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TECHNOLOGY AND RESEARCH DEVELOPMENTS IN MAGNETIC ABRASIVE FINISHING (MAF): A REVIEW

Engineering

KEYWORDS: Non-conventional finishing, magnetic abrasive finishing, stock removal, material removal rate, surface roughness.

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ABSTRACT

Automated CNC plasma cutting is an effective process for building complex two dimensional metallic parts in a short period of time. The research and development in the precise and accurate machining technology of hard metals (Ferrous and non-ferrous etc) is gaining much importance in the industry since last many years. Due to the tremendous competition and cost factor, the non-conventional machining technology is becoming the first choice of the engineers and technicians. In this era of advanced technological processes the CNC plasma arc machining is gaining tremendous ground in the industry. The main objective and targets of this practical experiment is based to achieve the best possible setting and parameters of operation on a CNC plasma arc machine to maximize the Maximum material removal rate (MRR) and to minimize the TAPER.

1. INTRODUCTION

Magnetic abrasive finishing (MAF) is a magnetic field assisted finishing process. In this process, the magnetic field controls the forces, in the finishing zone. A small amount of material is removed by producing a relative motion between the work surface and abrasive particles so that a mirror like surface can be obtained. Magnetic Abrasive Finishing process can be used to produce efficiently good surface quality on flat surface as well as internal and external surfaces of tube type workpiece. In magnetic abrasive finishing or machining pressure can be controlled by the input current. Magnetic abrasive finishing has been able to give good surface and edge finishing by means of a magnetic abrasive brush formed in magnetic field. There has been much interest and demand in rationalizing finishing, deburring, and chamfering operations of the parts produced manually. This MAF process is one of the premier processes to give very good result for rationalization finishing operations [1].

2. WORKING PRINCIPLE OF MAF

A homogeneous mechanical mixture of abrasive and iron particles is prepared for magnetic abrasive finishing process. This mixture is called Magnetic Abrasive Powder and the particles are consequently, called as Magnetic Abrasive particles (MAPs). The MAPs are used in magnetic abrasive finishing of flat and cylindrical (external and internal) surfaces. Many times the abrasive particles are bonded by sintering process, to the magnetic particles. The particles are then called bounded magnetic abrasive particles (BMAPs). Lubricating oil is sometimes added to the mixture to obtain bonding strength, and then it is called as loosely bounded magnetic abrasive particles (LMAPs) or it may be a simple mechanical mixture of the two, called as unbounded magnetic abrasive particles (UMAPs). A magnet is brought close to the surface of the work-piece maintaining some gap between the two. The shape of magnet depends upon the shape of the work surface which is to be finished. The magnetic field generator can be either electromagnetic coils or permanent magnets. The gap between the magnet and work piece is known as finishing gap or machining gap or working gap. The Magnetic Abrasive Powder is filled in this gap. When magnetic field is produced by the magnet, the iron particles in the mixture get magnetized and get aligned along the lines of magnetic force. The abrasive particles in the mixture get trapped in the iron particles matrix or, get sandwiched between the iron particles and thereby, the abrasive particles are held by the magnetic force too. Overall, this alignment of the magnetic abrasive particles forms a brush like structure known as Flexible Magnetic Abrasive Brush (FMAB). The brush is termed "Flexible" due to its capacity to take the shape of any of surface profile irregularities, if present on the work surface. The normal magnetic force acting on the abrasive particles that are in contact with the workpiece produces indentation into the workpiece. The relative motion between the induced abrasive particles of the FMAB and workpiece generates the necessary shearing action at the abrasive–workpiece interface to remove material from the work-piece in the form of miniature chips. The pressure imparted on the work-piece in this process is very low compared to rest of the conventional processes due to the absence of a very rigid structure to hold the abrasives. Thus, material is removed in the form of chips which are very small (so called microchips) giving the effect of finishing [2].

MAF process has been used to finish flat surfaces, cylindrical work pieces (external as well as internal). Figs. 1, 2 and 3 shows schematic views of external cylindrical MAF process, internal cylindrical MAF process and plane MAF process, respectively. A finishing setup in which the magnet is stationary and the work-piece rotates is called a work-piece rotation system. And the reverse in which the magnet rotates and the work-piece is stationary is called pole rotation system [3].

