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Procedia CIRP 24 (2014) 68 – 73

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New Production Technologies in Aerospace Industry - 5th Machining Innovations Conference (MIC 2014)

# On-machine tool resharpening for dry machining of aluminum alloys

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**Abstract**

The present study proposes a novel strategy for removing the adhesion layer from the tool surface and recovering the cutting tool performance without detaching the cutting tool from the machine tool; namely, an on-machine tool resharpening process, in order to address the issues related to the dry machining of aluminum alloys. A series of experiments clearly showed that the developed strategy employing the phenomenon of liquid metal embrittlement (LME) successfully removes the aluminum adhesion from the tool surface without damage to the tool substrate, and the resharpened tool shows excellent cutting performance nearly equivalent to its virgin state.

Selection and peer-review under responsibility of the International Scientific Committee of the "New Production Technologies in Aerospace Industry" conference in the person of the Conference Chairs: Prof. Berend Denkena, Prof. Yusuf Altintas, Prof. Pedro J. Arrazola, Prof. Tojiro Aoyama and Prof. Dragos Axinte

*Keywords:* On-machine tool resharpening; cutting tool; adhesion: aluminum alloys; gallium; liquid metal embrittlement; dry machining

## 1. Introduction

In recent years, the movement towards minimizing or eliminating the use of cutting fluids; namely near-dry/dry machining, is one of the most important challenges in the field of metal cutting, because the use of cutting fluids increases costs for waste disposal and environmental loads [1-3]. In particular, aluminum alloys are well known as critical materials with regard to dry machining [1, 2]. Without the use of any cutting fluids, these materials severely adhere to the tool surface and form a built-up edge due to their low melting point and high ductility, leading to deterioration of the surface integrity of the workpiece and tool failure. Therefore, a wide range of studies related to cutting tool technologies, including tool materials, geometry, surface coating and surface finishing, have been conducted. For instance, diamond-like carbon (DLC) coated tools are considered to be suitable for dry machining of aluminum alloys [4, 5]; however, a flooded cutting fluid is required in practical use to avoid adherence of aluminum chips to DLC-coated tools [6].

In contrast to the conventional approaches described above, other methods have been developed, such as on-machine cutting-edge forming or tool reconditioning processes, for maintaining performances of cutting tools without detaching the tool from the machine tool. These processes allow for not only increasing the life of cutting tools, but also reducing any positioning error due to tool exchange and the use of rare metals used as tool materials. Kurahashi et al. proposed a repeatable on-machine cutting-edge forming procedure using composite electroplating and electrolytic etching with a $H_2SO_4$ electrolyte, and developed a prototype system for a milling machine [7, 8]. While at the same time, the researchers also pointed out a problem of their procedure that WC-Co cemented carbide tool substrate was consumed in the etching process [7]. On the other hand, Katahira et al. reported an electrochemical technique for reconditioning surfaces of polycrystalline diamond (PCD) tools used for silicon micromachining [9]. The result indicated that the process can successfully remove the surface contamination on the PCD tool and maintain the machining performance. However, the application of this method to the dry machining of aluminum alloys is difficult, because sodium hydroxide which was used as an anisotropic etchant for silicon reacts with aluminum alloys and produces flammable hydrogen gas.


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doi:10.1016/j.procir.2014.07.001

In this study, a new strategy for the dry machining of aluminum alloys that can effectively remove the adhesion layer from the tool surface and recover the cutting tool performances without detaching the cutting tool from the machine tool; namely, an on-machine tool resharpening process, has been developed. The present paper discusses the concrete processes for removing the aluminum adhesion layer without damaging a tool substrate, and a series of cutting experiments was conducted to evaluate the feasibility and superiority of the newly developed resharpening process.

