISF on the basis of below formula:

PISF = (Initial Surface Roughness – Final Surface Roughness)/ Initial Surface Roughness X 100

TABLE III WEIGHT CHART OF MAGNETIC ABRASIVES WITH LUBRICANT

S.No.	Total mixture weight (gm)	Al_2O_3 20% of total weight (gm)	Iron Powder 80% of total weight (gm)	Lubricant 5 % of total weight (gm)
1	4.0	0.8	3.2	0.2
2	6.0	1.2	4.8	0.3
3	8.0	1.6	6.4	0.4
4	10	2.0	8.0	0.5

TABLE IV BEST-16 NUMBER OF RUNS

Run Order	Independent Parameters			
	Speed (rpm)	**Lubricant (5% of total wt.)**	**Quantity (gm)**	**Finishing Time (Min.)**
1	250	Water	4	30
2	250	Hydrogen peroxide	6	40
3	250	Paste	8	50
4	250	Engine oil	10	60
5	400	Water	6	50
6	400	Hydrogen peroxide	4	60
7	400	Paste	10	30
8	400	Engine oil	8	40
9	550	Water	8	60
10	550	Hydrogen peroxide	10	50
11	550	Paste	4	40
12	550	Engine oil	6	30
13	700	Water	10	40
14	700	Hydrogen peroxide	8	30
15	700	Paste	6	60
16	700	Engine oil	4	50

TABLE V INPUT PARAMETERS FOR FOUR RUNS

S.No.	Lubricant	RPM	Qty	Time
1	Engine oil	550	6	50
2	Tooth paste	550	6	50
3	Water	550	6	50
4	Hydrogen peroxide	550	6	50

V. RESULTS AND DISCUSSIONS

To establish the feasibility of usage of MAF, the experiments were conducted. Only three independent factors (speed (rpm), quantity (gm) and times (min.)) were considered in this research work for analysis of results by using RSM, because the fourth input parameter was non numeric (type of lubricants). The RSM technique is capable only for analysis the numeric input parameters. After designing 16 number of experiment by Taguchi method, the RSM was used to analyses the results. The effect of interaction between different inputs parameters on PISF were analyzed from these results. The RSM also generates the 3-D surface plots of PISF vs. Interaction of input parameters.

A. Effect of interactions between Speed & Quantity on PISF

Fig. 4 shows the effects of Speed and Quantity on PISF. As quantity of abrasives increases at lower level of speed PISF first decrease then increases up to certain extent but after 8 gm, PISF again starts decreasing. At lower level of quantity with increase in speed, PISF first decreases then starts increasing but PISF goes on decreasing with increase in speed. The PISF is better at medium level of quantity and medium level of speed.