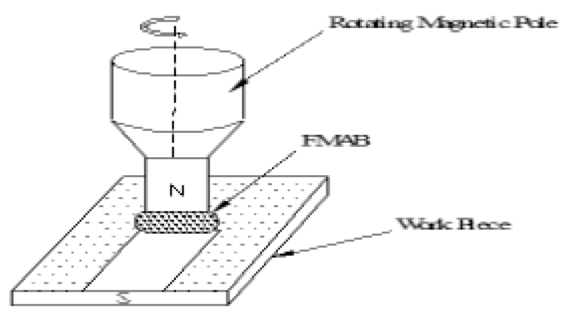

Fig. 1 Schematic view of Plane MAF

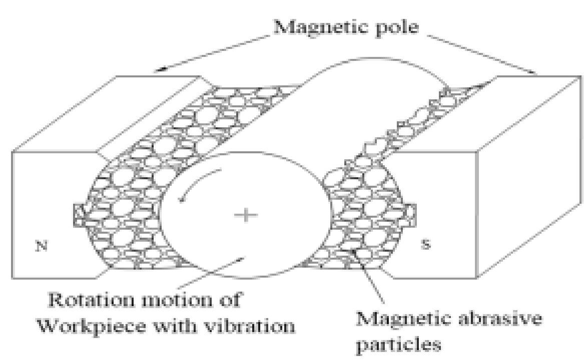

Fig. 2 Schematic view of external cylindrical MAF

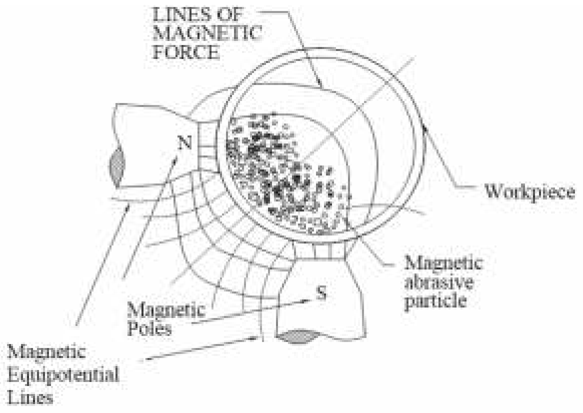

Fig. 3 Schematic View of Internal Cylinder MAF

3. LITERATURE SURVEY

The idea of using magnetic field for achieving good surface finish was originally introduced in the Soviet Union in 1938. After that, fundamental research in MAF has been done in Soviet Union, Bulgaria, and USA. More extensive work has been done in Japan since 1980. Many researchers have conducted experimental work taking both ferromagnetic and non-ferromagnetic work materials and studied the effect of process parameters on the process performance.

In one of the early works in MAF, Shinmura et al studied the effects of various working factors on the finishing characteristics using a test apparatus which they made for trial. The apparatus was designed to give vibration to the work piece with rotation using a lathe machine. They used a 30 mm and length 45 mm stainless steel as work-piece. They used work-piece vibration of 15 Hz as a means to assist the MAF finishing. They used 29 m/min circumferential speed, 1.5 mm working clearance, 1.2 T magnetic flux density, 1.5 mm amplitude of work-piece vibration, 4min finishing time, 6 g abrasive as parameters, and found an increase in finishing efficiency of MAF process due to the application of vibration [4].

Jeong-Du Kim et al. said that the process is controllable because the machining pressure is controlled only by the current that is input to the coil of solenoid, but it needs the monitoring of the surface roughness for the automation of the process and for the achieving of machining efficiency by preventing over-finishing of the surface. The surface roughness is predicted as a function of finishing time by a model that hasbeen 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 [5].

Yamaguchi et al. developed an internal magnetic abrasive finishing process using a pole rotation system. That was proposed to produce highly finished inner surfaces of work-pieces used in critical applications. Yamaguchi characterized the in-process abrasive behavior against the surface and its effects on the finishing characteristics and described the finishing mechanism. 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. The study examines the relationships between the magnetic field, the force on the abrasive, and the abrasive behavior. The surface roughness and material removal measurements resulting from finishing experiments demonstrate the effects of the abrasive behavior on the surface modifications [6].

Chang et al. studied the potential of unbounded MAP. They used iron and steel grits as ferromagnetic particles and SiC as abrasive. The work piece material was SKD11 tool of which the hardness is HRC55. They found that owing to its superior hardness and polyhedron shape steel grit is better suited to magnetic abrasive finishing. Iron particles are somewhat round. If the hardness of a work-piece is more, steel grit MAP gives good finish compared to a softer material because in hard material, the indentation of the grit is shallower. A SiC abrasive of any particular size will give better finish in case of a hard material as compared to a softer material under the same experimental conditions. MAF does not change hardness of the surface on which it acts [7].

