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Device of magnesium alloy grinding using periodic cleaning of the grinding wheel cutting surface of during machining

Sposób szlifowania stopu magnezu z okresowym czyszczeniem czynnej powierzchni ściernicy w trakcie obróbki

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In the paper the range of requirements concerning grinded surface layers for deposition of protective PVD coatings on magnesium alloys has been presented. Also difficulties concerning the preparation of surface layer and literature review have been depicted. For solving of the problems concerning proper preparation of magnesium alloy surface layer the conventional grinding process using ceramic grinding wheels and the process of cleaning of GWCS (Grinding Wheel Cutting Surface) during machining has been applied. The machining parameters has been determined and the surface geometrical structure has been assessed using optical profiling in 3D configuration.
KEYWORDS: magnesium alloys, grinding, ceramic grinding wheels, surface geometrical structure, cleaning of CSGW

Magnesium alloys are a very attractive construction material, characterized by, among others: high ratio of mechanical strength to mass, very good thermal conductivity, low thermal expansion, good machinability and good casting properties as well as high functional integrity, enabling production objects in the shape of a semi-final. For these reasons, they are widely used, especially in those industries where weight reduction is essential, e.g. in the automotive, aerospace and sports equipment industries [1].

Unfortunately, magnesium alloys also have disadvantages, the greatest of which is high corrosion susceptibility, especially electrochemical, causing both loss of mass and reduction of mechanical strength [1]. Other significant defects of magnesium alloys include, among others: low resistance to wear, loss of strength at high temperature and interference with the electromagnetic field. Magnesium alloys are also difficult to grind and polish because they are mashing during these processes and are very sensitive to the corrosive effect of a lubricant containing water. Hence obtaining a very low surface roughness, required, among others in the process of applying protective-decorative coatings using PACVD plasmo-chemical method (Plasma Activated Chemical Vapour Deposition), it presents great technical difficulties [2–5]. An additional requirement is the lack of anti-pollution products in the surface layer (SL).

A commercial magnesium alloy AZ31HP (high purity), which is characterized by very good mechanical properties, is weldable, susceptible to plastic working and machining (tab. I).

TABLE I. Composition and properties of magnesium alloy AZ31HP

Chemical composition (% of weight)	Physical and mechanical properties
Al: 2.5÷3.5; Mn: 0.20; Zn: 0.7÷1.3; Si: 0.10; Fe: 0.005; Ni: 0.005; Cu: 0.05; Ca: 0.04; Mg: remaining	Density: 1.77 g/cm^3
	Melting point: 605˚C
	Hardness: 50 HB
	Tensile strength: 260 MPa
	Limit of plasticity: 200 MPa
	Young's modulus: 45 GPa

In order to meet these requirements, a smooth-abrasive machining of the AZ31HP magnesium alloy was developed with a conventional ceramic bonded grinding wheel, in which cleaning of its active surface during the grinding operation was envisaged.

During the grinding process of magnesium alloys – similarly as materials containing chromium, nickel, aluminum or titanium [6] – on the surface of the grinding wheels, the areas to which the work material adheres are created, which limits the cutting ability of the tool. The sludge rubbing can be reduced by optimizing the process parameters, using liquid cooling lubricant (LCL), grinding wheel design and cleaning [6, 7]. The methods of cleaning grinding wheels aimed at removing adhered material particles include cleaning with a laser beam, high-pressure water jet or water-abrasive stream [7, 8]. As mentioned, water has a corrosive effect on magnesium and cannot be used to clean the grinding wheel.

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This paper presents the results of investigations of an alternative grinding wheel cleaning method carried out in a mechanical manner with a rotating flexible brush (patent protection).

Experimental research

The tests were carried out on a SPG 30 × 80 surface grinding machine. 10 × 50 mm samples were ground in depth. The conditions for dressing the grinding wheel and the grinding process are presented in the table II.

TABLE II. Test conditions

Grinding wheel characteristics	Dressing conditions	Polishing conditions
1-350×20×127 M 463 I7 VE01NPB5-35	a_d = 0,01 mm b_d = 1 mm k_d = 2 10 passes, without LCL	a_e = 0,01 mm v_{ft} = 10 m/min v_s = 26.5 m/s without LCL
Legend: a_d – sharpening feed, b_d – diamond rubbing width, k_d – degree of coverage during sharpening, a_e – grinding infeed, v_{ft} – object speed, v_s – grinding speed		

A monocorundum grinding wheel with an open structure was used, in which a mixture of abrasive grains with two granulations, i.e. 46 and 60 in a given volume ratio was used. During the tests, the grinding power P_s, tangential force F_t and normal F_n as well as the temperature of grinding of the mantle thermocouple placed in the sample were recorded. Periodically, after the assumed number of grinding passes, the surface roughness of the sample was measured and photographs of the active surface of the grinder were made. The description of the measurement stand and the conduct of measurements is included in the chapter of the conference monograph [11].

Two methods of conditioning the grinding wheel surface were used in the tests:

- traditional, limited to the procedure of sharpening, seeded diamond dress,
- assisted cleaning, in which besides the dressing procedure, mechanical cleaning of the active surface of the wheel was additionally performed by a rotating flexible brush after a specified number of grinding wheel transitions.

