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Research Article

EFFECT OF BRUSHING PARAMETERS UPON EDGE STATES AFTER WIRE BRUSHING OF AZ91 HP MAGNESIUM ALLOY

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ABSTRACT

When the tool leaves the part during machining operations, burrs can form as a result of material plastic flow. Wire brushing is one of burr removing methods. Low cost of brushes which can be mounted in a milling center gives the perspective of developing this method. The article was aimed at presenting the results of brushing process upon edge radius after wire brushing of AZ91HP magnesium alloy. Three kinds of brushes were tested with different types of fibers and the diameter of a single fiber. Brass and steel brushes were used.

Keywords: edge state, wire brushing, magnesium alloy.

INTRODUCTION

Brushing tools have been used for surface finishing operations for many years. The most popular applications of brushing are cleaning and deburring as well as removal of old varnish coats and corrosion. Brushes can be classified according to the shape and type of fiber which generally can be divided into metallic, non-metallic and natural fiber. Besides simple cleaning operations brushing can be used for more sophisticated applications, such as generating specific surface topography, as well as desirable properties of surface layer. Surface roughness can be controlled after brushing and depends on cutting parameters and type of brush [11]. Surface roughness decrease when the fiber tips of the brush cut or round up at the tops of the highest peaks of the profile after wire brushing. This effect may be desirable when it is important to increase material ratio which influences the wear behavior of parts in frictional contact [15]. On the other hand, in many situations it is desirable to develop surface topography, especially before applying protective or decorative coatings, during adhesive bonding technology and soldering process. Increased developed interfacial area ratio (Sd_r) contributes to increased adhesion. Brushing process can increase Sd_r parameter. Wire brushing affects the properties of surface layer.

The results presented in the article [5] show the ability to generate compressive stresses in the surface layer after wire brushing. Transforming the tensile residual stress into the compressive meant that fatigue cracks were shorter by 20–40 microns, compared to baseline (150–200 microns).This treatment led to an increase in fatigue strength by tens of percent.

The authors of articles [8, 9] applied wire brushing under varying conditions to surfaces of AZ31 magnesium alloy sheets for the purpose of grain refinement. Ultrafine grains were obtained in all wire-brushed sheets. The mean grain size depended mainly on the feed speed. The 0.2% proof stress and tensile strength slightly increased after the wire-brushing. The wire-brushed sheet shows high corrosion resistance for the salt spray test, which was approximately 4 times higher than that of a starting sheet. The results confirm the concept that wire brushing can improve mechanical properties and corrosion resistance of AZ31 magnesium alloy sheet.

The article [14] presents results of microhardness study after wire brushing of 6061-T6 aluminum alloy. In order to improve the understanding of the process of material removal, scanning electron microscopy was used.

The authors of the article [10] presented results of surface layer properties after wire brushing of 3103 and 7075 aluminium alloys. Significant increase of microhardness was observed for low values of feed rates and high values of rotational speed after wire brushing of 3103 and 7075 aluminium alloys.

Milling is one of the most commonly used processes in industry for machining parts of precise sizes and shapes. Unfortunately, when the tool leaves the part during machining operations, burrs can form as a result of material plastic flow. Currently there are many different definitions and classifications of burrs depending on the manufacturing process, shape, mechanism of burr formation and the type of treatment [2, 6, 12].

In many cases, there is a need to change the edge states after milling, because edges with burrs can sometimes cause difficulties in assembly operations, where high accuracy is needed. On the other hand, if burrs do not have to be removed from a workpiece for accuracy reasons, they can be very sharp and dangerous for workers and consumers, because they can cause injuries and scratches. According to ISO 13715 edge state is a geometrical shape and the size of the edge. External edge of the part can be sharp, with undercut or with burr [7].

State of an edge can be changed with the use of a variety of methods. The most common ones include hand deburring, grinding, milling. There is a group of methods using abrasive media such as vibratory finishing, abrasive flow machining, and magnetic abrasive finishing. Burrs can be removed by using chemical, electrochemical or thermal treatment. These methods are widely described in [1, 3, 4, 13].

Wire brushing is one of burr removing methods. Low cost of tools which can be mounted in a milling center gives the perspective of developing this method.

The article was aimed at presenting the results of brushing process upon edge radius after wire brushing of AZ91HP magnesium alloy. Three kinds of brushes were tested with different types of fibers and the diameter of a single fiber. Brass and steel brushes were used.

MATERIALS AND EXPERIMENTAL CONDITIONS

The workpiece material used during the experiment was AZ91HP magnesium alloy, commonly used in aerospace industry and many other branches of industry, due to low density and good mechanical properties such as castability and machinability. Cubicoid samples with dimensions of 15x10x50 mm were used. The chemical composition and physical properties are presented in Table 1.

