

Study on the passivation layer in ELID-grinding

B. Kersschot, J. Qian, D. Reynaerts
K.U.Leuven, Department of Mechanical Engineering, Belgium
Bruno.Kersschot@mech.kuleuven.be

Abstract

In ELID-grinding, most frequently cast iron is used as wheel matrix and a thin passivating layer is formed on the wheel surface due to electrolysis. According to the Pourbaix diagram of the main element iron, a protective $\text{Fe}(\text{OH})_3$ hydroxide layer is generated in an alkaline and oxidizing environment. The growth of this layer is an important parameter and has been experimentally examined. The results are reported in this paper.

1 Introduction

Dressing is essential for keeping a superabrasive metal-bonded grinding wheel sharp and for maintaining its cutting capability. These wheels have a better stiffness and durability compared to vitrified or resin bonded wheels but suffer from quick blunting during machining because little space is available to remove the grinding debris. Grinding forces may therefore increase rapidly so these wheels require an efficient and continuous dressing mechanism to get a good protrusion of fresh and sharp abrasives. In ELID-grinding, the metallic bond of the grinding wheel is continuously removed through electrolysis and a passivating layer is formed on the surface. ELID-grinding has proven to be successful to obtain very smooth surfaces, with roughness R_a values in the nanometer range on hard to machine materials like ceramics and cermets [1].

In essence the growth of the layer is a matter of corrosion on the wheel matrix. The idea is to grow a layer so there is a need for a little corrosion. But once there is a firm passivating layer formed on the wheel, the base wheel shouldn't corrode any further.

1 Theory on the passivation of the ELID-grinding wheel

1.1 The Pourbaix diagram

The Pourbaix diagram of a material states the electrochemical equilibriums of the different phases of a base metal under atmospheric pressure and at room temperature. Figure 1 illustrates the Pourbaix diagram of iron in a wet environment [2]. The

abscissa in the diagram states the pH value and the ordinate lists the electrode potential E_H of the solution. Depending on these two parameters one can distinguish 3 different regions (see figure 2).

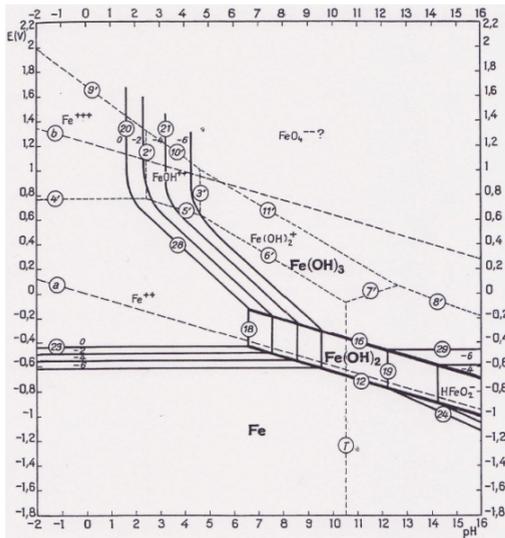


Figure 1: Pourbaix diagram for the system iron-water, at 25°C [2]

In the area of immunity the base metal is not attacked at all, this area is marked with the original element in figure 1: Fe. In the regions of corrosion the material is dissolved and these territories are marked with an ion (e.g. Fe^{2+} and Fe^{3+} in figure 1). In the third area the material is passivated. In this case the material is corroded for a small instance until a protective covering layer has developed. This layer has the ability to inhibit further corrosion if three conditions are met: the dimensions of the elementary cells of base metal and layer are within certain proportions, the layer has a dense and uniform morphology and it is badly soluble. The area of passivation can be expanded by using corrosion inhibitors, like molybdates in the case of iron. These elements form complex substances which cover weak spots in the porous layer. Figure 2 shows the corrosion areas of iron, copper, tin and cobalt. These elements are mostly used as bonding for superabrasive metal-bonded grinding wheels.

The resulting rust layer on iron is actually more complex and is assumed to consist of a thin conductive Fe_3O_4 layer covered with an insulating gel of $Fe(OH)_3$. This hydroxide can transform into $FeOOH$ through ageing, which is even more protective.

