Investigation of Magnetic Abrasive Finishing on Inner Surface of AL 6061 Tube

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Abstract
In magnetic abrasive finishing (MAF), abrasive grains as a tool move on surface and can remove chip from surface of work piece. In this study AL 6061 tube was considered as the work piece and the effect of finishing parameters such as gap distance between tube and poles, rotational speed of tube, abrasive ration and finishing time on surface roughness was investigated. The mixture of ferromagnetic grits (Fe) and Al_2O_3 grains was considered as the abrasives. The result showed increasing in rotational speed, finishing time and abrasive grains up to certain value decreases surface roughness and increasing in air gap increases surface roughness.

Keywords
Magnetic abrasive finishing, Al 6061, Surface roughness

1. Introduction

A lot of production processes affect the surface properties which per se can have a significant effect on the parts functions during working. For polishing the workpieces that have form limitations such as free-form surfaces and the curves which cannot be finished with traditional finishing methods like grinding and etc, non-traditional machining where the cutting process is aided by a secondary source were introduced. In order to overcome these problems, some researchers proposed that a magnetic abrasive polishing process is one potential polishing technique for 3D microcurved surfaces because its tool (magnetic brush) is flexible in navigation on the surface profile of the workpiece [1-3].

In Figure 1, the MAF process to finish the internal surface of the tube is illustrated. This process is based on the magnetic field and the magnetic abrasive particles (MAPs). Figure1 shows the two-dimensional magnetic field distribution in the working zone. The magnetic forces affect the ferromagnetic particles (FP) at position “A” outside the working gap as follows [4, 5]:

$$F_x = V X_m \mu_\circ H\left(\frac{\partial H}{\partial x}\right) \tag{1}$$

$$F_y = V X_m \mu_\circ H\left(\frac{\partial H}{\partial y}\right) \tag{2}$$

Where x is the direction of the line of magnetic force, y is the direction of the magnetic equipotential line, X_m is susceptibility of the FP, μ_o is permeability of vacuum, V is volume of the FP. Also H is the magnetic field strength at point “A”, and $\partial H/\partial x$ and $\partial H/\partial y$ are gradients of magnetic field strength in the x and y directions, respectively.

From Eqs.1 and 2, it is obvious that the magnetic forces of F_x and F_y are proportional to both the susceptibility and the volume of FP, the magnetic field strength and its gradient. The magnetic forces were represented in Eqs.1 and 2 not only concentrate the FP in the working gap where magnetic field strength is superior, but also prevent the FP from splashing due to workpiece rotation. The abrasive particles (AP) do the primary cutting and ferromagnetic particles are responsible for the required pressure on abrasive particles. Accordingly, the FP motion behavior has an important effect on the finishing operation.

