4^{th} *International Conference on Mechanical Engineering, December 26-28, 2001, Dhaka, Bangladesh/pp.* V *81-85*

SEMI MAGNETIC ABRASIVE MACHINING

P. Jayakumar
Priyadarshini Engineering College, Vaniyambadi – 635751. (T. N. –India)

Abstract Magnetic field assisted polishing is an unconventional polishing method which is capable of generating fine finish on components without any sub-surface damage. This process is suitable not only for polishing external and internal surfaces also for complex shaped components. Magnetic field assisted polishing can be classified into two types. They are Magnetic Abrasive Machining (MAM) and Semi Magnetic Abrasive Machining (SMAM). In MAM, abrasives such as Aluminium Oxide (Al_2O_3) and Silicon Carbide (SiC) are conglomerated with ferromagnetic iron particles of definite ratio. This conglomerate is magnetised by external field and used as the tool for polishing pre-machined surfaces. Another approach is to have magnetic abrasive particles, specially made for this purpose. In case of semi magnetic abrasive machining, abrasive grains such as Al_2O_3 and SiC possessing certain magnetic properties are directly magnetised by external magnetic field and are used as polishing tool. These abrasive particles are coated with iron particles when they are milled and hence exhibit magnetic properties.

Keywords: Semi Magnetic Abrasive Machining

INTRODUCTION

Surface finish has a vital influence on important functional properties such as wear resistance and power losses due to friction on most of the engineering components. Poor surface finish will lead to the rupture of oil films on the peaks of the micro irregularities, which lead to a state approaching dry friction, and results in excessive wear of the contacting surfaces. Therefore fine finishing processes are employed in machining the surface of many critical machined components to obtain a very high surface finish apart form high dimensional accuracies. Such processes include grinding, lapping and super finishing among the traditional methods and elastic emission machining, Ion beam machining, mechano-chemical polishing and magnetic abrasive machining among unconventional methods. Even though these processes are in use for various applications, each process had its limitations in producing the desired surface finish on the components. Some of them are discussed in the forth coming sections.

In traditional mechanical surface finishing operation such as grinding, lapping and super finishing, a shaped solid tool grinding wheel, a lapping plate or an abrasive stone is used. These processes introduce surface defects such as cracks while finishing brittle materials. These cracks can significantly reduce the strength and reliability of the components in working. [Umehara,1994].

Although grinding is more efficient for removing material than other finishing methods, it is still difficult to achieve a mirror like finish by grinding. Though the finish can be improved with the application of grinding wheels with fine grits, they get excessively loaded with debris during the grinding process. Moreover, very frequent dressing needed to remove the loading, which causes excessive wheel loss and interruption of production. On the other hand, finishing of intricate shaped parts require expensive profile grinding wheels.

In lapping, which employs free abrasives, it is essential that the abrasive grains be fine and of uniform size. Suitable lapping pressures have to be selected to avoid micro cracks on the polished surface. Excessive pressure may cause scouring of the work piece surface.

In super finishing, the work surface is finished by means of a fine grained low grade bonded tool that is pressed against work piece under low pressure. This operation requires several controls on motions such as oscillating motion in the axial direction and feed motion in the longitudinal direction and vibratory motion to the tool for surface finishing operations. Finishing of a complex surface requires more complex system for providing these desired motions to the tool. Super finishing operation is carried out either on a special machine or with attachments. Thus, there are certain limitations to these traditional polishing methods especially when applied for complex surface finishing.

Non-traditional machining methods are used for removing very small amount of materials. There are

---

pjkumar@flashmail.co

other abrasive machining methods which can be applied for such super finishing operations such as dry-mechano chemical polishing, elastic emission machining, Ion beam machining and magnetic abrasive machining. These methods can produce the required surface finish with out many defects but these processes need highly sophisticated equipments. In Elastic emission machining needs very fine abrasives are used, which are very costly and not easily available. In the case of Ion beam machining, the processing speed is very low and the equipment is special in nature. In mechano-chemical polishing, the strength of the magnetic field required is very high. Magnetic abrasive machining is another unconventional machining process where the abrasive particles are mixed with iron powder and used. Also for non traditional processes which are capable of producing high surface finish and material removal rate, the cost of the equipment along with its specialized accessories are very high compared to magnetic abrasive machining.

Table 1 illustrates the characteristic features of various abrasive machining processes indicating the surface finish achievable and the amount of material that can be removed with these processes. Magnetic abrasive machining comes in the category of super finishing process.