The research allowed to verify the usefulness of grinding wheel surfaces as a way of limiting the loss of their machinability as a result of overfilling. The results of measurements of the quantities characterizing the wheel grinding, the size of the grinding operations and the grinding results for both grinding conditioning variants obtained during the same number of grinding passes were compared.

Test results

Fig. 2*a* shows examples of photos of the same GWCS (Grinding Wheel Cutting Surface) section depicting the development of the mating surface between the fifth and 80th grinding wheel transition. In fig. 2*b*, there is a brightness histogram of the image points and a binary image, which is the basis for determining the statistical parameters describing the grinding of the grinding wheel surface.

The change in the size of the covering surface and relative coverage (related to the entire surface of the analyzed images) during the period of use of the grinding wheel are shown in fig. 3. These are average values determined on the basis of analysis of five photographs of randomly selected locations on the surface of the grinding wheel. Photographs were taken after a specified number of grinding passes, and in the case of cleaning, also after cleaning.

The changes in power related to the grinding process are shown in the diagrams – fig. 4. The marked points depict the maximum power values occurring during the contact between the grinding wheel and the workpiece. They were used to determine the trend line of changes in grinding power. The course of these lines indicates that with the time of the grinding wheel's operation after traditional conditioning there is an increase in the grinding power, and as a result of cleaning, the average grinding power remains at a similar level and increases periodically between successive cleaning operations.

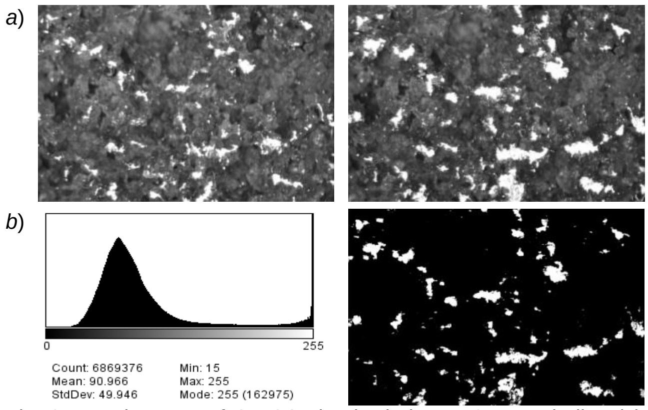

Fig. 2. Development of GWCS plug-in during AZ31HP grinding (*a*), brightness histogram and binary GWCS image (*b*)

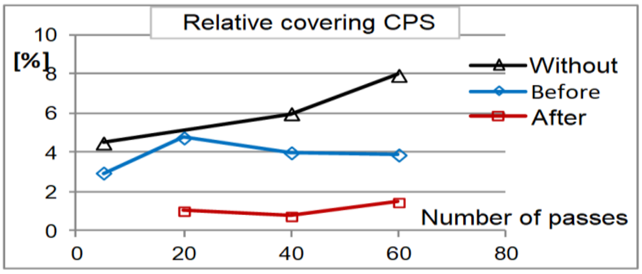

Fig. 3. Characteristics of wheel grinding changes in two ways of the process: traditional (without cleaning) and assisted cleaning (before cleaning, after cleaning)

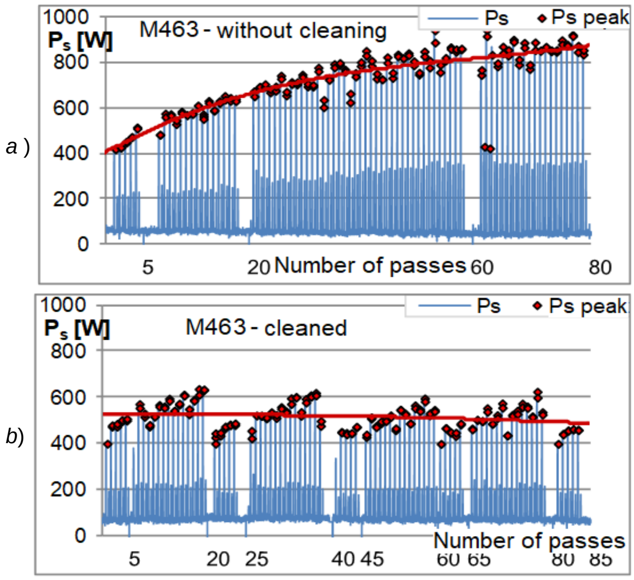

Fig. 4. Grinding power of the AZ31HP alloy grinding wheel with a grinding wheel: *a*) traditionally loaded, *b*) assisted cleaning

The temperature measurement of the thermocouple placed in the sample was interpreted as an index of the abrasive capacity of the abrasive, as the thermocouple's mantle material was not made of AZ31HP alloy, hence its grinding did not directly represent the phenomena occurring in the grinding wheel's contact zone with the sample. The indicated temperature was also a function of the GWCS state shaped by tribologic interaction of the ground magnesium alloy.