Mori et al. explained the mechanism of MAF process. They used a non-magnetic 1 mm thick and 80 mm in diameter stainless steel work piece. They stated that the FMAB is formed due to the magnetizing energy supplied by the electromagnet to the ferromagnetic particles. Upon magnetization, the iron particles form bundles. In order to form the FMAB, the energy supplied by the electromagnet has to supply energy to magnetize the iron particles in the MAP, to counter the tension energy between the ferromagnetic particles and to counter the repulsion between the bundles. They stated that if the abrasive indenting point is near to a hill of surface roughness profile material gets removed but if abrasive stands in a valley of surface roughness it will not cut the material but tries to climb a hill until the energy is not sufficient to cut the material [8].

Yamaguchi et al. studied the MAF process for finishing of the inner surface of alumina ceramic component which has a wide range of applications but are difficult and so, costly to machine and finish. By experimentation on alumina ceramic tubes they examined the effect of volume of lubricant, ferrous particle size, and abrasive particle size on the finishing characteristics. They conducted experiments on alumina tubes with 99.5% alumina content using iron and diamond abrasive MAP. They finished the internal surfaces of the tubes at 1800 RPM and 0.37T magnetic flux density. They found that on increasing the lubricant supply, the material removal and surface finish improve, reach to an optimum value and then start to decrease [9].

Wang Y. and Dejinhu studied the process principle and the finishing characteristics of unbounded magnetic abrasive within internal tube finishing. They found that the abrasive behavior is primarily determined by the relative strength of opposing force: the magnetic force and the friction force acting on the abrasive against the inner surface of the tube. When the magnetic force is greater than the friction force, the abrasive follows the rotation of the magnetic field. They designed a MAF setup for three types of tubing materials viz. Ly12 aluminum alloy, 316 L stainless steel, and H62 brass. They showed experimentally that finishing parameters such as polishing speed, magnetic abrasive supply, abrasive material and grain size have critical effect on the material removal rate [10].

V.k Jain experimented the application of pulse DC power supply to the electromagnet instead of static DC power supply. It was found that finishing rate increases at Nano level, surface finish (SF) is more uniform and process could be efficiently controlled with the help of magnetic field by using finite element analysis [11].

Wang and lee studied the characteristics of magnet finishing with novel abrasive medium (use of silicone gel to mix the ferromagnetic particles and abrasives). It was found that surface roughness of cylindrical part was reduced to .1 μm from initial value of .677 μm after 10 minutes which was 3 times the surface roughness reduction in case of simple magnetic abrasive finishing (MAF) with unbounded magnetic abrasive as medium. It was also found that gel abrasive has excellent ability to recycle [12].

Mulik and Pandey experimented that Ultrasonic assisted magnetic abrasive finishing (UAMAF) has better finishing abilities as compare to magnetic abrasive finishing (MAF). It was found that by controlling the process parameters (rotation of magnet, supply voltage, abrasive mesh no., abrasiveweight percentage, pulse on time) on hardened AISI52100 steel using unbounded silicon carbide (Sic) abrasive the surface roughness improves [13].

Yamaguchi et al. concluded that through particular heat treatment process, a metastable austenite steel tool can be fabricated to show alternating magnetic and non-magnetic region which enables the feasibility of MAF process for internal finishing of long flexible tubes

[14].

Kang et al. experimented a high speed multiple pole tip finishing equipment for internal finishing of capillary tubes by MAF at high speed of 30000 per minute. It was found that highly smooth surface of order approximately .1μm [15].

Liu et al. experimented the application of electrochemical magnetic abrasive finishing (combination of electro chemical machining and magnetic abrasive finishing) for polishing of material Al 6061. It was found that surface roughness (SR) of order .2 μm to 1.3 μm could be obtained in few minutes [16].

Sihag et al analyzed the use of chemo assisted magnetic abrasive (combination of chemical oxidation and magnetic field assisted abrasion) finishing by performing experiments using Taguchi method on tungsten work piece. It was found that better surface quality with minimum surface defects could be achieved [17].

Wu et al. studied a new ultra-precision magnetic abrasive finishing process using low frequency alternating magnetic field on SUS304 stainless steel plate under the impact of significant process parameters (namely rotational speed of magnetic pole, grinding fluid, current frequency) . It was found that the process can realize ultra-precision finishing of plane by using oily grinding fluid and surface roughness improved from 240.24 nm to 4.38 nm [18].

CONCLUSIONS

1. Improvement in material removal rate and surface roughness increases with increase in rotational speed of electromagnet.

2. When an ultrasonic vibration source in attached to the workpiece, material removal rate increases.

3. Performance of magnetic abrasive finishing process can be improved by application of pulse DC power source instead of smooth DC power source to the electromagnet. In case of Pulsed DC supply to AFM uniformity of surface finish improves, finishing rate increases and process can be easily controlled by magnetic field.

4. FUTURE TRENDS- Research can be done to improve material removal rate and surface roughness by giving rotary motion to the workpiece in anti-clockwise direction w.r.t electromagnet.

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