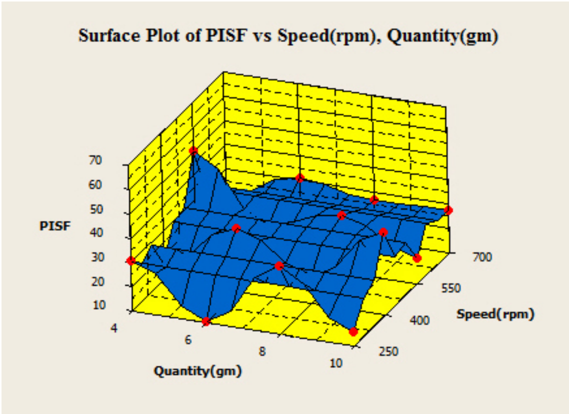

Fig. 4 Effects of Speed and Quantity on PISF

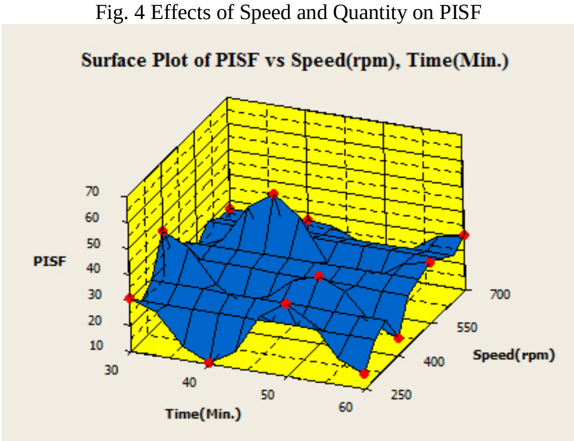

Fig. 5 Relationship between the speed & time

B. Effect of interactions between Time & speed on PISF

Fig. 5 shows the relationship between the speed & time. As the machining duration increases at lower level of speed surface finish improves but decreases at higher levels of duration. The surface finish is better at lower values of rpm, as the speed increases the surface finish decreases.

C. Effect of interactions between Time & Quantity on PISF

Fig. 6 shows the effects of machining time and quantity on PISF. As quantity of abrasives increases at higher level of machining duration PISF increases up to certain extent but after 8 gm, PISF starts decreasing. But at minimum duration of machining PISF increases with increase the quantity of abrasives.

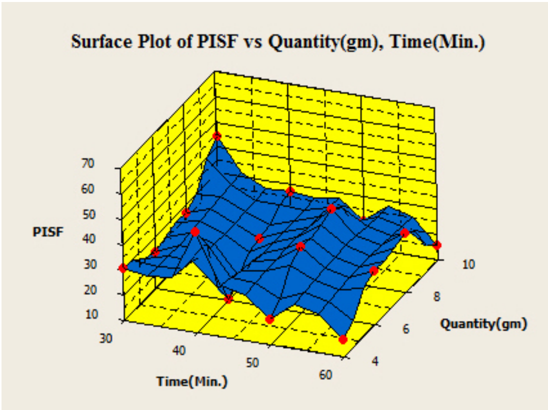

Fig.6 Effects of machining time and quantity on PISF

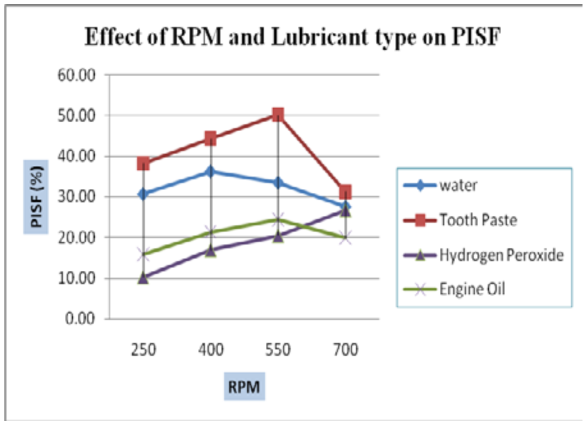

Fig. 7 Influence of RPM and Lubricant type on surface finish

D. Influence of RPM and Lubricant type

The analysis of effect of input factors on PISF with using different types of lubricants was also done. Influence of RPM and Lubricant type on surface finish shows in Fig. 7. It can be seen that the improvement in surface finish is more with the use of toothpaste on all the rpm. It was also noticed that the 50% PISF achieved with the tooth paste which was the highest value of PISF in this experimentation. The PISF values are very low with the use of engine oil and hydrogen peroxide. The improvement in surface finish can be due to more abrasives that come in contact with the work piece because the dispersion rate of toothpaste is very low and it was worked as very good bonding agent between AL_2O_3 and iron particles. It is also observed that PISF not increased with the increase of rpm, the results shows that after 550 rpm, the PISF was came down with the use lubricant water, toothpaste and engine oil.