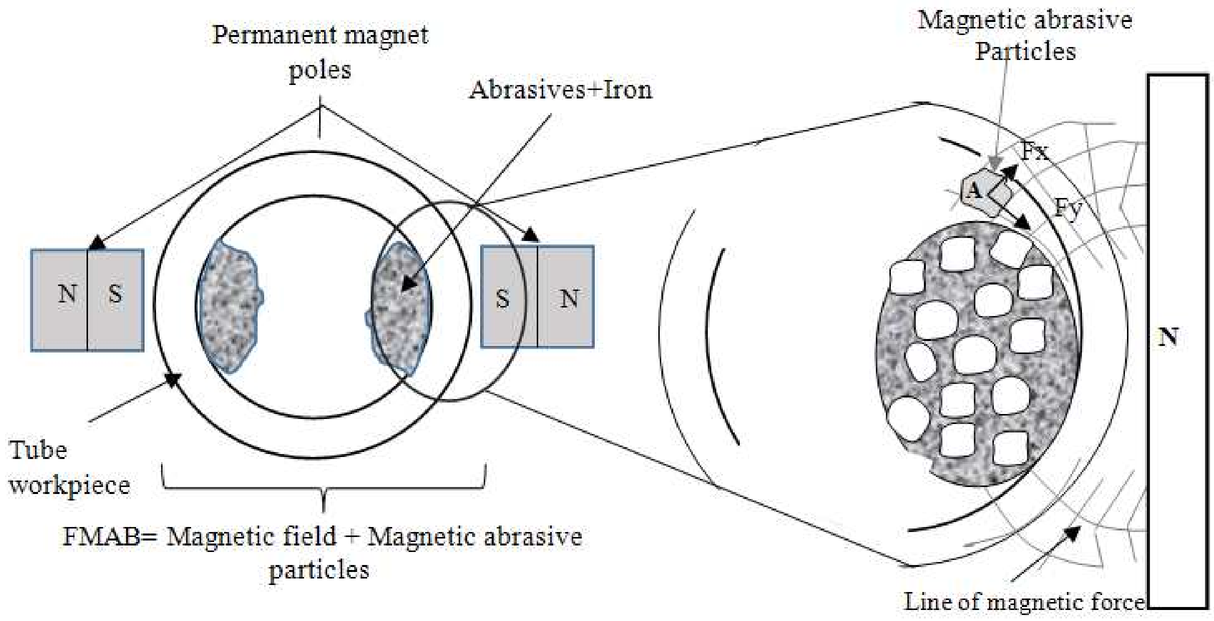

Figure1. MAF schematic of finishing the cylinders internal surfaces

As shown in Figure1, penetrating force pushes AP into surface and tangential force leads to pressure and push it forward that separates a very small part of surface like micro-chip. This phenomenon is repeated by other APs, which leads to reduce peaks of surface roughness, gradually.
Shinmura proposed Plane Magnetic Abrasive Polishing Process in which the magnetic pole rotates at a high speed and the workpiece is fed [6–9]. Anzai [10] also developed a polishing process to keep a magnetic pole standing in the normal direction against the machined surface using a 5-axis machining center. Kim [11] developed a twostage magnetic polishing of a curved surface using an abrasive wheel and a magnetic brush. Natsume [12] developed the same method to polish grooves of stainless steel. Yamaguch et al. [13] developed an internal magnetic abrasive finishing for nonferromagnetic complex shaped tubes. Wang and Hu [14] studied on the inner surface finishing of medical tubes. They produced the tube by surface roughness (R_a) under 0.3 µm.
The aim of this this research is to characterize the effects of air gap, rotational speed, abrasives ratio and finishing time on surface roughness of AL6061 tube workpiece.

2. Experimental work

2.2 Materials and instruments

The AL6061 was used as workpiece in this study. The chemical composition of this alloy presented in Table 1 The outer diameter and thickness of tube is 50 mm and 5 mm respectively. The AL6061 tube can be seen in Figure 1. Before experimental work, the surface roughness on inner surface of workpiece was measured. The surface roughness presented by the parameter Ra. The surface roughness instrument (MarSurf M300C (Mahr, Germany) has been shown in Figure 2.

Table1. Chemical composition of Al 6061

Al	Ti	Zn	Cr	Mg	Mn	Cu	Fe	Si
reset	0.15	0.25	0.04-0.35	0.8-1.2	0.15	0.15-0.4	0.7	0.4-0.8

Figure2. The tool used for surface roughness measurement

The unbounded magnetic abrasive particles are used in the working gap. The mixture of Al_2O_3 as abrasive and Fe grits as ferromagnetic particles in the weight ratio of 50:50, 75:25 and 25:75 were used. The mesh size of particles is presented in Table 2.

Table2. The mesh size of particles

Powder	Mesh size
Al_2O_3 abrasives	800
Fe grit	120-180

2.2 Experimental Setup

The used experimental apparatus has been shown in Figs.3 and 4. Figure 3 shows the aluminum fixture to hold the poles. Four permanent poles with were fixed in the inner surface of fixture. The angle between poles is 90 degree. The fixture mounted on lath machine support and workpiece was chucked on spindle. Figure 4 shows that the tube workpiece is entered into fixture, so the poles surround the outer surface of tube, and tube can rotate. Before starting the process, magnetic abrasives (the mixture of ferromagnetic grits and Al_2O_3 abrasives) introduced into the tube, and then attracted by magnetic field of poles. The magnetic field pushes the abrasives on the inner surface of tube. Rotation of the tube workpiece causes the relative movement of abrasives against the inner surface, and result to remove chips from the inner surface of tube.

