

Study on the Burr Formation Process in Micro Milling of High Aspect Ratio Structures

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Research Article

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Abstract

High-aspect-ratio (HAR) micro-structures of harden steel (SKD11) are widely used in the national defense and electronic fields. Micro-milling is a suitable method for machining HAR micro structures, however the inevitable generation of burrs deteriorates the machined surface. Previous studies have mostly focused on the burr formation process of shallow grooves, but have ignored HAR grooves. This paper investigated the burr formation mechanism in HAR (2:1) grooves on harden steel (SKD11). Due to the fact that the burr formation process was difficult to be observed in the actual micro-milling process, a finite element model was established. A corresponding experimental research was conducted, which revealed a good consistency between simulation and experimental results. Moreover, a new burr type was formed on the sidewall of the HAR groove, which was transformed from top burrs and was named as side burr. The results demonstrated that the chip flow on the rake face of the micro-mill was hindered by the sidewall, which caused chip crumbling, chip accumulation, and surface scraping, seriously affecting the burr formation mechanism. This paper revealed the burr formation mechanism for HAR grooves, and provided research direction for improving the machining accuracy of HAR grooves.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the latest manuscript can be downloaded and [accessed as a PDF](#).

Figures

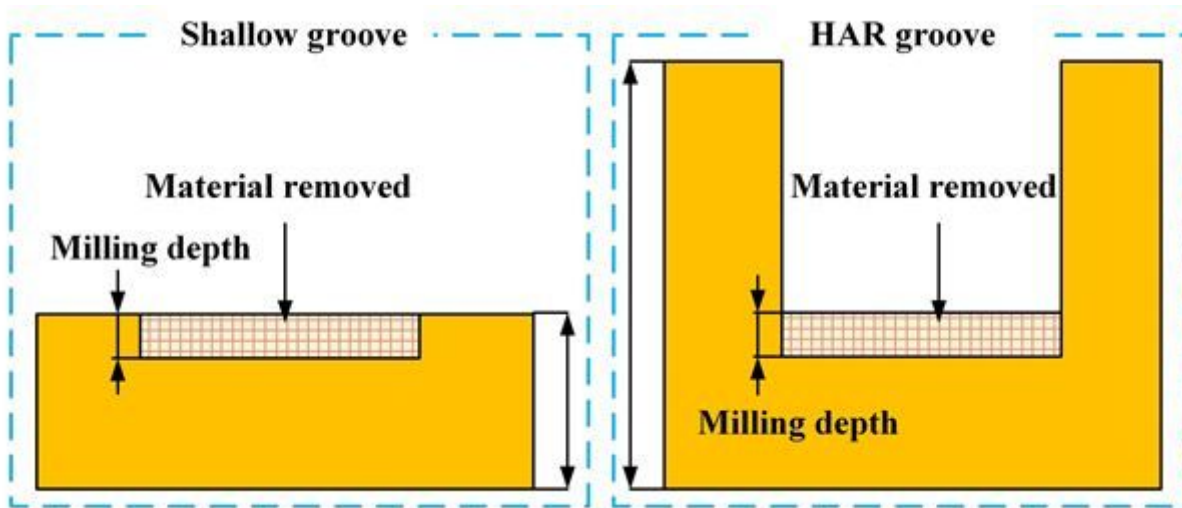


Figure 1

Processing area of shallow and HAR (2:1) grooves

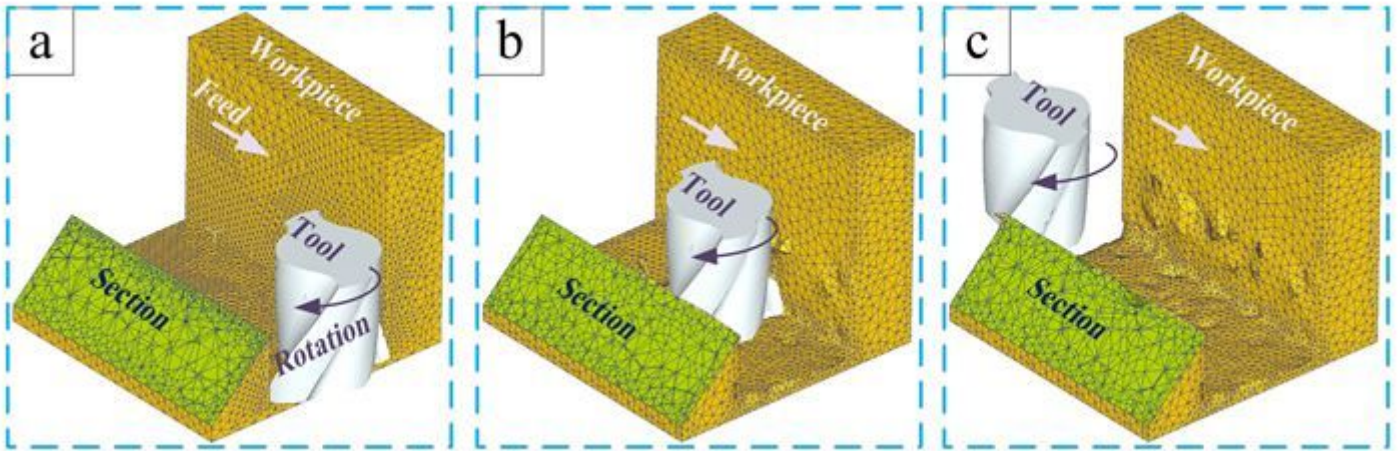


Figure 2