Table –1 Comparison of characteristic features of some of the abrasive machining processes

Type of process	Surface finish achieved (μmRa)	Quantity of material removed (μm)
Lapping	0.1-0.2	12-15
Superfinishing	0.2-0.5	15-20
Magnetic abrasive machining	0.01-0.04	1-5
Fluidized abrasive polishing	0.02	0.5
Ion beam machining	0.01 -0.05	1-5
Elastic emission machining	0.005-0.01	0.5-1
Mechano chemical polishing	0.01-0.05	1-5

Thus varying the magnetic flux density, which would vary the rigidity of the tool and also the cutting action of tool on the workpiece, can easily control the tool performance in semi magnetic abrasive machining. When the workpiece in motion is kept in between the magnetic poles, the magnetic abrasive brushes perform polishing operation as shown in Fig 1. Magnetic abrasives are introduced between the workpiece and the magnetic heads (poles) where the finishing pressure is executed by the magnetic field as shown in Fig 2. The finishing action takes place predominantly in this region. The magnetic flux density (MFD) is stronger around this area.

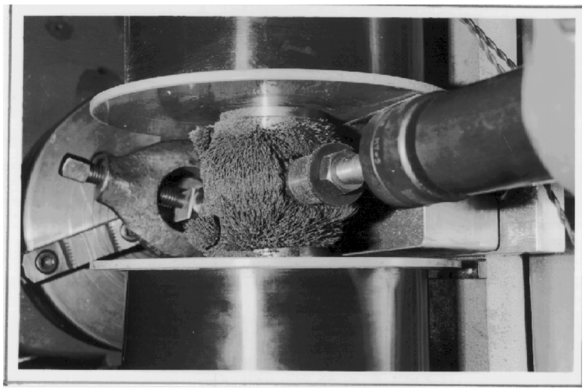


Fig 1. Working zone of machining process

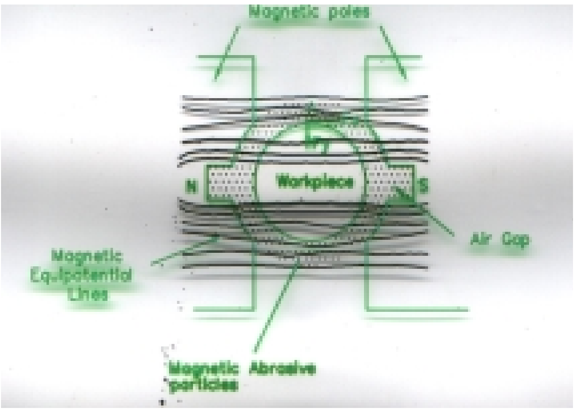


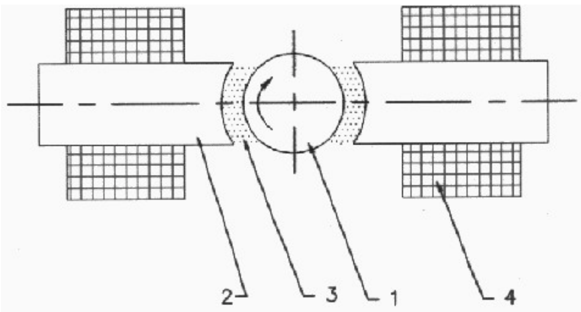
Fig 2. Magnetic Field distribution in the working zone

The essence of the method lies in the use of semi magnetic abrasive powder compacted by magnetic energy as a tool, to abrade the workpiece and improve the surface finish by reducing the micro-irregularities. The abrasive used in SMAM process is a bi-product of grinding wheel manufacturing industries and they are not useful to them for their products. These abrasive particles are coated with iron particles when they are milled. Since they exhibit magnetic properties, and they are being used as polishing tool with the help of external magnetic field.

Even though the process is similar to magnetic abrasives, used in magnetic abrasive machining is different from the one used in semi magnetic abrasive machining.

