Study of Parameters for Internal Finishing Process using Magnetic Field

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ABSTRACT

Magnetic field assisted finishing process is a truly precision machining process of nontraditional processes. In this process, surface finishing and deburring are done in the presence of a magnetic field. These systems are used as equipment in critical applications such as high pressure gas or liquid pipelines. Today, the demands placed on production by the industry are unlimited due to the complexity of working profiles, the need for precision and micro surface treatment. A review of the literature shows that although significant research has been done on many aspects of the efficient use of DC driven electromagnets, there is not enough information regarding the use of electromagnets in home machining. In this study, an experimental setup will be designed and constructed to determine the internal processing of pins (stainless steel) using magnetic materials. The pins receive AC frequency conversion and are precision machined. Additionally, the oscillating motion of the pin imposes residual compressive stresses on the surface, increasing the fatigue integrity of the product. The performance of the developed device was checked with some tests. Important parameters such as magnetic flux density, number of pins, workpiece spindle speed, working combination were selected for testing. The range of these parameters was investigated with the help of experimental setup. The results show that many factors do not have a significant impact on the improvement of workpiece surface quality. The main problems faced by MFAM users are the cost and impracticality of abrasives. Therefore, it is necessary to investigate other methods. Data shows that small pins made of stainless steel can be used to finish and replace metal surfaces. However, dynamic movement must be applied to the pin. The configuration created in this thesis is to check the suitability of various parameters so that the finished area of the given area can be improved.

Index Terms: Non Traditional Machining, Magnetic field assisted Machining, Electromagnet, oscillation, frequency

INTRODUCTION

Today the manufacturing industry is facing challenges from advanced difficult to machine materials such as tough super alloys, ceramics and composites with stringent design requirements like high precision, complex shapes and high surface quality and machining costs. The advanced materials play an important role in modern manufacturing industries especially in aircraft, automobile, tool, die and mold making industries. The greatly improved thermal, chemical and mechanical properties of the material such as improved strength, heat resistance and corrosion resistance are required today as they have given higher economic benefits to manufacturing industries through improved product performance and product design.

This is because traditional machining is often based on removing materials using tools harder than work pieces. For example Polycrystalline diamond (PCD) which is almost as hard as natural diamond cannot be effectively machined by traditional machining process. One of the most commonly used conventional techniques is diamond grinding. In order to remove the material from PCD blank the diamond layer of the grinding wheel must be renewed by turning or dressing operations resulting in rapid wear of wheel because the G - ratio(ratio of workpiece volume removal rate to grinding wheel volume wear rate) is 0.005to0.02.Thus the grinding wheels wear rate is 50 to 200 times higher than work piece removal rate. Hence classical grinding is suitable only to limited extent for production of PCD profile tools. The high costs associated with machining ceramics and composites and damage generated during machining also are major impediments to the implementations to these materials.. Moreover it is observed that the cost of machining structural ceramics (Silicon nitride) of ten exceeds 50% of the total production costs in the engine industry thus in many cases current machining methods cannot be used and innovative techniques or modifications in existing methods is required. In addition to the advanced materials, stringent design requirements also pose major problems in manufacturing industry as more and more complex shapes (such as aerofoil section of turbine blade, complex cavities in dies and molds, non circular, small and curved holes),low rigidity structure and micro mechanical components with tight tolerances are required. The traditional machining processes are ineffective in machining these parts so development of new processes is required It is also observed that the finish accuracy and surface integrity of parts produced by conventional machining depends upon machine tool, cutting tool, work piece, cutting conditions and cutting fluids. For accomplishing higher removal rates or higher surface finish the machine tools need to be rigid, free from deflections and vibrations. It is difficult to economically build machine tools that are extremely rigid, vibration free and error free. Moreover with the introduction of many difficult to machine materials such as hardened Steels, Nickel, Cobalt and Titanium based alloys oscillations in the cutting process (cyclic variations of forces) become inherent to the cutting process (cyclic chip formation) which cannot be modified significantly by machine tool systems. Also with the advent of advanced materials such as ceramics and glasses very few cutting tool materials (including diamond cubic boron nitride) with geometrically defined edges are capable of material removal effectively. Ceramics and glass are inherently brittle and failure of parts made from these materials is initiated by cracks formed during machining as well as by other defects.