Micro-milling simulation process: (a) start; (b) midway; (c) end

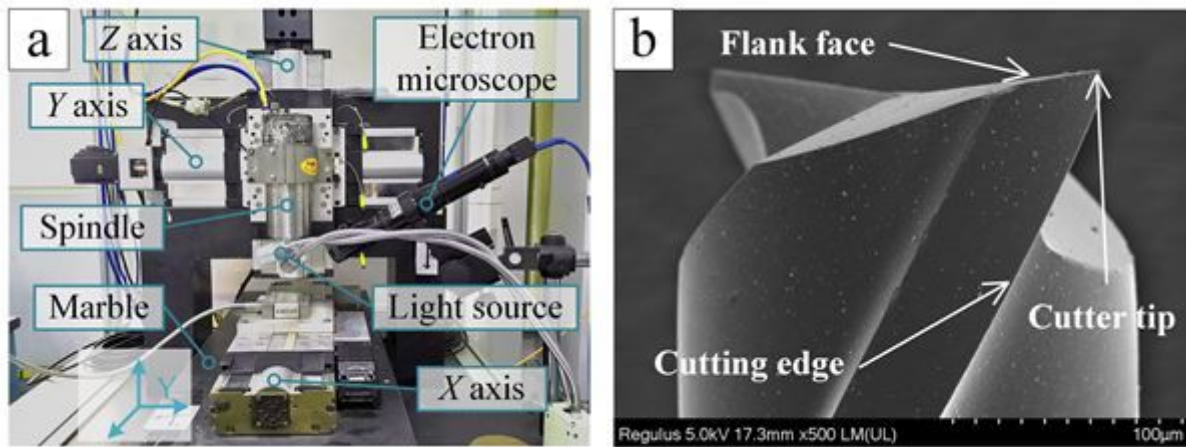


Figure 3

Experimental set-up: (a) micro-milling machine tool; (b) micro-mill

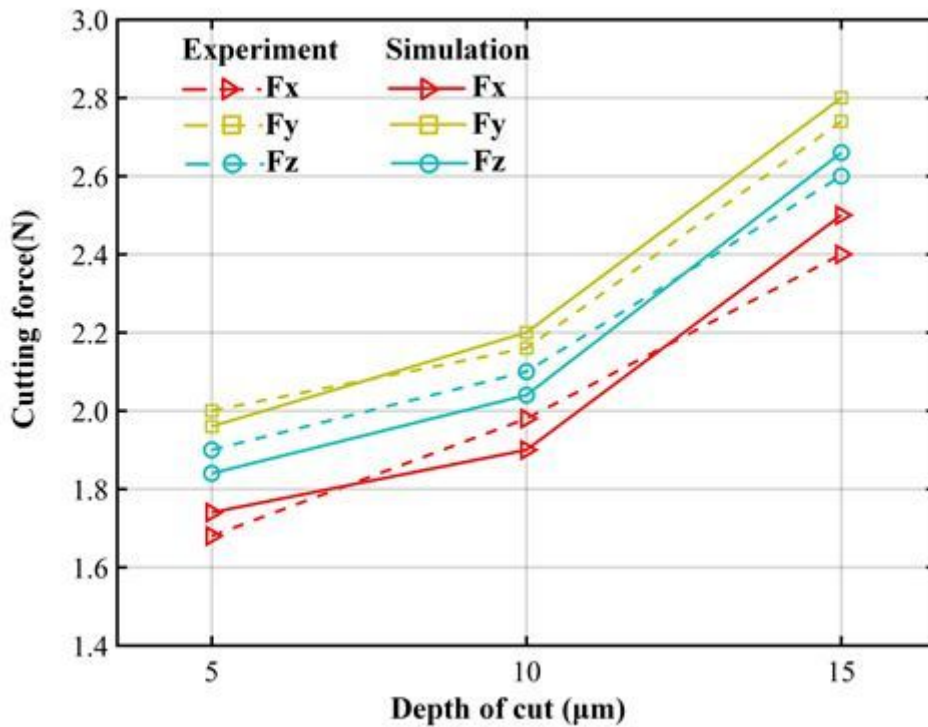


Figure 4

Cutting force between simulation and experiment with different depth of cut

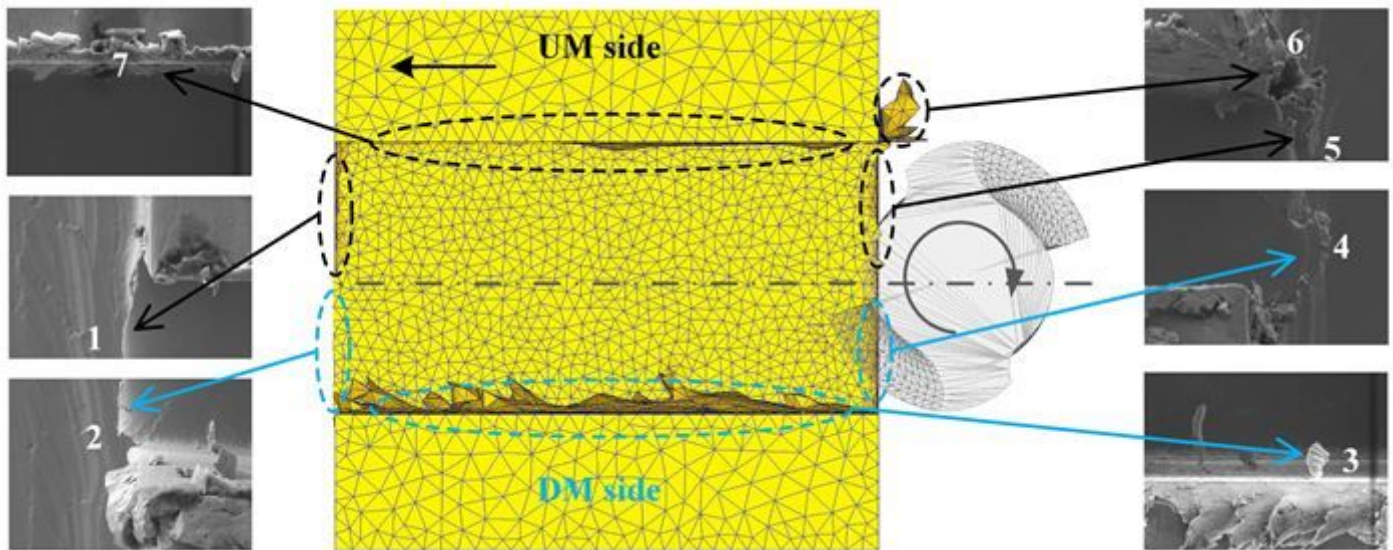


Figure 5

UM and DM sides and burr locations: 1-Entrance burrs on the UM side; 2-Entrance burrs on the DM side; 3-Side burrs on the DM side; 4-Exit burrs on the DM side; 5-Exit burrs on the UM side (at the bottom); 6-Exit burrs on the UM side (at the side); 7-Side burrs on the UM side

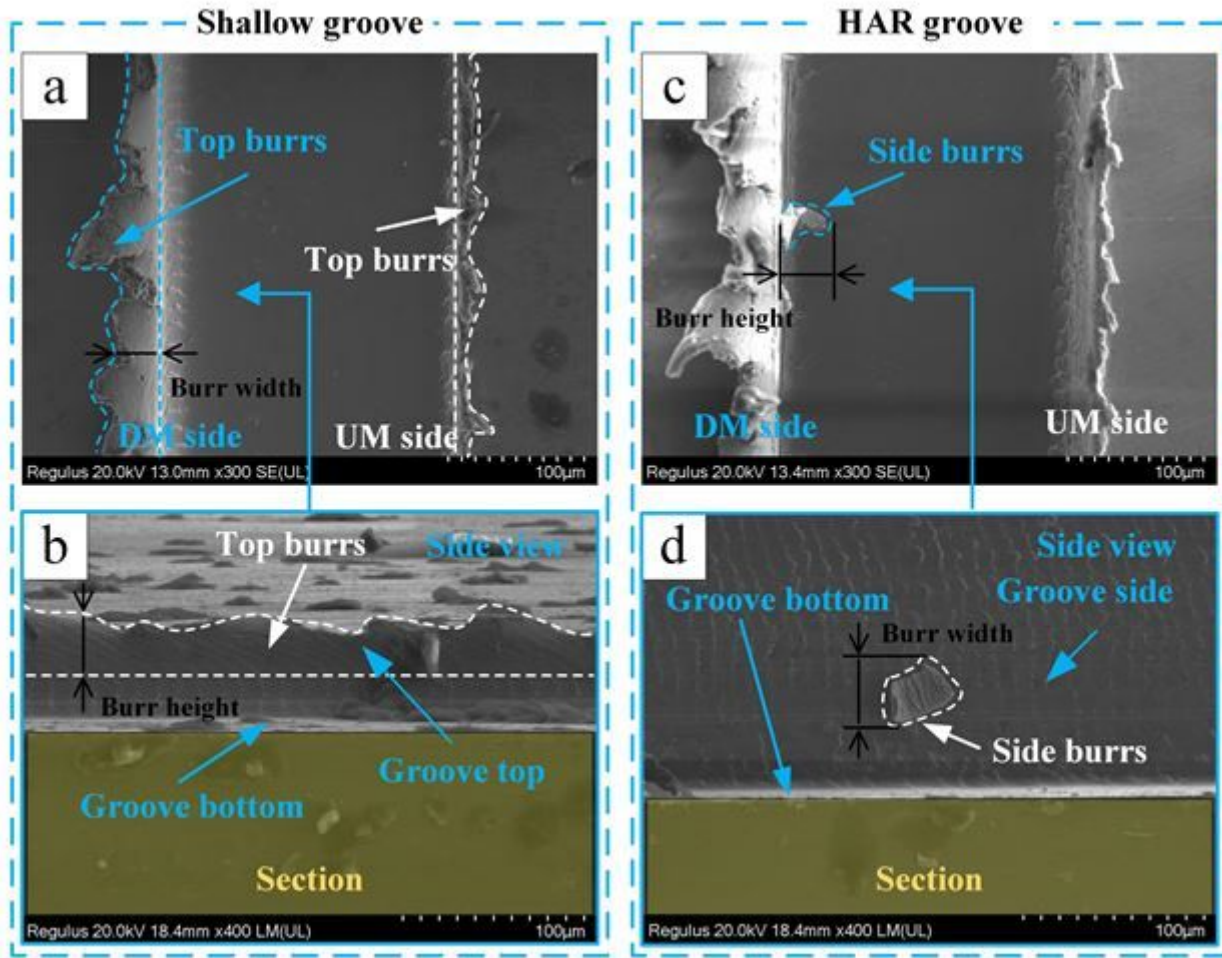


Figure 6

(a) Top burrs of the shallow groove (SEM); (b) top burr of shallow groove on DM side (section view); (c) side burrs of the HAR groove (SEM); (d) side burr of HAR groove on DM side (section view)

