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Research of the Cutting Possibility of Magnesium Alloys with Abrasive Diamond Wire Saw

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Wire saw technology is a method that works great in industrial applications – it is a dominant method in the production of silicon wafers. But almost all kinds of brittle materials (ceramics, rocks, meteorite and minerals or wood) can be cut using wire saw. Question, this article will try to answer is whether this is also applicable to magnesion alloys? Article presents selected problems from an area of abrasive treatment of magnesium alloys. This includes effects of research, concerning possibilities of application of abrasive diamond wire in the process of cutting magnesium alloys AM60 and AZ91 as well as results concerning surface quality obtained after cutting with the abrasive diamond wire German Company HK Präzisionstechnik.

Keywords: diamond wire, wire saw, magnesium alloys.

1. Introduction

Cutting technology using abrasive diamond wire is mainly associated with slicing of monocrystalline and polycrystalline silicon ingots [1, 2, 3]. But this precision method can be also used for different materials like geological samples, ceramics, carbon fiber, composites and many more [4, 5, 6]. Nowadays this method is being used in many applications across hundreds of industries, universities and laboratories.

Concentrating on laboratory applications it is necessary to emphasize that there is no more universal tool that can cut very hard materials, very brittle, very expensive and rare, also on very thin and small samples. Simultaneously a small cutting width generates very low loss of material [7, 8].

In this article experimental research was conducted to investigate the possibility of cutting magnesium alloys with abrasive diamond wire. The wire cutting method was chosen due to low surface damage and narrow kerf. It was crucial because of the type of samples being prepared for microscopic research. In samples of magnesium alloys inner threads were made and the goal was to cut samples in half to expose the surface of threads. Considering small diameter of threads (M 2,0) majority of cutting methods were destroying samples. Mentioned problem decided about the attempt of application cutting with diamond wire.

2. Magnesium alloys

A low density of magnesium alloys, corrosion resistance and the ability to dampen vibrations are the particular characteristics that make the role of this material continuously increase [9, 10]. Magnesium alloys find application in different industries i.e.: automotive, air, electronic, medical, sports (Fig.1).

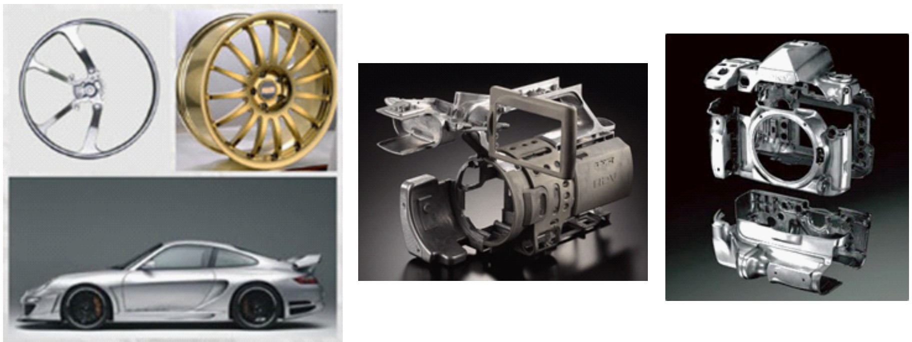

Figure 1 Examples of components made of Mg alloys for the needs of the electronics industry and aviation [11, 12]

They accompany us in everyday life, when we use laptops, mobile phones and household appliances. Increasing use of magnesium alloys as structural material stems from desire to reduce weight of products. It is especially noticeable in the areas of transport, where lighter automotive or aviation constructions contribute to reducing fuel consumption. Therefore in a growing number of industries, so-called light metals, with density less than 4,5 g/cm^3 [13] find numerous applications. Magnesium alloys have a good machinability [9, 10, 13]. However, depending on machining type and conditions, following problems can occur:

– the risk of chip ignition,

– inaccuracy of shape and size due to thermal deformations,

– inferior finished surface quality due to adhesion and the creation of buildup edge,

– formation of hydrogen during processing with cooling emulsions [9, 10].

Abrasive machining of magnesium alloys can be very effective if provided with appropriate tools and compliance with the basic safety rules, related to the risk of micro-chips ignition [9, 10]. Filling of the chip space on active surface of tools may result in increased cutting force and the temperatures that lead to intensive tool wear [9, 10, 13].

Machining of magnesium alloys is often accompanied by the phenomenon of accretion edge, which adversely affects the condition of the surface layer of the workpiece. Moreover, burrs often appear at the point of exit of the machining tool from the material, and they must be removed.

Cutting is one of the basic operations used in manufacturing processes. Depending on technological requirements and purpose of the shaped element, cutting may be the first operation prior to further processing, or the first and the last, so-called ,,cut on demand" [7, 8]. Cutting plays a very important role in manufacturing processes, but even so, its importance often lessens when compared with other types of machining.