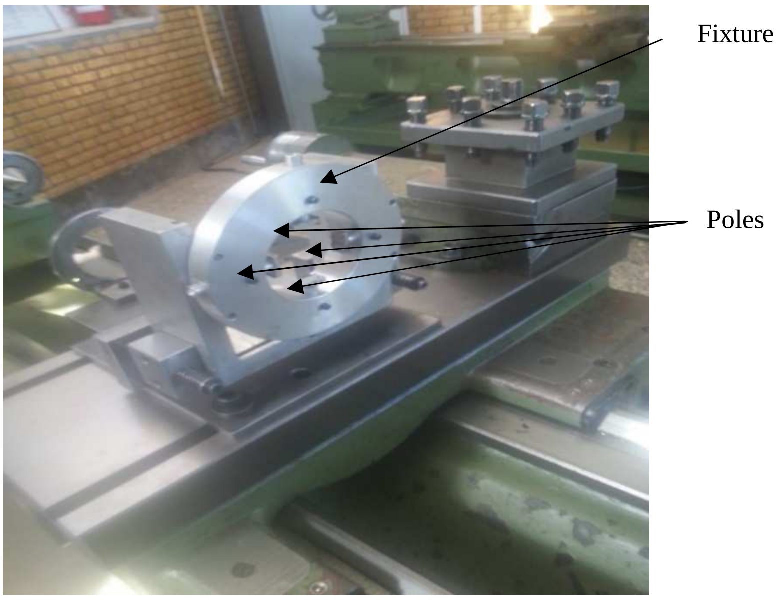

Figure3. Designed Aluminum fixture

Figure4. Setup of magnetic abrasive finishing of inner surface

In this work, four variables such as working gap, rotational speed, the ratio of Fe grits to Al_2O_3 abrasives and polishing time were considered. The main objective is determination of the effect of these parameters on surface roughness of tube. Table 3 shows the levels of these parameters.

Table3. The level of parameters

Parameter	Levels			
Air gap (mm)	0.5	1	1.5	2
Rotational speed (RPM)	355	500	750	1000
Particles ratio (ferromagnetic grits to Al_2O_3 abrasives)	1 to 3	1 to 1	3 to 1	
Finishing time (min)	5	12	20	

3. Results and discussion

3.1 The effect of air gap on the surface roughness

As regards the power of magnetic field of poles is constant, the magnetic flux (number of field lines per area) decreases by increasing of the distance from pole to tube. By decreasing the magnetic flux, the force on abrasives decreases, and as a result the finishing efficiency decreases. In practice, in the air gap more than 2 mm, fishing is very low. Figure 5 shows the effect of air gap on surface roughness of inner surface of tube. According to this figure, surface roughness increases by air gap.

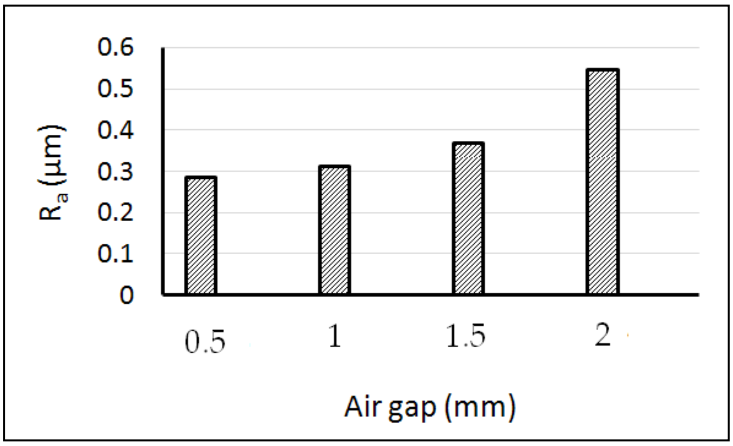

Figure5. The effect of Fe powder on surface roughness

3.2 The effect of abrasive ratio on the surface roughness

By increasing the abrasive particles, the number of participating particles in finishing process increases, and therefore the surface quality becomes uniform, and improves. As regards the power of magnetic field is constant, excessive abrasive particles is not allowed. The figure 6 shows the effect of the ratio of Fe grits to alumina particles. By increasing the ratio from 25% to 50%, the surface roughness decreases. In ratio of 25%, the amount of Al_2O_3 particles is high, so the magnetic field cannot apply the enough force to abrasive particles, but in ratio of 50% the amount of Al_2O_3 particles decreased, and therefore the magnetic field can be effective. The surface roughness increases by ratio percent from 50 to 100 due to the amount of abrasive particles is not sufficient.