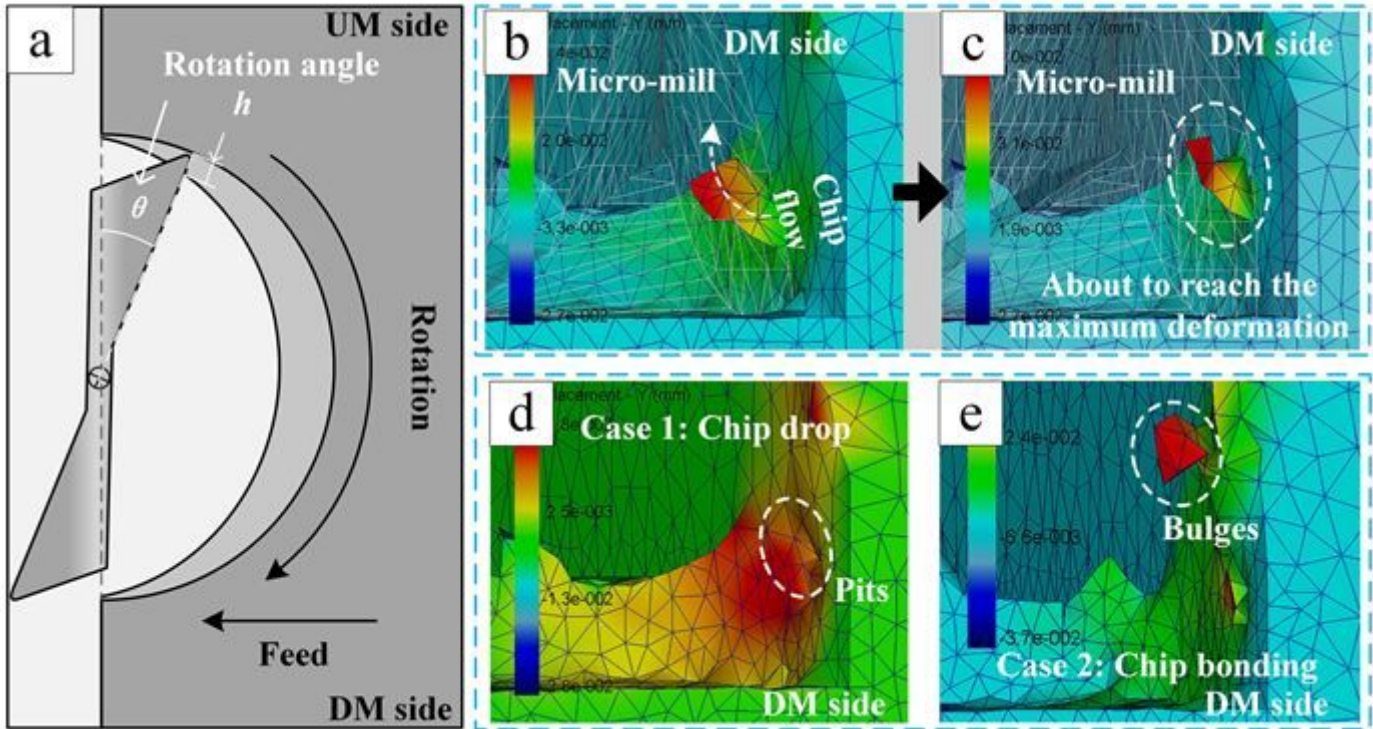


Figure 7

Side burr formation process in the HAR groove during micro-milling: (a) milling area per tooth; (b) chip flow on the rake face; (c) chip about to reach the maximum deformation; (d) case 1: chip drop; (e) case 2: chip bonding