Experiments were carried out on a vertical milling center FV 580a. Before brushing the samples were milled with the use of fixed parameters.

The experiment was carried out with the use of three different circular brushes with a diameter of 120 mm, brush-B1: brass filament with fiber diameter 0.2 mm, brush B2: steel filament with fiber diameter 0.2 mm, brush B3: steel filament with fiber diameter 0.3 mm. The main difference between these brushes is that the brass brash is very flexible. The use of fibers with a bigger diameter results in greater rigidness. Dry brushing was carried out. The brushing parameters are presented in Table 2. For each sample two passes were carried out, first pass with the right hand spindle rotation and second return pass with the left hand spindle rotation. Two passes provide the stability radius of the rounded edge. Specimen orientation and brushing kinematics are presented in Figure 1.

To represent the edge outline after brushing replica method was used with Plastiform LK-AD two-component mass. Polymerization started after mixing the two components. Its characteristics

Table 1. Chemical composition and physical properties of AZ91HP magnesium alloy

<table>
<tr><td rowspan="7">Chemical composition (%)</td><td>Cu</td><td>0.016</td><td rowspan="7">Physical properties</td><td>Rm (MPa)</td></tr>
<tr><td>Mn</td><td>0.17</td><td rowspan="2">20–240</td></tr>
<tr><td>Mg</td><td>89.61</td></tr>
<tr><td>Zn</td><td>0.72</td><td>$Rp_{0.2}$ (MPa)</td></tr>
<tr><td>Si</td><td>0.03</td><td rowspan="3">150–170</td></tr>
<tr><td>Fe</td><td>0.002</td></tr>
<tr><td>Al</td><td>9.45</td></tr>
</table>

Table 2. Brushing parameters used during the experiments

No.	Feed rate, v_f (mm/min)	Cutting speed, v_c (m/min)	Feed-in, *a* (mm)
1	370	422	3
2		844	
3		1266	
4		1689	
5	140	1266	
6	370		
7	1000		
8	3700		

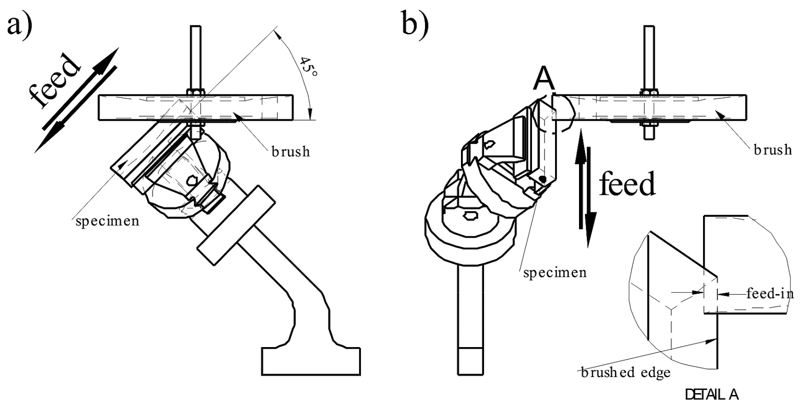


Fig. 1. Specimen orientation during brushing on a vertical machining center FV 580a: a) front view, b) side view

ensure moulding with high level of detail accuracy and faithful replicas. Cross sections of replicas were analyzed under a microscope. Scaled images were imported into AutoCAD software. An example replica specimen is shown in Figure 2. Circle radius inscribed in a rounded edge determines the edge radius after brushing. The experiment was repeated five times. The radius was measured six times at each edge.