3. Magnesium alloys selected for research

Cutting tests were conducted on casting magnesium alloys AM60 and AZ91. Alloy AM60 is characterized by an increased flexibility and a possibility of cold processing, due to the addition of manganese (∼min of the 0,13%). Addition of aluminum (∼ 6,5%) increases the hardness and endurance properties [10, 14]. This kind of alloy finds application mostly in the car industry e.g. as steering wheel armature [11, 12]. A great endurance and hardness also characterize AZ91 alloy (9,7% Al and min Mn 0,13%) therefore it is applied widely in electronics, electrical engineering and car industry as lids, casings and housings [13, 14]. Their selected properties and chemical composition are shown in Tables 1 and 2. The figures relate to raw casts, without additional thermal treatment.

Table 1 Selected properties of cast magnesium alloys selected for the study [14]

Alloy	Density [g/cm^3]	Tensile strenght Rm [MPa]	Yield strenght [MPa]	Elongation A_5 [%]	Brinell hardness [HB]
AM60	1,80	190-250	120-150	4-14	55-70
AZ91	1,81	200-260	140-170	1-6	65-85

Table 2 Chemical composition of magnesium alloys AM60 and AZ91 [14]

Element [%]	Al	Mn	Si	Cu	Zn	Ni
AM60	5,97	0,27	0,032	0,002	0,036	-
AZ91	9,61	0,19	0,028	0,003	0,62	0,001

4. Methodology and research conditions

Cutting was carried out on the wire saw PS4 (Figure 2a), with use of diamond abrasive wire (Figure 2b), by German company HK Präzisionstechnik. HK abrasive wires with commercial designation SD-0,9-2500-G10-3D126 are tools in the form of endless loops connected in the butt welding process. Diamond grains are embedded on the wire surface through a galvanic coating process. Diameter of the wire is about 1000 μm, the size of grains is in the range 120/140 μm [15].

a) b)

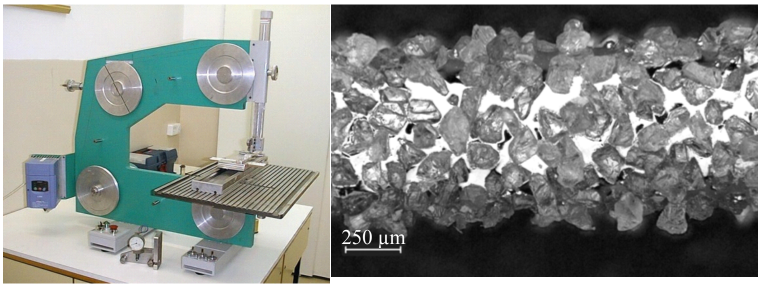

Figure 2 Research position and tool applied in examinations: a) general view of the cutting machine, b) view of the active surface of HK wire

Table 3. The measured values of roughness in feed direction

		AZ91	AM60
vc [m/s]	Fd [N]	Ra [μm]	Ra [μm]
5	3,95	0,72	0,53
5	4,5	0,71	0,62
5	5,65	0,72	0,55
5	6,2	0,58	0,8
10	3,95	0,69	0,69
10	4,5	0,71	0,68
10	5,65	0,72	0,93
10	6,2	0,71	0,85
15	3,95	0,63	0,75
15	4,5	0,65	0,78
15	5,65	0,68	0,8
15	6,2	0,72	0,58
20	3,95	0,68	0,66
20	4,5	0,65	0,72
20	5,65	0,68	0,65
20	6,2	0,59	0,63

Cutting was conducted at four values of speed of v_c = 5; 10; 15; 20 m/s, as well as at four values of downforce material to wire of F_d = 3,95; 4,5; 5,65; 6,2 N. Wire tension was constant (145N).

Abrasive diamond wires are tools commonly used in the process of cutting hard - machinable nonmetallic materials [3, 7, 8]. Although during literature studies no information was found about the possibility of using this type of tool for cutting magnesium alloys. Due to lack of information relating to cutting parameters they were chosen experimentally. Safety rules used in these trails were the same as in the case of abrasive machining. Cutting was run without cooling.

Samples with inner threads made in magnesium bars were cut without any problems. The samples of cross section of threads were received for further microscopic research (Fig. 3). Threads weren't damaged during cutting process unlike when using other cutting tools.

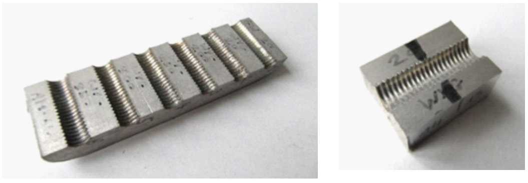

Figure 3 Samples of threads made in magnesium alloy – view od cross – section after wire cutting

After completing the cutting process, obtained samples were subjected to surface roughness measurement. To graphically describe the surface roughness parameter Ra was selected. Profiler Taylor Hobson Talysurf 120L was used in studies of surface texture. Table 3. shows the average measured values of roughness.
At the cutting stage it was noticed, that alloys showed different machinability. Process of cutting alloy AZ91 was more time-consuming. However parameter Ra dispersion was small for the entire cutting speed range and the downforce material to wire. In the case of AM60 alloy for the same cutting conditions, greater efficiency was achieved, but the dispersion of the Ra value was significant. Alloy AZ 91 "behaves" stable while cutting, whereas effects of cutting alloy AM60 were unpredictable.