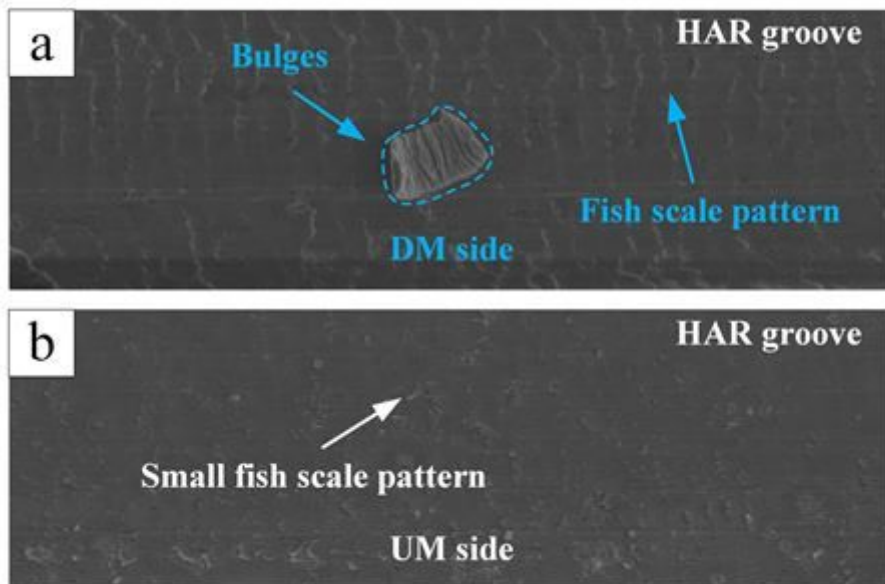


Figure 8

Contrast of side burrs on the DM and UM side of HAR groove

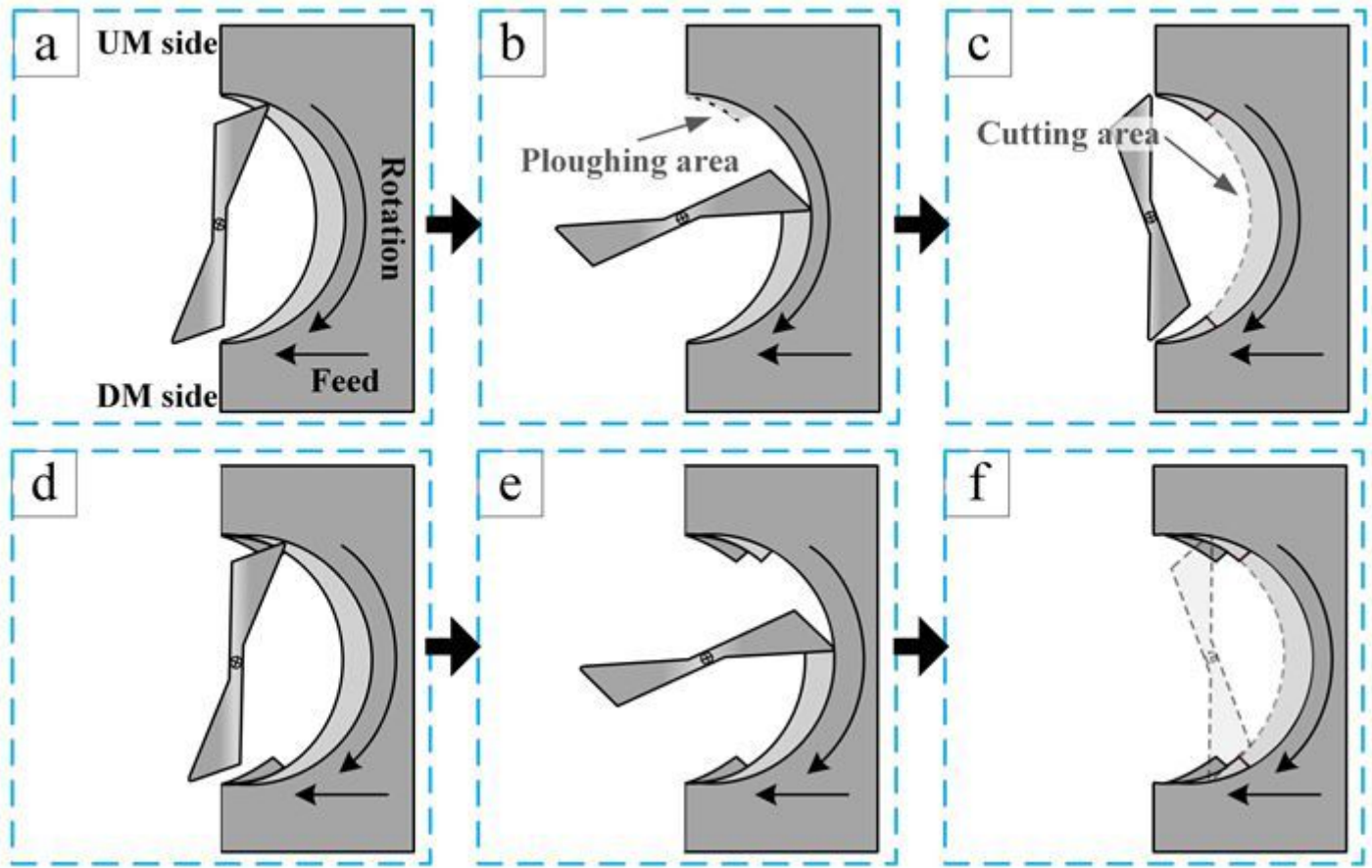


Figure 9

The formation principle of fish-scale burrs on the sidewall

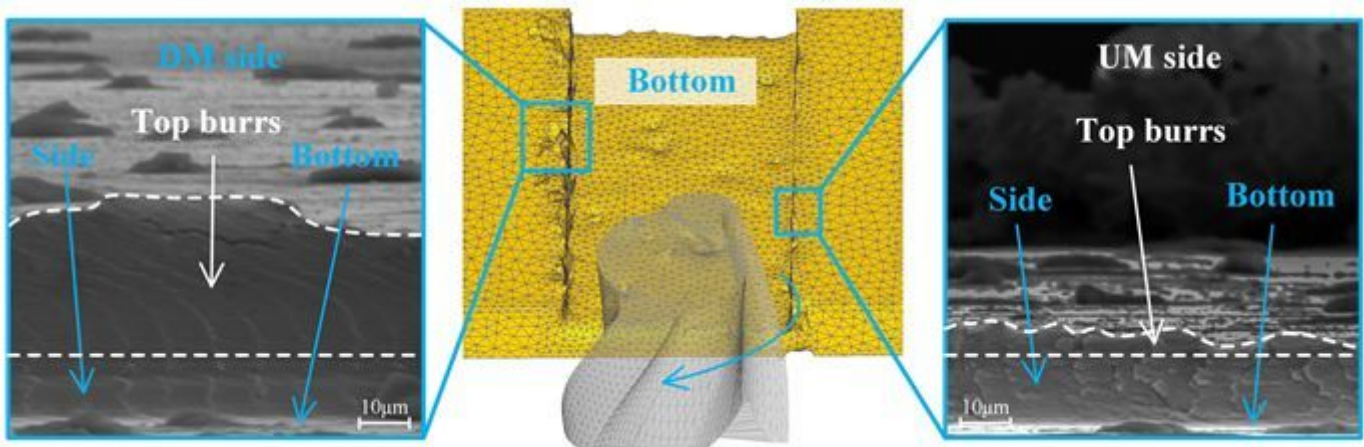


Figure 10

Top burr on the UM and DM sides of the shallow groove

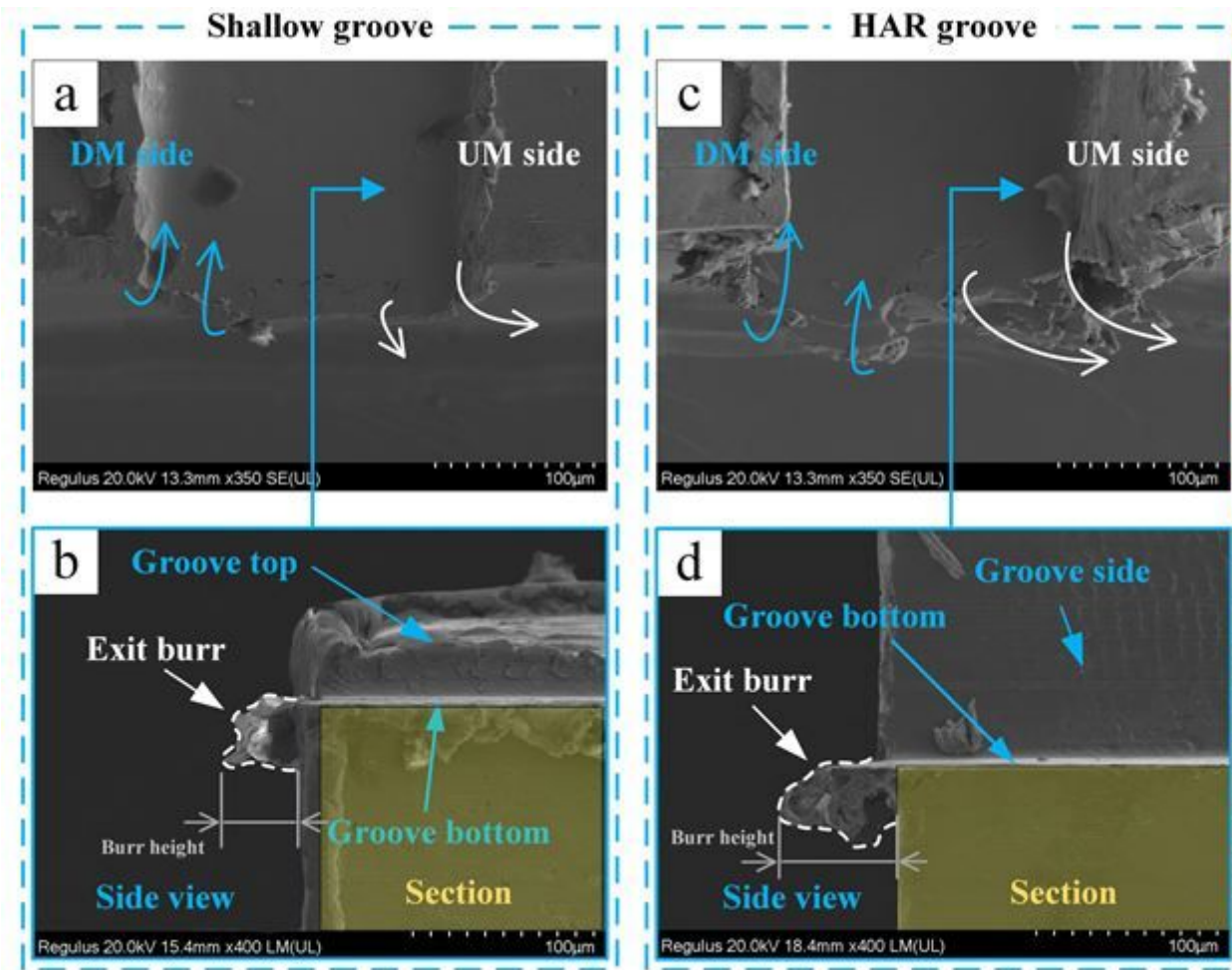