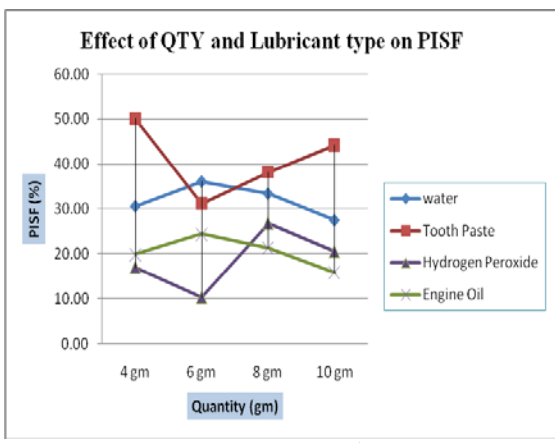

Fig. 8 Increase in quantity of magnetic

E. Influence of Quantity and Lubricant type

In Fig. 8 the result shows that the increase in quantity of magnetic abrasives reduced the improvement in surface finish this could be due to the abrasives with large quantity, the movement of the abrasives is also redirected in the machining zone. The PISF was reduced with the use 10gm quantity of abrasives with the use of lubricant type water, hydrogen peroxide and engine oil. But when 10gm quantity of abrasives was used with the toothpaste lubricant the PISF also increased.

F. Influence of machining time and Lubricant type

Result shows in Fig. 9 that, the highest values of PISF were achieved between the 40- 50 min duration of machining process. PISF decreased with the increase of machining time with all the lubricants. Surface finishing with tooth paste is again shows better results on with all the machining duration.

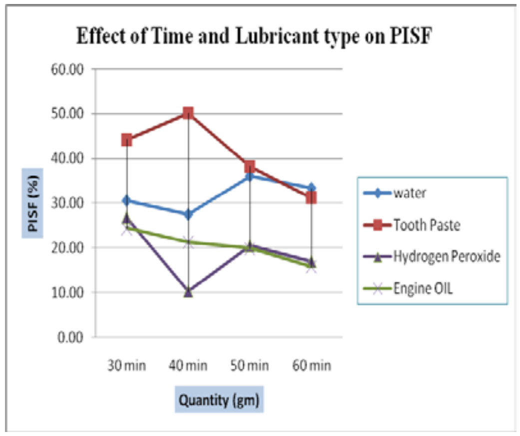

Fig. 9 Highest values of PISF

G. Influence of type of Lubricant on PISF

In this experiment except the lubricant all other input parameters were kept constant. The rpm of the work piece 550, quantity of abrasives 6 gm and machining duration 50 min were taken. All these three input parameters were chosen on the basis of results of 16 experiments. After performing the experiment the results shows that in Fig. 10 the highest values of PISF were achieved with the use of toothpaste as a lubricant. PISF decreased with the use of engine oil and hydrogen peroxide lubricants this could be due to the engine oil having good lubricant properties to reduce the friction and hydrogen peroxide is more oxidized lubricant.

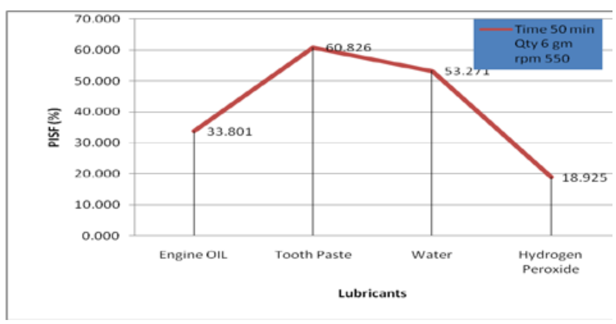

Fig. 10 Highest values of PISF

H. XRD analysis

To further study the improvement in surface finish, the surface was microscopically examined using X-Ray Diffraction (XRD). In Fig. 11 and 12 shows the XRD graphs of inner surface of a pipe before and after finishing, respectively. The magnitudes of the initial and final values are very small that's why it is not clearly visible on the graphs, but we can see the improvement in surface finishing in the peak and D-spacing list tables as shown below the graphs.