Table 1. Cutting conditions

| | | |
|---|---|---|
| Workpiece | Aluminium A5052 Alloy<br>W 76 (mm) - L 210 (mm) | |
| Tool | Cemented carbide K10, SEKN42M,<br>(Sumitomo Electric Hardmetal Corp.) | |
| Tool geometry | Axial rake angle | 20 degrees |
| | Radial rake angle | -3 degrees |
| | True rake angle | 12.4 degrees |
| | Corner angle | 45 degrees |
| | Cutter diameter | 80 (mm) |
| Cutting speed | 380 (m/min); 1500 (rpm) | |
| Depth of cut | 3 (mm) | |
| Feed rate | 0.12 (mm/tooth) | |
| Cutting fluid | Dry | |

## 2. Dry cutting performance of aluminum alloy

### 2.1. Dry cutting experiments of aluminum alloy

In order to investigate the basic machinability of aluminum alloys and influences of the adhesion layer on the cutting performances without the use of cutting fluids, face milling experiments with a WC-Co cemented carbide cutting tool (Sumitomo Electric Hardmetal Corp., SEKN42M: ISO K10-type, Non-coated tool), which is used most extensively for aluminum alloys cutting, were conducted on an aluminum 5052 alloy using a vertical machining center (Yamazaki Mazak Corp., AJV-18). The experimental setup is illustrated in Fig. 1. The center of the cutter was set on the center line of the workpiece. A dynamometer (Kistler Co., Ltd., 9257B) was set under the workpiece to measure three components of the cutting forces. Table 1 lists the cutting conditions.

Figure 2 shows three-dimensional profiles of the tool rake face measured by using a stylus type profile instrument (Kosaka Lab. Ltd., Surfcorder SE3500K) after cutting for 180 m, 900 m and 1800 m. Figure 3 shows SEM images (Hitachi Hi-Technologies Corp., TM3000) of the cutting tool before and after cutting for 1800 m. As shown in these figures, aluminum chip strongly adhered to the surface of the virgin tool as cutting length increased and formed an adhesion layer under the dry cutting condition. In addition, Fig. 4 and Fig. 5 show changes in the cutting forces in the X and Y directions with respect to cutting length and shapes of removed chips, respectively. These figures indicate that the cutting forces gradually increased and the chip curl diameter became larger with an increase in cutting length, suggesting that the adhesion layer on the tool rake face degenerated the frictional property between the tool and the workpiece.

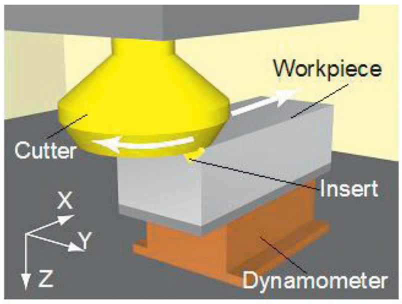


Fig.1. Experimental setup of face milling tests

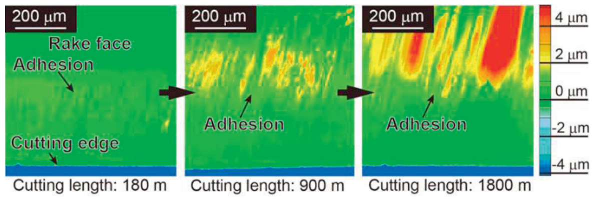


Fig. 2. 3-D profiles of rake face of virgin tool after cutting for 180 m, 900 m and 1800 m

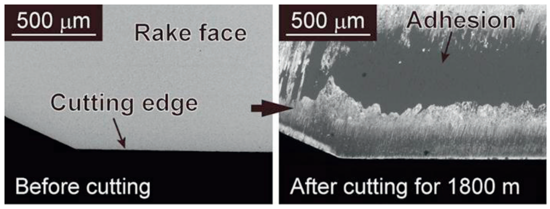


Fig. 3. SEM images of rake face of virgin tool before and after cutting

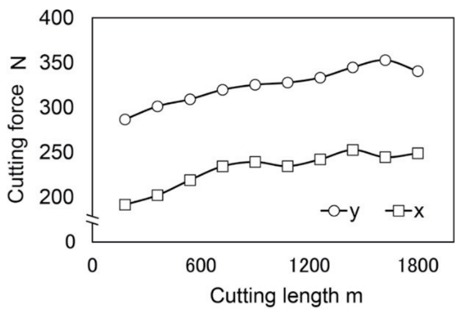


Fig. 4 Changes in cutting forces in X and Y directions with cutting length when using virgin tool

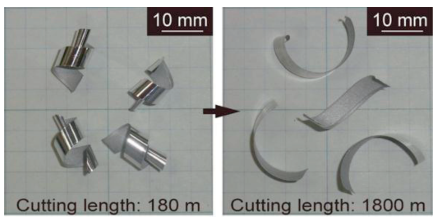


Fig. 5 Shapes of removed chips after cutting when cutting length reached 180 m and 1800 m using virgin tool