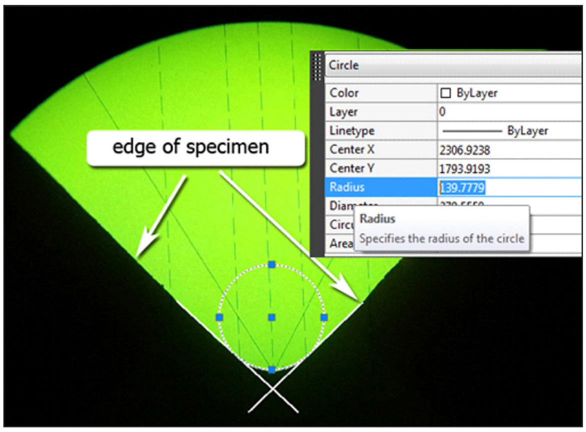


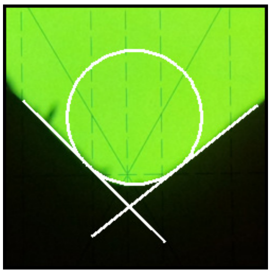
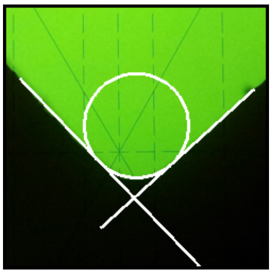
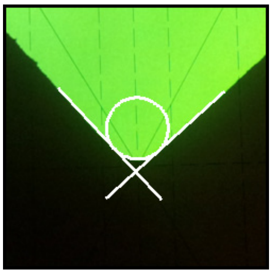
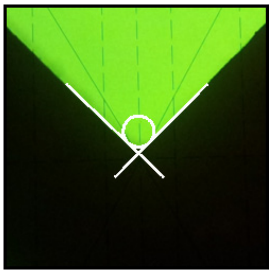
Fig. 2. Radius determining method

RESULTS

Milling process led to the burr formation on the specimen edges. The average value of burr height of AZ91HP magnesium alloy was 43µm. In order to remove burrs, brushing process with different parameters was used. Table 3 presents an example a replica cross section views of rounded edges for B2-brush and corresponding views of real edges after wire brushing. Figure 3 presents edge states after brushing with different parameters for brass brush. B1-brush with very flexible brass fibber is unable to remove burrs for most of the used parameters. Only at the highest brushing speed when the kinetic energy is greatest, burrs were removed, but the edge radius was very small. Another case in which the B1-brush provide effective burrs removal was for feed rate v_f = 140 mm/min. In this case the contact time of brush with specimen is long enough to remove burrs. However, from an economic point of view, it is important to reduce the time of deburring process.

B2 and B3 brushes provide an effective deburring process for the whole range of technolog-

Table 3. Replica cross sections and real views of rounded edges after brushing

v_f = 140 mm/min	v_f = 370 mm/min	v_f = 1000 mm/min	v_f = 3700 mm/min
			
Real view of brushed edges			
			

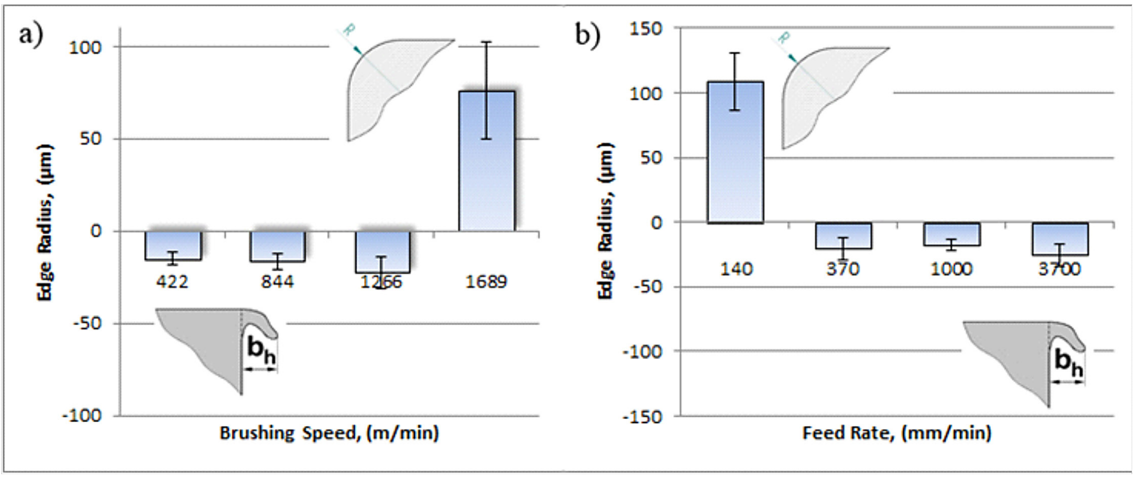


Fig. 3. Influence of brushing parameters upon edge radius for B1 brush: a) variable brushing speed, b) variable feed rate

ical parameters. When brushing speed increases, the edge radius increases as well. Edge radius changes ranging from 120 µm to 600 µm were observed for B2-brush, what is shown in Figure 4.

The highest values of edges radius compared to other brushes were observed for B3-brush. Tool rigidity caused a strong impact on the area at the edge. The largest edge radius was almost 700 µm for feed rate v_f = 140 mm/min.

Strong plastic deformation for the highest brushing speed and the lowest feed rate translate into a higher standard deviation.