To minimize the damage due to machining it is necessary to process advanced ceramics under gentle conditions i.e. very low cutting forces and with improved machine tools this will certainly facilitate in reducing deflection and chatter, .Also the finish Process operation has to be economical and this led to the introduction of mechanical advanced machining process where the cutting process is aided by secondary source. Moreover a machining process was required to safely remove the material from work piece without inducing new sub surface damages and this machining was done by means of magnetic field assisted machining (MFAM).Moreover the machining process has to safely remove the material from work piece without inducing new sub surface damages, the machining by work piece by means of magnetic field assisted machining (MFAM) could be such a process. Unlike traditional grinding, lapping or having process with fixed tools; MFAM applies no such rigid tool with important advantage of subjecting the work piece to substantially lower stresses.

Machining of Plane Surfaces

Fig. 1.1 shows the process principle of MFAM for plane surfaces. MFAM has been successfully applied for plane machining and its finishing performance is found to be remarkable. A bench type plane magnetic abrasive machining apparatus using rotary type electromagnet is used for machining of plane surfaces by MFAM.A prescribed machining clearance is set between magnetic pole and the work piece surface magnetic abrasives are packed therein to form a magnetic abrasive brush and the magnetic pole is rotated at a high speed and at the same time feed is given to the surface to be machined thereby achieving fine finishing.

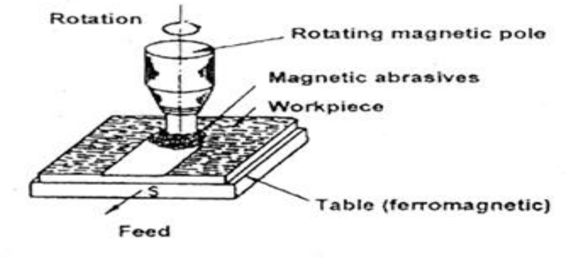

Fig.1.1. Schematic View of MFAM Process for Plane Surfaces.

Figure 1.2 shows the process principle of MFAM process for an external surface of a cylindrical workpiece. Magnetic abrasive grains are combined to each other magnetically between magnetic poles along a line of magnetic force, forming a magnetic abrasive brush. When a rotated cylindrical work piece is subjected to such a magnetic field, fine machining action takes place. In this process the metal removal rate and surface finish depends on the work piece circumferential speed, magnetic flux density and hardness of work piece material, size and type of magnet.

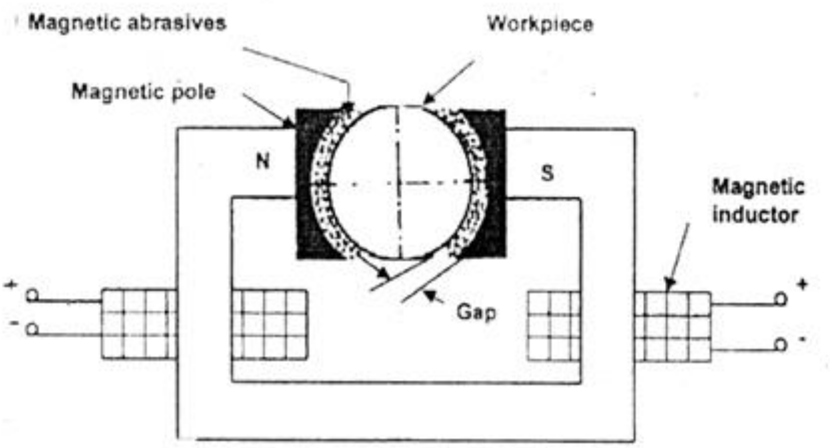

Fig. 1.2 Schematic view of MFAM process for cylindrical (external)surface.