1.2 Passivation in the case of ELID-grinding

During the ELID dressing process a hydroxide layer is grown on top of the grinding wheel. A typical ELID liquid mixture, which is diluted with demineralised water, has a pH value of 10.3 and contains corrosion inhibitors. Previous research [3] concluded that cast iron bonding exhibited the best dressing behavior: the ratio of the layer growth to electrochemical removal of the bonding is higher than that for cobalt or bronze bonding. Investigation [4] shows that bronze bonded superabrasive grinding wheels (85% Cu and 15 % Sn) don't develop a protective passivation layer: only corrosion has been observed. This can partly be explained by looking at the passivating areas of Cu (and of Sn) which are relatively small compared to the one of Fe (see the upper hatched areas of figure 2). For the cobalt bonding (70% Co, 25% Cu, 5% Sn) a protective passivation layer was encountered in [4]. The passivation area of Co is situated in a wider range of pH-values for very oxidizing environments.

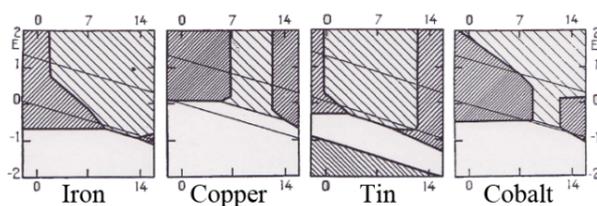


Figure 2: Pourbaix schemes for iron, copper, tin and cobalt [2]

2 Experiments on the dressing mechanism

Figure 3a depicts the setup used for the experiments. The lower part contains a small piece of cast iron bonding (ordered from the Nexsys corporation), indicated by number 4. This part stands for the grinding wheel and is connected to the anodic pole of the power supply. The block is mounted on top of a xyz stage assembly and moves in a reciprocating way at a constant velocity of 3 m/s in the y-direction, indicated by the arrows. The upper part (number 2) is an injection electrode through which the electrolyte is supplied. This cathode can be positioned through one rotational degree of freedom (number 1) for aligning purposes. The gap between both electrodes is an important parameter and is set with the z-slide at 0.2 mm (in most literature a gap width of 0.1 to 0.3 mm is recommended). The cast iron block was partly covered with an isolating lacquer which acts as a reference to measure the grown (hydr-)oxide thickness. In the final experiments the block was divided into 5 equal parts and

dressed for different durations with a Fuji Elider ED921 with parameter setting of 90V, 20A and 50% current duty ratio. Figure 3b shows the oxide thickness, measured with a Zeiss Discover V.20, in function of the dressing time.

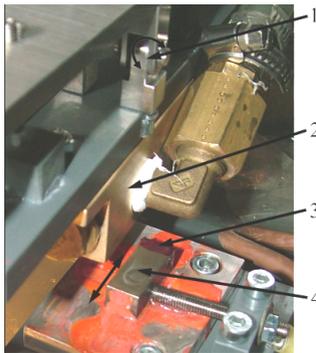


Figure 3a: Dressing setup

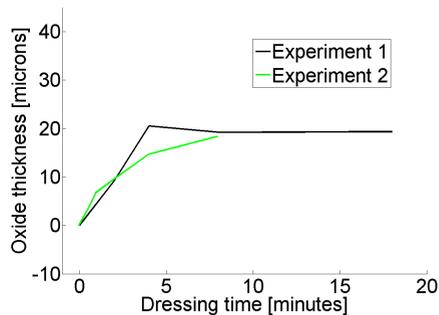


Figure 3b: Oxide thickness vs dressing time

The experiments indicate that the oxide layer mainly grows in the first 5 minutes and saturates at a thickness of about 20 micron. The current density starts at 10 mA/mm² and drops down to 3 mA/mm² from 5 minutes on. Then the oxide becomes denser with dressing time, increasing its electrical resistance.

The layer is very fragile and tends to break when mechanical contact is made. Removal of the oxide will increase the conductivity locally which promotes local electrolysis. Therefore the layer is sustained continuously. A side effect of the loose oxide is that it can act as a thin polishing pad or abrasive powder in the grinding area.

References:

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