VI. CONCLUSION

The conclusions of this research work are as follows:

1. It is concluded from this research work that if all the input parameters were kept constant and only the type of lubricant is changed, then the surface finishing of brass pipe were significantly affected. In this work the comparison of results of internal finishing of brass pipes is done on the basis of using different types of lubricants (water, toothpaste, hydrogen peroxide and engine oil (20W-40 Castrol)) in the field of internal finishing of pipes with magnetic abrasives.
2. This work results shows that the minimum surface roughness Ra (0.16 µm) was achieved at 550 rpm with using toothpaste as a lubricant. It is found that the PISF increases with increase of speed up to certain extent but after 550 rpm PISF decreases with increase of speed.
3. It was observed that the highest PISF (50 %) was achieved at 4 gm of magnetic abrasive quantity. The value of PISF goes down with the increase of quantity of abrasives because at the high level of quantity of abrasives the Flexible Magnetic Abrasive Brush (FMAB) was not generated.
4. From the results, it can be noticed that the increase in machining duration reduced the improvement in surface finish with all the lubricants this could be

due to the heat up of the work piece and all lubricants lose their bonding strength so the abrasive particles Al_2O_3 was not concentrated on finishing area. The highest PISF obtained at 40 minutes of machining duration.

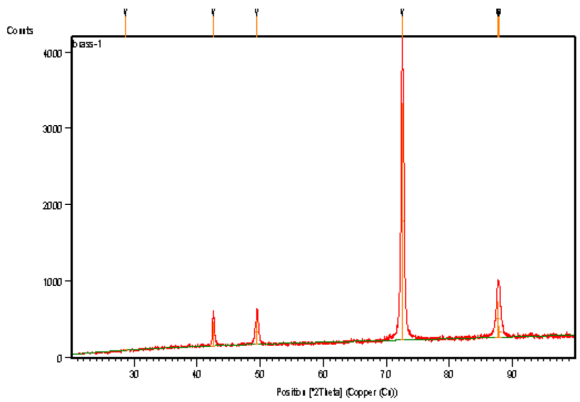

Fig. 11 (before)

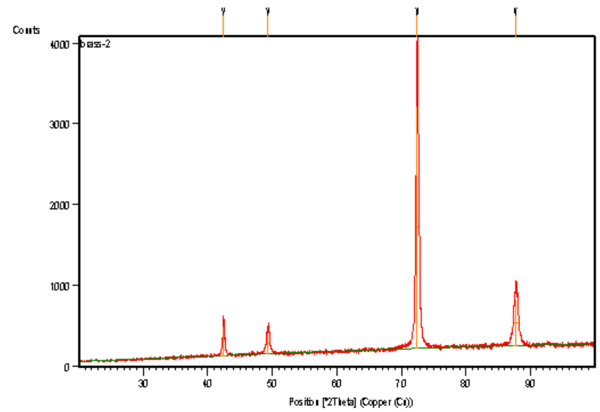

Fig. 12 (after)

Peak List

Before machining

Pos.[°2Th.]	Height [cts]	FWHMLeft[°2Th.]	d-spacing [Å]	Rel. Int. [%]
28.64(8)	6(2)	0.5(2)	3.11461	0.19
42.569(3)	321(9)	0.29(1)	2.12202	10.29
49.467(4)	316(7)	0.50(1)	1.84107	10.14
72.5129(8)	3121(29)	0.417(2)	1.30250	100.00
87.67(2)	483(94)	0.57(4)	1.11220	15.48
87.93(9)	653(70)	0.5(1)	1.10963	4.91

After machining

Pos.[°2Th.]	Height [cts]	FWHMLeft[°2Th.]	d-spacing [Å]	Rel. Int. [%]
28.64(8)	4(2)	0.5(2)	2.81461	0.19
42.433(2)	298(11)	0.26(1)	1.62852	12.24
49.326(4)	259(6)	0.47(2)	1.14599	8.63
72.4260(9)	3004(27)	0.396(3)	0.90385	100.00
87.681(3)	575(8)	0.64(1)	1.11210	19.15

VII. FUTURE SCOPE

In addition to the present work further work can be done in following directions:

1. Study can be done further for finding out the suitable composition of lubricant to find maximum improvement in surface finish.
2. The residual stress analysis of the inner surface of pipe can also do by using SEM technique.

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