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Porous metal bonds increase the resource efficiency for profile grinding

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Abstract

Profile grinding is irreplaceable for the machining of various brittle and hard workpieces, e.g. cutting tools for milling and drilling, seal components made of ceramics and bearing components. Grinding is rather inefficient regarding the energy demand for the machining of one volume element of material compared to other manufacturing processes. However, the process forces can be reduced without influencing the tool wear by using grinding wheels with a porous metal bond and grains that tend to splinter. This allows higher material removal rates without increasing the process forces, ultimately reducing the energy consumption per workpiece manufactured. Additionally thermal and mechanical loads on the workpiece are reduced leading to increased life cycles of grinded products. The application of these grinding wheels is currently on hold for profile grinding since the dressing process is not in control. Therefore, this paper investigates the dressing operation for grinding wheels with a porous metal bond in order to reduce the energy consumption in profile grinding of brittle and hard materials.

Keywords: Resource Efficiency; Profile Grinding; Brittle Materials; Metal Bond

1. Introduction

In terms of the necessary energy for machining one volume element grinding is inefficient compared to other manufacturing processes. Compared to hard milling or hard turning, up to 200% more energy is required during grinding [1]. At the same time grinding is irreplaceable for machining various primarily brittle materials such as cemented carbide or ceramic materials [2, 3]. Especially the profile grinding process is of great importance for the stated applications [4, 5]. Cutting tools such as milling tools or twist drills, ceramic sealing components and bearing components or components made of quartz glass for the semiconductor industry are also processed by profile grinding [6]. Basically, the following two principal approaches are applicable in order to improve the energy efficiency of the manufacturing process.

Coolant pumps have the main impact regarding the total energy consumption of machine tools [7, 8]. The coolant supply is necessary during grinding to dissipate the heat of the process. It was shown for the production of camshafts that the use of minimum quantity lubrication can reduce the total energy requirement by up to 20% compared to flooding lubrication. Therefore, new tool concepts and new machine tool components were used [9, 10]. In order to implement the minimum quantity lubrication strategy, investments in new coolant units are necessary.

The second approach is the attempt to increase the material removal rate in order to reduce the energy consumption per produced part by reducing the machining time. Exemplarily, the application of cleaning nozzles prevents the clogging of grinding wheels. Therefore, the power demand of the spindle is reduced by up to 20% while maintaining a constant material removal rate. Low power demands allow an increase of the material removal rate and therefore an optimization of the energy efficiency is possible [11]. At the same time the cleaning nozzles are dependent on the highly energy consuming coolant pump units.

By using a new kind of metal bond with implemented pores, the spindle power can be reduced by up to 40 % compared to current applications with no need for additional energy

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consuming units [12]. The impact of using porous metal grinding wheels in terms of resource efficiency in general and compared to tools used in the industrial practice is addressed. Additionally, the influence on the ground workpieces and their life cycle performance will be discussed. Since the application of grinding wheels is directly dependent on their dressability, this paper focusses on the dressability and the influence of grinding wheel specifications and dressing parameters on the profile stability of the new bond type. The profile stability is of great importance for the application in the profile grinding process.

2. Porous metal bonds

Diamond grinding wheels with different bonding systems are used for the profile grinding of the materials mentioned before. Multilayer-metal bonds have similar to resin-bonded tools only very small pore fractions. This leads to low grain protrusion and consequently friction between bond and machined workpiece. Thus, the low grain protrusion has a negative effect on the energy efficiency. In contrast to the multilayer-metal bonded grinding wheels, widely used vitrified bonds can be dressed mechanically. They have bigger pore fractions, which leads to less friction in the grinding process. However, their wear resistance is comparatively low. Crushable metal bonds are an attempt to increase the dressability of multilayer-metal bonds by adding graphite inclusions into the bond that serve as artificial pores. This way they can be dressed with high dressing tool wear. Furthermore, the dressed grinding wheels show decreased resistance against tool wear. The conventional multilayer-metal bonds have a high resistance against tool wear and therefore a high profile stability. The main reason for the lack of their wide industrial application is that conventional multi-layer metal bonds are difficult to dress. Processes known in the state of the art, e.g. based on mechanical, optical, electrochemical or electrophysical principles, are either time consuming and or costly.

Novel highly porous metal bonds have the potential to increase the energy efficiency of grinding processes. These tools are similar in construction to vitrified bonded grinding tools, but at the same time show the high thermal conductivity, good profile stability and high grain retention forces of metallic bonds.

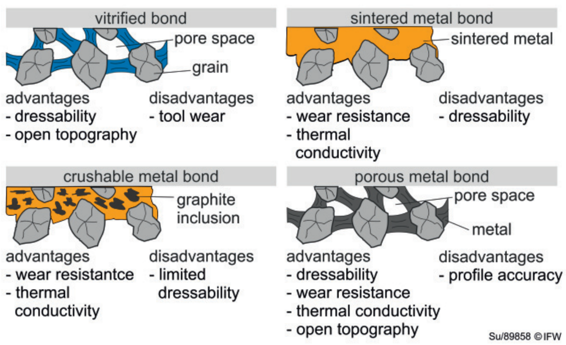

Fig. 1. Grinding wheel structure of the new bond type

Their structure in comparison to vitrified, sintered metal and crushable metal bonds is shown in figure 1. They can be mechanically dressed and provide coolant in the contact zone better than tools with a lower pore content. During profile grinding high thermal and mechanical loads occur since the contact length is higher and the coolant is difficult to distribute in the contact zone. Therefore, the porous metal bond is ideal to be applied in this case considering the tool and workpiece quality. The dressability of the new bond type is presented in this paper and its grinding performance is evaluated in terms of resource efficiency.

2.1. Experimental setup

A Walter Helitronic Vision 400L grinding machine has been used for all dressing and grinding experiments. Cemented carbide probes with the specification “KXF” measuring 10×20×100 mm have been machined primarily by a creep-feed grinding process. In all dressing experiments porous metal bonded grinding wheels with diamond grains have been used. The mechanical dressing process to implement profiles into the grinding wheel can be distinguished into form and profile dressing. While the latter needs less process time it is limited to one shape. Therefore, in this study a so called DDS-form roller is used to verify the dressability of porous metal bonded grinding wheels. This dressing tool consists of CVD-cutting particles implemented into a sintered multilayer bond. The different grinding wheel specifications are shown in Table 1. Profile wear is evaluated by means of imprints of the grinding wheel before and after profiling, after the sharpening process if it is performed and finally after the grinding process. A comparison of the different imprints of the grinding wheels allows the characterization of the profile stability of the new tool type.

Table 1: Grinding wheel specifications used for the investigations

Tool	Grain size	Concentration	Grain type	Porosity
1	D54	D168	Cracking	38
2	D30	D168	Cracking	38
3	D76	D168	Cracking	38
4	D54	D184	Cracking	38
5	D54	F152	Cracking	38
6	D54	D168	Cracking	0
7	D54	D168	Cracking	46

The imprints of the grinding wheels are measured by a Mahr LD130 contour measuring machine in order to estimate the grinding wheel wear at the edges and the loss of the profile. In order to evaluate the grinding wheel topography the process forces are measured parallel to the grinding process. The reaching of a certain grain protrusion level is represented by the performance of the grinding wheel while machining. The stated process steps are summarized in figure 2 and can be seen in the included photographs.