CONCLUSIONS

In this study a simple and inexpensive method for deburring process was presented. The effect of brushing parameters upon edge radius of AZ91HP magnesium alloy was investigated. Additionally, three types of brushes were tested for the impact of the fiber material, fiber diameter, on edge radius. The following conclusions summarize the results of the performed experiments:

- tool stiffness is important in deburring process,

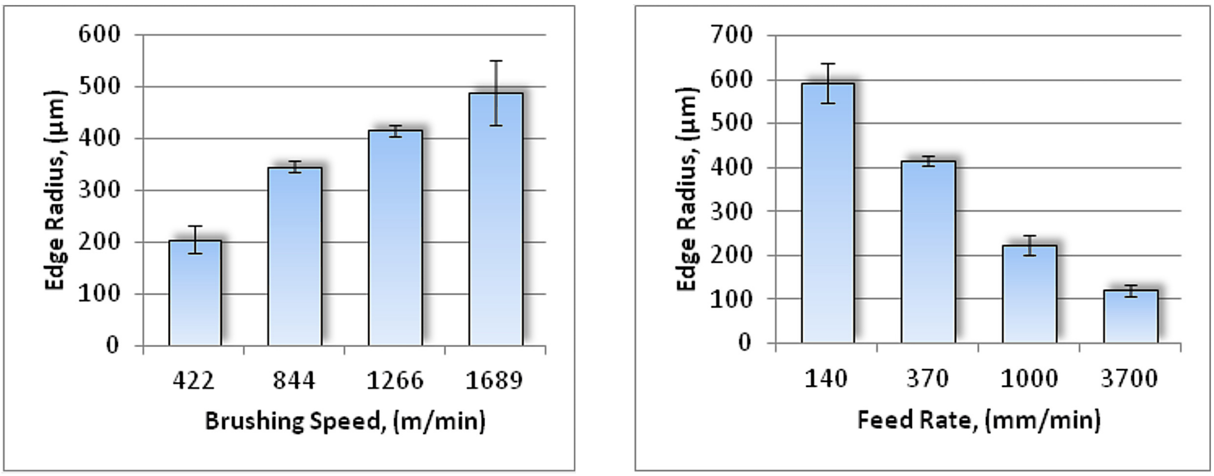


Fig. 4. Influence of brushing parameters upon edge radius for B2 brush: a) variable brushing speed, b) variable feed rate

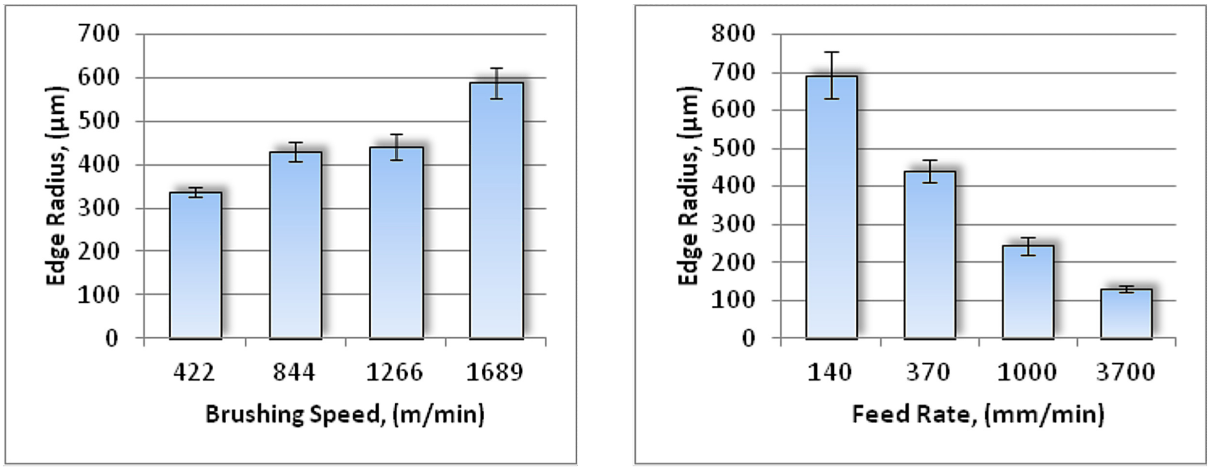


Fig. 5. Influence of brushing parameters upon edge radius for B3 brush: a) variable brushing speed, b) variable feed rate

- the state of the edge can be precisely controlled by the brushing parameters,
- with the increase of brushing speed edge radius increases,
- the edge radius increases with the decrease of feed rate, which is due to a longer contact time with the brushed edge.

During brushing process, a significant increase in temperature was observed. Future research will focus on the analysis of the surface layer after deburring by wire brushing.

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