Fig. 5 presents graphs of temperature changes registered during the tests. Trend lines, just like in the grinding power diagrams, were determined on the basis of maximum temperatures recorded in each grinding wheel passage. The diagrams of the charts clearly show that the introduction of the abrasive cleaning changed the trend of the signal from increasing to decreasing.

The grinding result was determined by the spatial parameters surface geometric structure, i.e. *Sa* and *Sz* (fig. 6). The results of the measurements indicate that the surface roughness of the abraded cloth is higher, which in addition to dressing was additionally cleaned. This is particularly evidenced by the height inequality parameter *Sz*, which in the range of 10÷15 µm increases to 15÷20 µm. The mean arithmetic deviation of the *Sa* roughness does not change so radically, but here you can also see an increase of 0.1 µm.

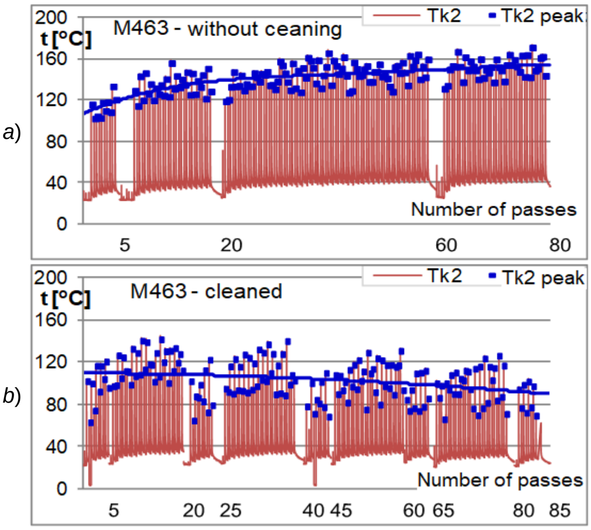

Fig. 5. Temperature of grinding the *K*-type thermocouple placed in the AZ31HP alloy sample with a grinding wheel: *a*) traditionally pulled, *b*) assisted cleaning

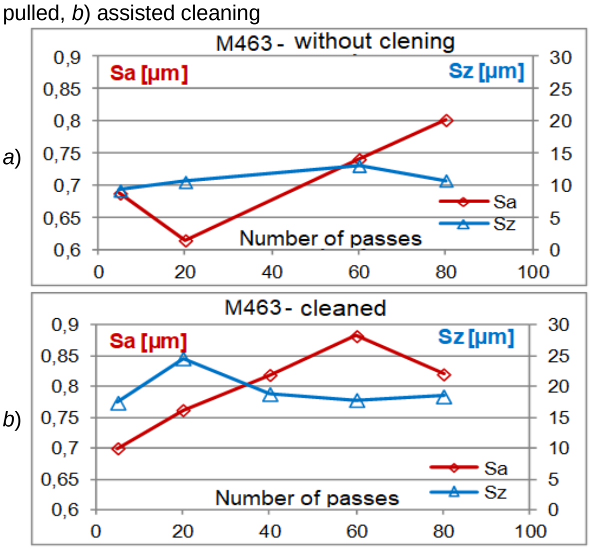

Fig. 6. Surface geometrical structure of AZ31HP alloy specimen ground with grinding wheel traditionally (*a*) and assisted with cleaning (*b*)

Evaluation of test results

The sharp edges and tops of the monocorundum grains, its high self-sharpening capacity as well as the open grinding wheel structure which was used to grind the magnesium alloy, did not ensure that the cutting ability of the grinding wheel was maintained during the economically reasonable period. Typical symptoms of the grinding process were observed, characteristic for the loss of cutting ability by the grinding wheel as a result of overfilling.

On the active surface of the grinding wheel, in the final stage of use, the mating area developed, covering approximately 8% of this surface (fig. 3). The effects of leveling the surface of the grinding wheel with grinding products were the deterioration of the possibility of penetrating the blades into the sample material and the increase of friction. This resulted in an increase in grinding power, the temperature of grinding the thermocouple (fig. 4*a* and fig. 5*a*), as well as the roughness of the sample surface (fig. 6*a*).

Periodic mechanical cleaning of the grinding surface ensured maintaining a constant level (about 1%) of the sizing, which translated into stabilization of the grinding power, and even a decrease in the average temperature of grinding the thermocouple.

The grinding results indicate that mechanical cleaning also affects, albeit to a small extent, the active roughness of the grinding wheel. The removal of the metal wheel attached to the surface of the grinding wheel is accompanied by the chipping of the abrasive grain particles, which results in a reduction in the smoothness of the sample surface.

Conclusions

The results of comparative tests of magnesium alloy grinding processes, in which two methods of grinding wheel use were used, demonstrated the usefulness and desirability of further development of the grinding method based on supporting continuous or periodic GWCS cleaning with a flexible, rotating brush. The short durability of the grinding wheel during the treatment of soft materials resulting from the application of its active surface, and the use to restore the cutting ability of only traditional dressing would be a reason for incurring high tooling costs. On the other hand, supplementing the dressing with GWCS cleaning during the shelf life allows for extending its cutting capacity and achieving the grinding effects required for this type of processing.

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