In MFAM process for internal surfaces, granular magnetic abrasive composed of ferromagnetic material(as iron particles) and abrasive grains(say Sic ,or diamond)are used as cutting tools and the necessary finishing pressure is applied by electro-magnetically generated field. In figure 1.3, magnetic poles North and South are placed face to face with non-ferromagnetic tubing.

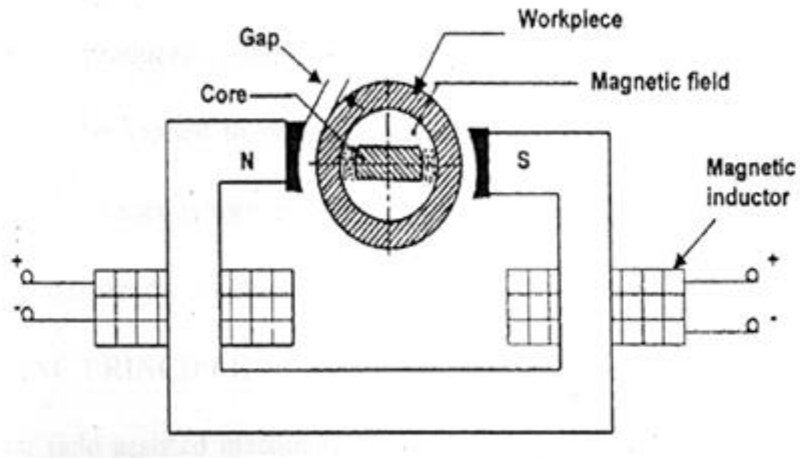

Fig.1.3 Schematic view of MFAM Process for Internal (Cylindrical)Surfaces

The magnetic abrasive supplied into the tube is conglomerated at the core. When the tube rotates at a high speed the relative motion between the tube and magnetic abrasives makes the inner surface smooth. It has been found that surface roughness of 4 µm (R_{max}) before finishing was improved to 0.1 µm (R_{max}) of stainless steel sanitary tubing. The process efficiency can be increased by using mixed type abrasives and using composite magnetic abrasives including diamond grains.

The major difference between the machining of internal surfaces and plane surfaces is that in internal machining of surfaces the work piece is given rotation and the magnetic polesare stationary whereas in the case of machining of plane surfaces the work piece is the stationary part and the magnetic pole is given the high-speed rotation.

EXPERIMENTATION

To assess the working performance of developed experimental set up a set of experimental trial was planned. The trials have been conducted to decide the range of selected process parameters that could be obtained in the developed set up. "Variation of one parameter at a time" approach has been applied and. the levels of various parameters have been selected depending upon the capabilities of the set up. Table 1 shows various levels of selected parameters for conducting the experiment

Before machining the trial runs were performed and Brass pipe of internal diameter 30mm. The internal surface of pipes to be used for various trials was provided with uniform surface finish with the help of reaming the hole with the same tool. For each process parameter, five work pieces (pipes) were prepared and surface finish of the surface was recorded after each level of parameter with Mitutoyo surface roughness tester. The surface finish was measured at three different locations on the surface and average value was recorded. Percent improvement in surface finish over initial surface finish was taken as performance parameter. It is obtained from the following relation

% improvement in surface finish= Ra (before finishing)/Ra(after finishing)X10

Effect of Magnetic flux: The trend of the curve obtained in this figure is indicate that there is sharp increase of % improvement in surface finish beyond magnetic flux density of 0.25 Tesla and it remains as such up to 0.45Tesla. After 0.45Tesla the finish of the surface starts stabilizing. This indicates that major improvement took place during initial rise in magnetic flux density. Therefore, the useful range of magnetic flux density for Designed set up for brass work piece seems to be 0.2 to 0.5Tesla.