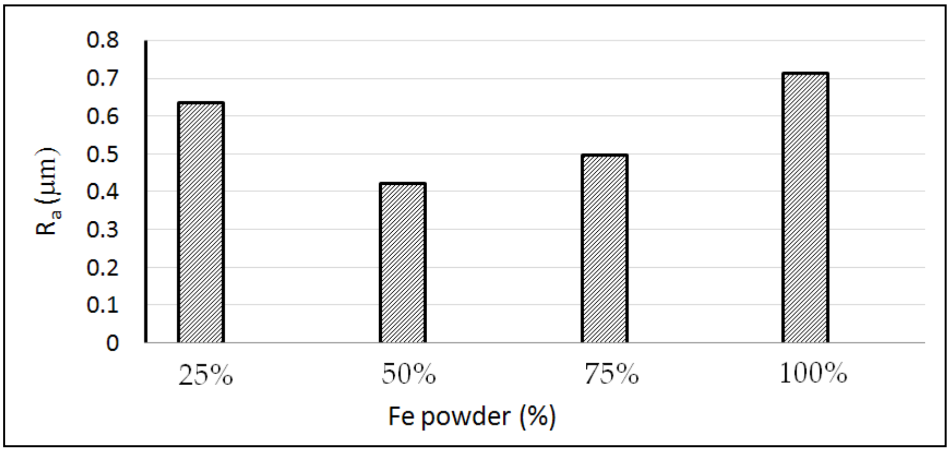

Figure6. The effect of Fe powder on surface roughness

3.3 The effect of rotational speed and finishing time on the surface roughness

Figure 7 shows the effect of rotational speed on surface roughness in three times of finishing. As shown in Figure, surface roughness decreases by increasing the finishing time. More finishing time resulting to more contact time of the abrasives and workpiece, and therefore abrasives have more time to reduce the roughness of surface. The difference of surface roughness between times of 5 min and 12 min is more than 12 min and 20 min. Thus, it can conclude that further increases in time have no significant effect on surface roughness.

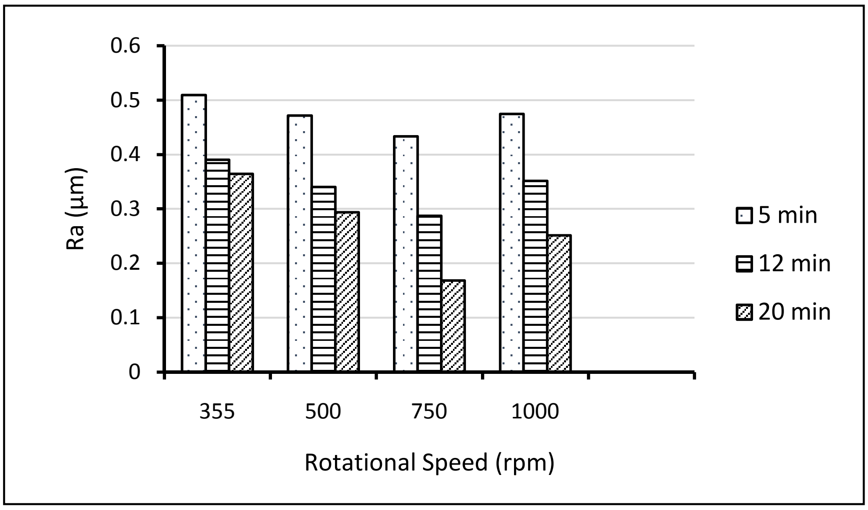

Figure7. The effect of rotational speed on surface roughness in three times of finishing

According to the Figure 7, it can be seen that the surface roughness decreases by increasing the rotational speed up to 750 r.p.m. The reason for such a behavior of this parameter can be expressed that when the workpiece rotational speed is increased, the contact length of abrasive particles with workpiece is increased, and surface roughness is decreased. But with increasing the workpiece rotational speed more than 750 r.p.m, the magnetic force (contrary to tangential direction workpiece rotational motion) will be less than the cutting resistance (tangential direction of the workpiece rotational motion). This causes the ferromagnetic particles throwing begins from on the inner surface and decreases the imposed pressure on the abrasive particles.

4. Conclusion

The results obtained in this research can be summarized as follows:

1. Increasing the working gap from 0.5 mm to 2 mm, the surface roughness increases. Regarding the conditions of the experiments, the best smooth surface was obtained as 0.5 mm in the working gap.
2. Increasing the ratio of Fe grits to Al_2O_3 abrasives from 25% to 50%, the surface roughness decreases. The further increase the ratio of Fe grits to abrasives increases the surface roughness.
3. Increasing the finishing time from 5 min to 20 min, the surface roughness decreases. The further increase the finishing time has no significant effect on surface roughness.
4. Increasing the workpiece rotational speed up to 750 r.p.m, the surface roughness is improved. From this speed forward an appropriate finishing is not done and the obtained smooth surface is not as well as the lower rotational speeds

5. References

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