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Automatic Regeneration of Cemented Carbide Tools for a Resource Efficient Tool Production

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Abstract

Cemented carbide tools have become widely established in machining of metallic materials in recent decades. However, due to rising prices of cemented carbide and an imminent scarcity of resources, there is a growing need for an efficient recycling of worn cemented carbide tools. This article presents a novel process chain for the automatic regeneration of cemented carbide tools. The process chain contains the measurement, classification and evaluation of the worn cutting tools as well as the automatic planning and simulation of the grinding process. In comparison to conventional manufacturing of cemented carbide tools the production costs are reduced by up to 50 % and the required resources are decreased significantly.

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Keywords: grinding; regeneration process; cemented carbide tools; measurement; identification; path planning; simulation

1. Introduction

Because of the favorable combination of high hardness with a relatively high toughness and good temperature wear resistance, cemented carbide is excellently suited for machining [1]. Cemented carbide tools resist high loads in the process and enable high cutting speeds. For this reason, cemented carbide tools are used to process difficult-to-cut materials such as titanium [2].

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The production of cemented carbide milling tools is currently carried out in two process steps. In the first step, a cemented carbide blank is sintered to the required diameter (usually as cylindrical blanks) in an energy intensive process. The blanks are either produced entirely from the scarce raw materials, such as tungsten and cobalt, or from an admixture of chemically elaborately recycled cemented carbide. In the second step, the cylindrical blanks are machined by grinding processes in order to create the form elements and functional surfaces of the cutting tool. Despite the large variety of tool shapes, shank tools can be produced in most cases by means of the manufacturing of flutes, end faces and flank faces [3] (Figure 1).

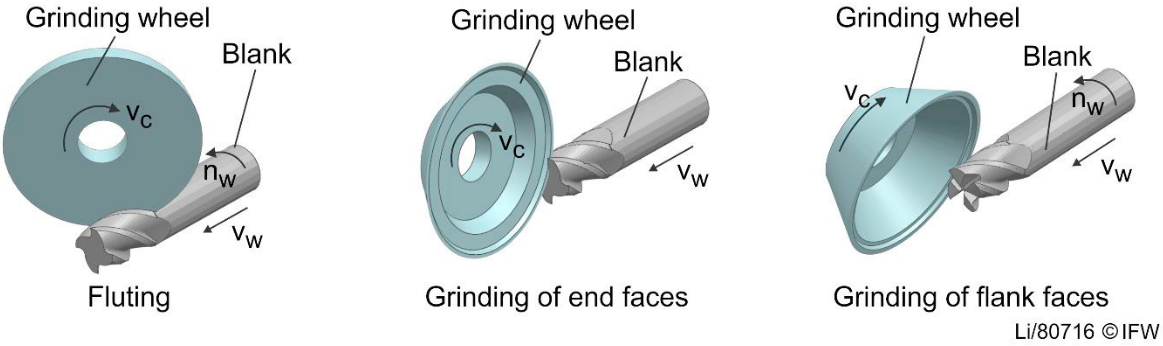

Fig. 1. Manufacturing of shank tools (n_w: rotational speed of workpiece; v_c: cutting speed; v_w: axial feed of the workpiece).

Investigations by [4] show that more than 50% of the total energy required for the production of cemented carbide milling tools is required for the production of cemented carbide blanks. The required energy for producing a blank having a diameter of 10 mm and a length of 73 mm is calculated to 9.01 MJ. In terms of the economical dimension, the costs for material purchase can account for up to 80% of the tool's price [5]. In addition, a large proportion of available raw materials are concentrated in very few countries such as China, Russia and Bolivia [6]. This situation gives the mining countries great market power, which results in a strong economic dependency on the cemented carbide producers. Thus, the recycling of cemented carbide tools is becoming increasingly attractive, despite high costs. In industrial application, worn tools are reused by reground, in which the functional surfaces of the tools are regenerated by grinding. The number of permissible regrinding processes is limited by the type and the level of the damage. If no regrinding is possible or if the tool is severely damaged by large breakouts, the tools are disposed of as scrap. However, conventional recycling techniques suffer from the problem that large quantities of chemicals and energy are used in the purification process, resulting in waste being generated with the consequence that great environmental loads are imposed [5].

Facing the situation, the authors have developed a process chain for a more energy efficient and less toxic recycling process of worn cemented carbide tools. In this method, the worn cemented carbide tools are directly used as blanks for grinding of new tools [6]. Thus, the process chain of recycling is shortened drastically. However, the shape of the worn tool results in complex engagement conditions as well as varying loads on the grinding wheel in the regenerative grinding process. For dealing with these matters, the process load is analyzed using an NC simulation. Based on the simulated results, a process strategy for the regenerative grinding process is developed and experimentally investigated.

2. Process chain for the regenerative grinding process

The planning and optimization of the regenerative tool grinding process is carried out by using a measuring and analysis system, a CAD-CAM system and a simulation module. In a first step, the worn tool is scanned by a 3D measuring system and prepared as a CAD file for use in a grinding simulation. Depending on the application scenario, the measured blank shape can be stored in a blank database or passed directly to the analysis system. A database for managing workpieces is linked to the CAD-CAM system. In the regeneration of a certain worn tool, a search algorithm