Figure 11

(a) Exit burrs of the shallow groove (SEM); (b) section view of shallow groove on DM side; (c) exit burrs of the HAR groove (SEM); section view of HAR groove on DM side

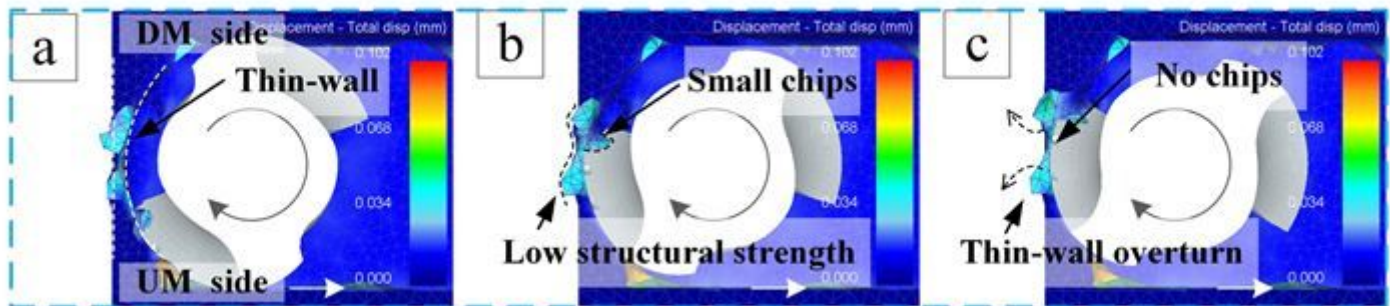


Figure 12

The formation of exit burrs: (a) thin-wall formation; (b) thin-wall deformation; (c) thin-wall overturn