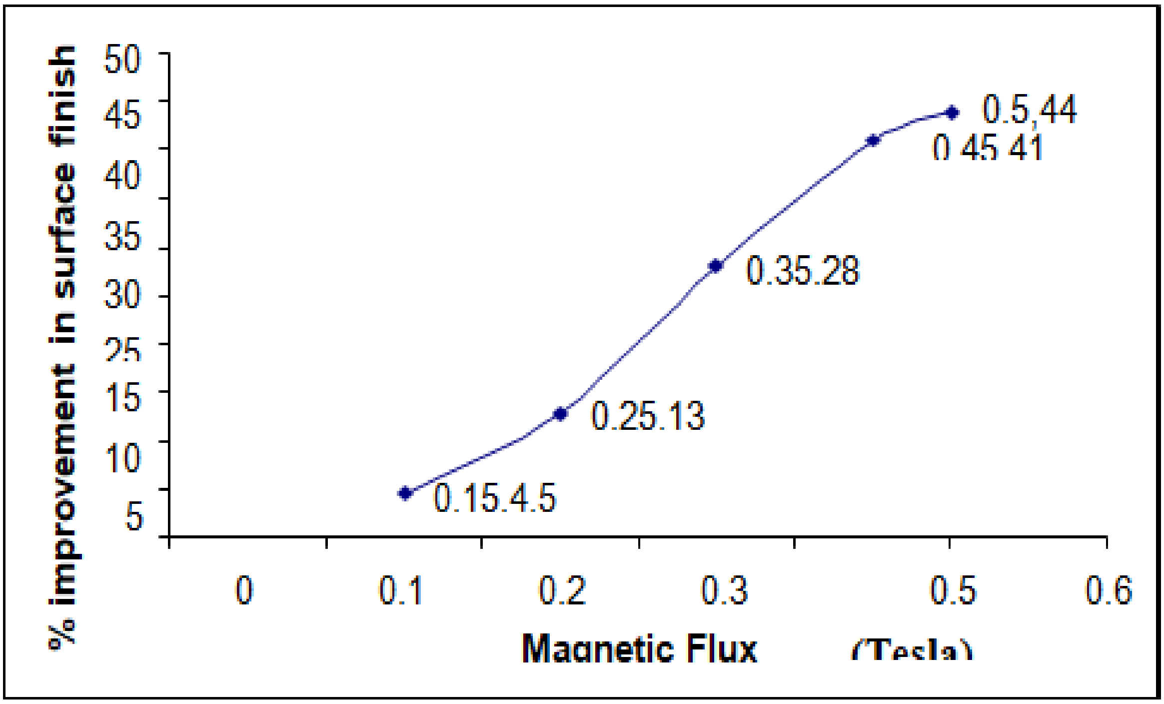

Fig.1 Effect of Magnetic Flux Density on Percent imrovement in surface finish

The reason of improvement in surface finish with increase in MFD is that with higher values of MFD, more magnetic attraction takes place and the pin gets more powerful impact on the surface. However, after certain values of MFD the freedom of pin to vibrate starts decreasing and there may be less improvement in surface finish at higher values of Magnetic Flux Density.

EFFECT OF MACHINING TIME

An experimental trial was conducted to check the improvement in surface finish with varying values of machining time. The machining time was varied at five different levels . All other parameters were kept constant (near to average of max. and min. value).