In magnetic abrasive machining, the abrasives are mixed with ferromagnetic iron powder, sintered and crushed to the required size. Thus introducing another process, which is going to cost more. The only similarity among these two processes is the use of magnetic field to hold the abrasives and flexibility in the abrasive movement while processing. The machining setup is shown in Fig.3. The principle of operation of semimagnetic abrasive machining is shown in Fig .4

Fig 3. Machining setup developed for semi-magnetic abrasive machining



1. Workpiece 2. Pole Piece 3. Abrasive Powder 4. Electro-magnetic Coils

Fig .4 Principle of magnetic abrasive machining

A study has been undertaken to develop a new process called Semi Magnetic Abrasive Machining (SMAM) for overcoming the above stated deficiencies. In semi magnetic abrasive machining process the magnetic abrasive like Aluminium Oxide (Al_2O_3) or silicon carbide (SiC) are joined to each other magnetically between magnetic poles, North (N) and South (S) along the lines of magnetic force, forming flexible magnetic abrasive brushes. There is no bond in the abrasives. The role of the bond is performed by magnetic field. This means, the magnetic abrasive powder could assume any shape/profile of the workpiece. This would be much more economical than making of different bonded abrasive stones as in case of honing, super finishing and grinding. Further the bond strength could be altered easily by changing the magnetic flux density.

EXPERIMENTAL PROCEDURE

From the preliminary studies, it was noticed that six variables can be varied. The same variables are used for the design of experimentation. The different ranges for these process parameters and different levels of their operation for detailed investigations are

- Abrasive grain size
  120,150 and 220 grits (106, 75 and 53 μm)
- Magnetic flux density
  3000, 4000 and 5000 gauss
- Surface speed of workpiece
  67, 90 and 160 rpm
- Gap between workpiece and pole
  2,3 and 4 mm
- Workpiece hardness
  45, 50 and 55 RC
- Machining duration
  60, 90, 120 min

SELECTION OF PROCESS PARAMETERS

To establish the feasibility of usage of SMAM, the experiments were conducted by selecting the process parameters based on the findings of trial runs and some of the parameters influenceare discussed below.

Influence of workpiece circumferential speed on surface finish

Fig. 5 shows the effect of workpiece circumferential speed on surface finish. In this study, the rotational speeds of 67, 90 and 160 rpm and the duration of machining of 60 minutes were experimented. It can be seen that the improvement in surface finish is more with higher rotational speed. The improvement in surface finish can be due to more abrasives that come in contact with the workpiece during high speed.

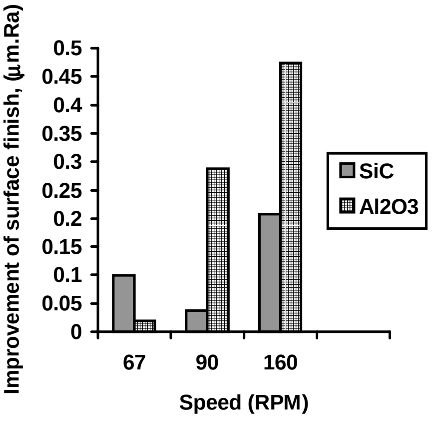


Fig. 5 Effect of work piece Speed on surface finish

Influence of Magnetic flux density (MFD) on surface finish

Fig. 6 illustrates the effect of magnetic flux density on surface finish. The flux density used in the experiments were 0.3, 0.4 and 0.5 tesla (T) and the machining duration was 60 minutes. From the results, it can be noticed that the increase in flux density reduced the improvement in surface finish this could be due to the abrasives with high magnetic field density, the movement of the abrasives is also redirected in the machining zone.

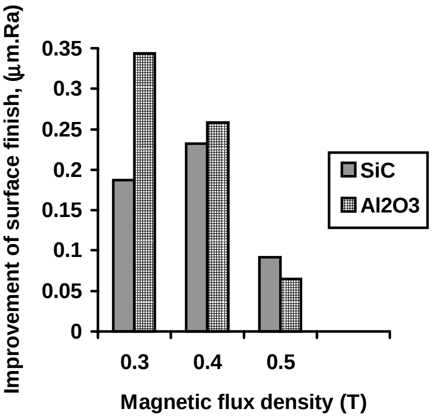


Fig. 6 Effect of Magnetic Flux density on Surface finish

Influence of gap between work piece and magnetic pole on surface finish

Fig. 7 illustrates the effect of gap between the work piece and the magnetic poles on work surface finish. The gap considered for the experimentation were 3,4 and 5 mm and the machining duration was 60 minutes. It can be seen that the work piece clearance of 4mm with Al_2O_3 abrasive grit contributed to an improvement in surface finish. Similar trend was noticed with SiC grits also.