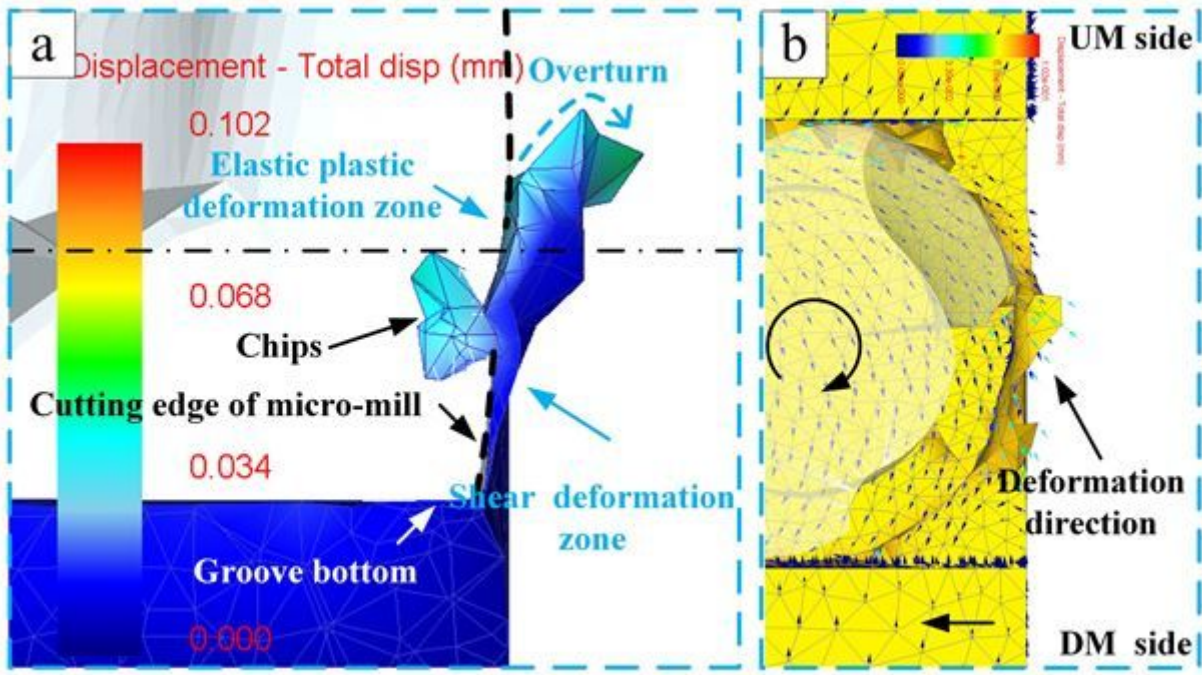


Figure 13

(a) The formation principle of bulged exit burr (UM side); (b) material displacement in micro-milling of the HAR groove