Figure 4 shows exemplary results of the effect of cutting parameters on the value of parameter Ra. Cutting of magnesium alloys was accompanied by slight abrasion wear of the tool. It is important to note that filling chip space of the wire with magnesium dust can become a significant problem. It affects the cutting forces and can lead to a danger of ignition. However, microscopic observations showed that the degree of clumping in the chip space of the tool was very small and negligible, as shown in Figure 5.

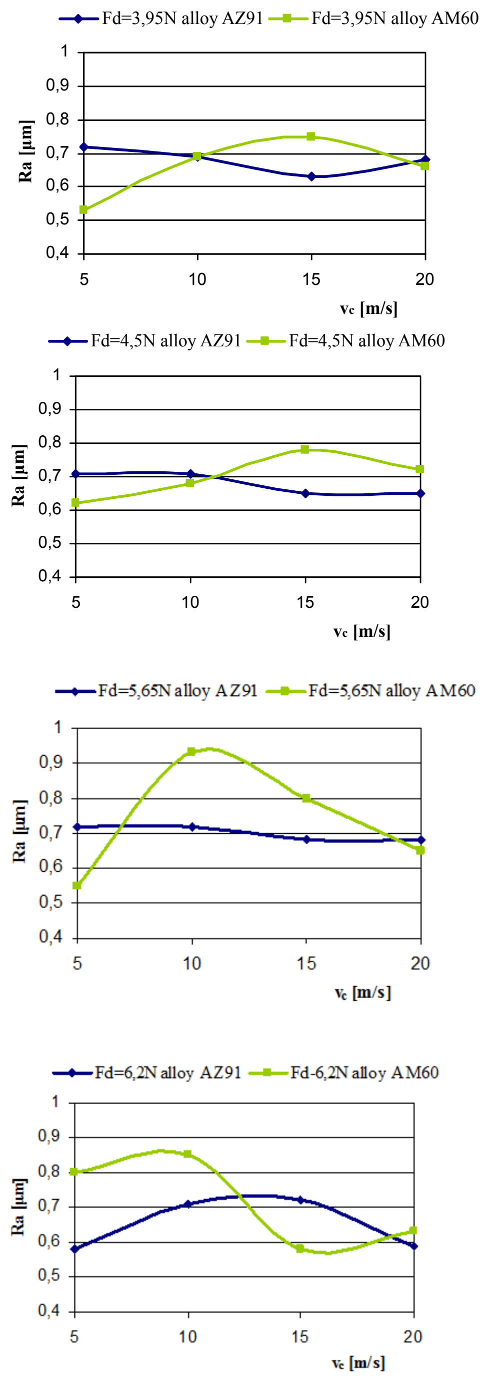

Figure 4 Ra parameter as a function of cutting speed for variable downforce material to wire

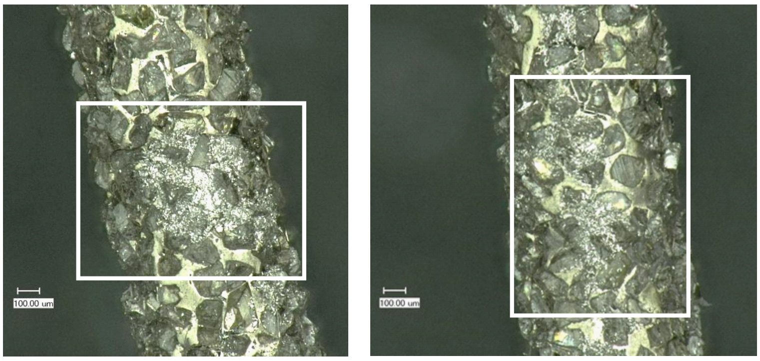

Figure 5 Local areas of fulfilled chip space on wire active surface

5. Summary

The main objective of the research was to determine the possibility of using abrasive diamond wires to cut selected magnesium alloys. In the absence of any information in the literature regarding the cutting parameters and safety measures for this type of tools, research was guided by the recommendations for grinding magnesium alloys. The values of obtained roughness parameter Ra and the state of the active surface of the tool during different stages of research were analyzed. Microchips which arise during cutting had an unfavorable form of very fine dust, which involves a risk of ignition. Magnesium dust (cutting carried out without cooling) is also a danger for the operator (health effects) and requires a very accurate cleaning of machine after completed tests. Selected speed range of cutting resulted in only a slight increase of the temperature of both: the material and the tool, which is characteristic for wire cutting.

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