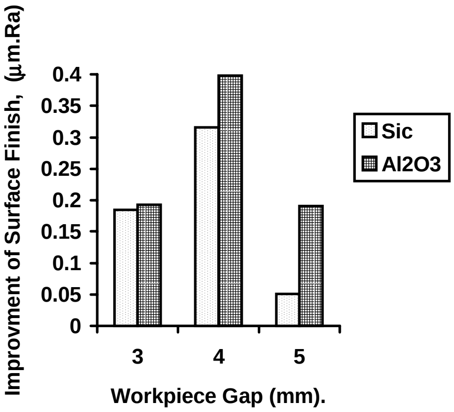


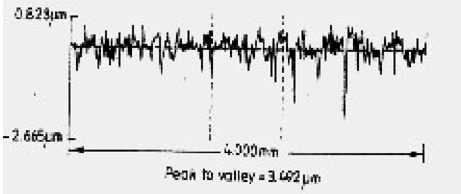
Fig. 7 Effect of Work piece gap on surface finish

Influence of Work piece hardness on surface finish

Fig. 8 illustrates the effect of work piece hardness after a machining duration of 60 minutes. Turned work pieces hardened to 45, 50 and 55 R_C and ground to 0.2 to 0.6 µm Ra are considered for this study. Large improvement in the finish is noticed on work piece with a hardness of 55 R_C with Al_2O_3 and SiC abrasives.

Fig. 8 Effect of Work piece hardness on Surface finish

A number of trials were conducted with various types of machined surfaces such as turned, ground specimen to ascertain the feasibility of this system for polishing the work surface. Fig. 9 shows the typical surface profile on the work surface before and after the semi magnetic abrasive machining.



Surface profile before machining (0.370 µmRa)

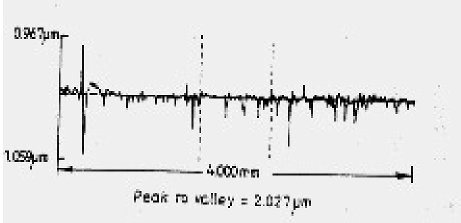


Fig. 9 Typical surface profile before and after SMAM

APPLICATION

To explore the different application areas for these process components with complex contours like gears, worm and threads were machined with semi magnetic abrasives. Results indicated the adaptability of the process for this components and improving in their surface finish. The improvement in surface finish of the worm, gear and thread components is about 35%.

CONCLUSIONS

The process of Semi Magnetic Abrasive Machining (SMAM) for polishing of cylindrical workpiece was developed using available abrasives. A machining setup was developed using a conventional lathe. The lathe was modified to accommodate a heavy-duty electromagnet on the carriage in place of tool post and a workpiece holding mandrel was supported between the chuck and the tailstock.

The experimentation with this process parameters reduced the surface roughness value on a cylindrical component from an initial Ra value of 0.257 µm to 0.075 µm Ra over a machining duration of 3 minutes with Aluminium Oxide, 220 grit semi magnetic abrasives. These studies also indicated the need to consider the workpiece initial roughness, apart from its hardness for achieving an improved finish on the work surface. From these studies it was clear that workpiece having initial roughness around 0.4µm Ra is found to give a significant improvement in surface finish with semi magnetic abrasive machining.

REFERENCES

Baron, J.M., “*Technology Of Abrasive Machining In A Magnetic field”, (*1975).

Childs, T.H.C., Mohmood .S, and Yoon H.J. “*The Material Removal Mechanism In Magnetic Fluid Grinding Of Ceramic Ball Bearings”*, Proc. Instn. Mech. Engrs., pp. 208,47-58 (1994).

Fox. M., Agrawal .K, Shinmura .T**,** and Komanduri .R**, “***Magnetic Abrasive Finishing Of Rollers”,*CIRP Annals, Volume 43/1**,.**pp. 181-184. (1994)

Shinmura, Takazawa T.K., Hatano .E**,** and Matsunaga**, “***A Study On Magnetic Abrasive Finishing”*. CIRP Annals, Volume 39/1**,** pp. 325-328. (1990)

Umehara, N. and K. Kato**, “***Principles Of Magnetic Fluid Grinding Of Ceramic Balls”*. Int. J. Applied Electromagnetics in Materials, Volume 1**,**pp. 37-43. (1990)

Umehara N.**,** Kato N., and Kanagawa K. (1992) *“Magnetic Fluid Grinding Of Ceramic Flat Surfaces”*, Int. J. Electromagnetics in Materials, Volume **2,**pp.143-145, (1990).