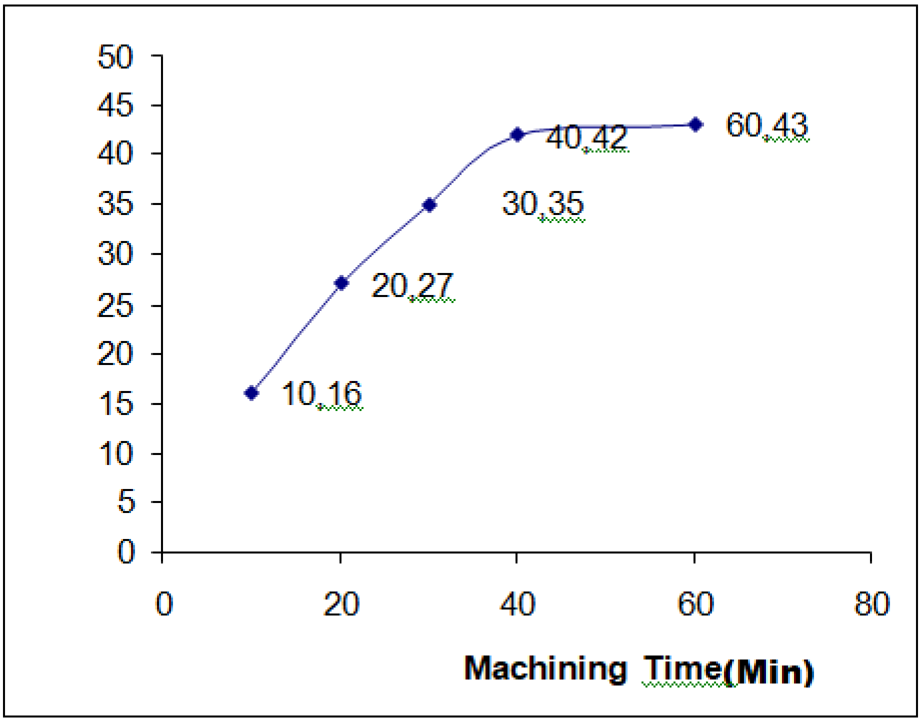

Fig 2 effect of machining time on % improvement in surface finish

The trend of the curve obtained in the fig.5.2 shows that with increase in machining time, the % improvement in surface finish increases. However, the improvement is not continuous as after 40 minutes of machining time, the improvement in surface finish gets stabilized. The trend of the curve further indicates that for the developed set up, 40 minutes of machining time is sufficient to cause maximum improvement in surface finish (i.e.50 – 60%). It is possible that further improvement in surface finish may take place if initial surface roughness of work piece is different. Moreover, faster improvement in surface finish can be possible if other parameters (Magnetic Flux Density, Weight of pins, Rotational speed of work piece, Frequency of supply of supply voltage) could be optimized. The reason for improvement in surface finish with increase in machining time initially is that the surface irregularities present in the surface of work piece are removed and get flattened and once they are removed there remains no scope of any further improvement in surface finish.

From the results of this study it can be stated that it is possible to do precision machining of the internal cylindrical surface with magnetic field assisted machining using SUS304 stainless steel pins. The developed experimental set up with alternative magnetic abrasives is capable of working as an experimental rig for parametric studies on MFAM within the range of parameters set on the developed set up. Following conclusions have been drawn regarding precision internal machining of cylindrical tube of brass with SUS304 stainless steel pins on the developed set up

Effect of Rotational Speed of Work Piece The rotational speed of the work piece was varied by changing the speed of the motor. The rotational speed of the work piece was varied at five different levels as per Table 1. Values of constant parameters are as follows

Magnetic flux density= 0.35Tesla

Machining time= 30 minutes

Weight of pins= 20 gm

Frequency of supply=30Hz

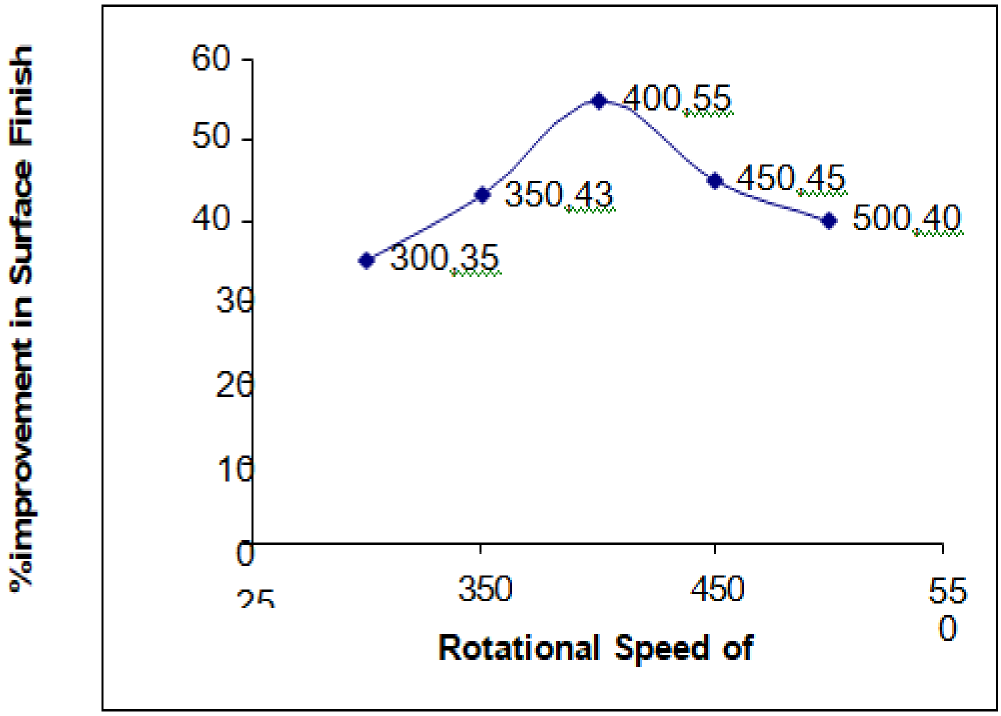

Fig3 Effect of rotational speed of work piece on % improvement in surface finish

The effect of rotational speed of work piece on % improvement in surface finish is depicted in Fig.5.5. The nature of variation of curve obtained in this figure shows that with increase in rotational speed of work piece the % improvement in surface finish improves up to 400rpm but at higher values of rotational speed it decreases. Therefore for the finishing of brass pipe with the designed set up a rotational speed up to 400rpm of motor may be suitable.

In the present trial maximum improvement in surface finish obtained is 50 – 60 % over initial surface finish. It is possible that further improvement in surface finish may takes place if other parameters (Magnetic Flux Density, Weight of pins, Machining time, Frequency of supply) could be optimized.

CONCLUSIONS

1. The quantity of pins plays an important role in affecting the surface finish of the component. With increase in quantity of pins the surface finish increases initially but then it starts deteriorating.
2. The frequency of supply voltage affects the surface finish as with increase in frequency the surface finish also increases.
3. The rotational speed of the work piece also plays prominent role in affecting the surface finish of the component as with the increase in speed of motor there is improvement in surface finish initially but then it tends to become constant.
4. Magnetic flux density is another influential parameter which affects the surface finish of the component. More the magnetic flux density, more improvement in surface finish takes place.

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The surface finish of a component is influenced by several parameters. Increasing the number of pins initially improves the surface finish, but beyond a certain point, it causes deterioration. Higher supply voltage frequency enhances the surface finish. Increasing the rotational speed of the workpiece initially improves the surface finish, but the effect plateaus at higher speeds. Additionally, greater magnetic flux density leads to better surface finish.

The manufacturing industry faces challenges when working with advanced, hard-to-machine materials like super alloys, ceramics, and composites, which are essential for high-performance applications in aerospace, automotive, and tool-making industries. Traditional machining methods are often ineffective or costly for these materials due to their properties, high wear rates, and the risk of damage. Additionally, complex shapes, microcomponents, and tight tolerances further complicate manufacturing processes. Conventional techniques like grinding generate rapid tool wear and high costs, especially for ceramics like silicon nitride. To address these issues, innovative and refined machining processes are needed. One such approach is magnetic field assisted machining (MFAM), which minimizes surface damage and stresses by avoiding rigid tools and applying gentle, controlled material removal. Overall, advancements in machining techniques are crucial for efficiently manufacturing modern high-performance materials and complex components.