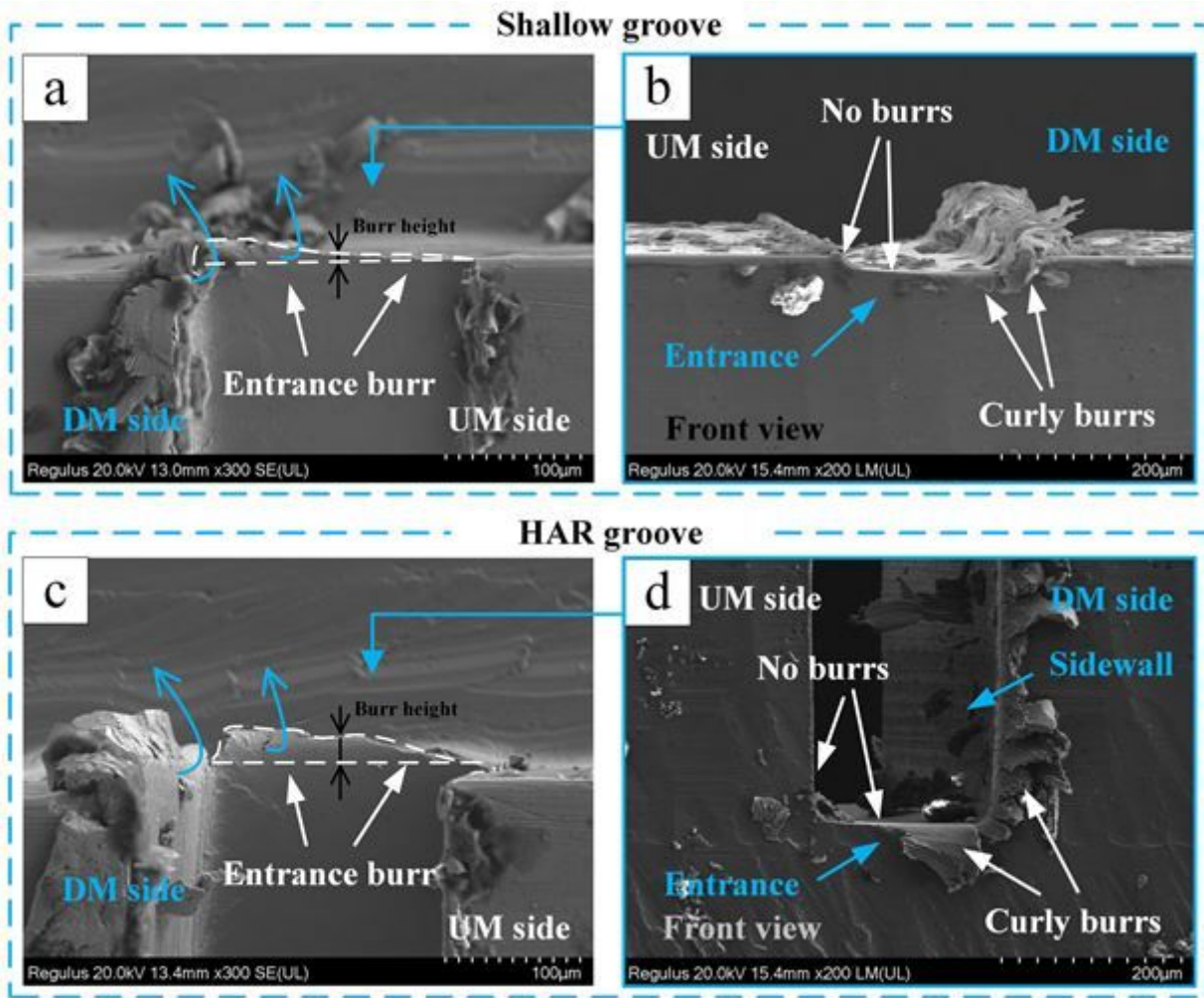


Figure 14

(a) Entrance burrs of the shallow groove (SEM); (b) front view of the shallow groove; (c) entrance burrs of the HAR groove (SEM); front view of the HAR groove

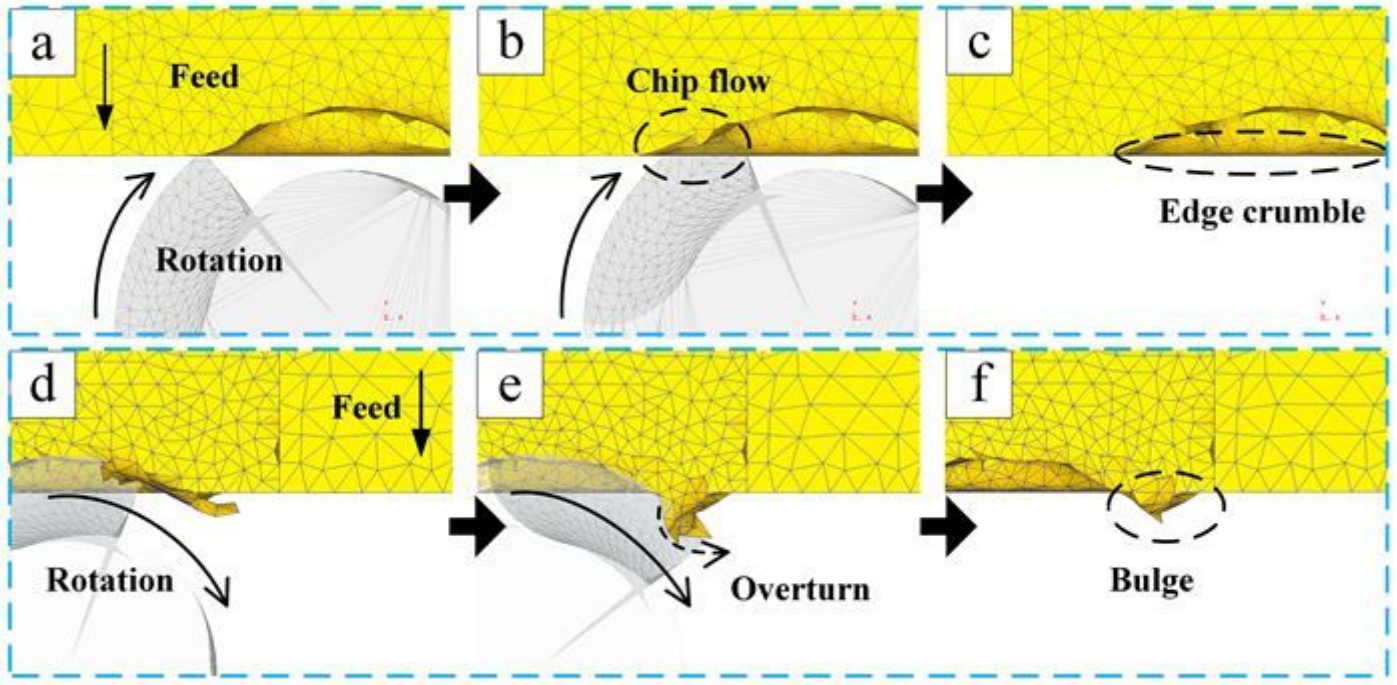


Figure 15

(a-c) Entrance burr formation process on the UM side of the HAR groove; (d-f) entrance burr formation process on the DM side of the HAR groove

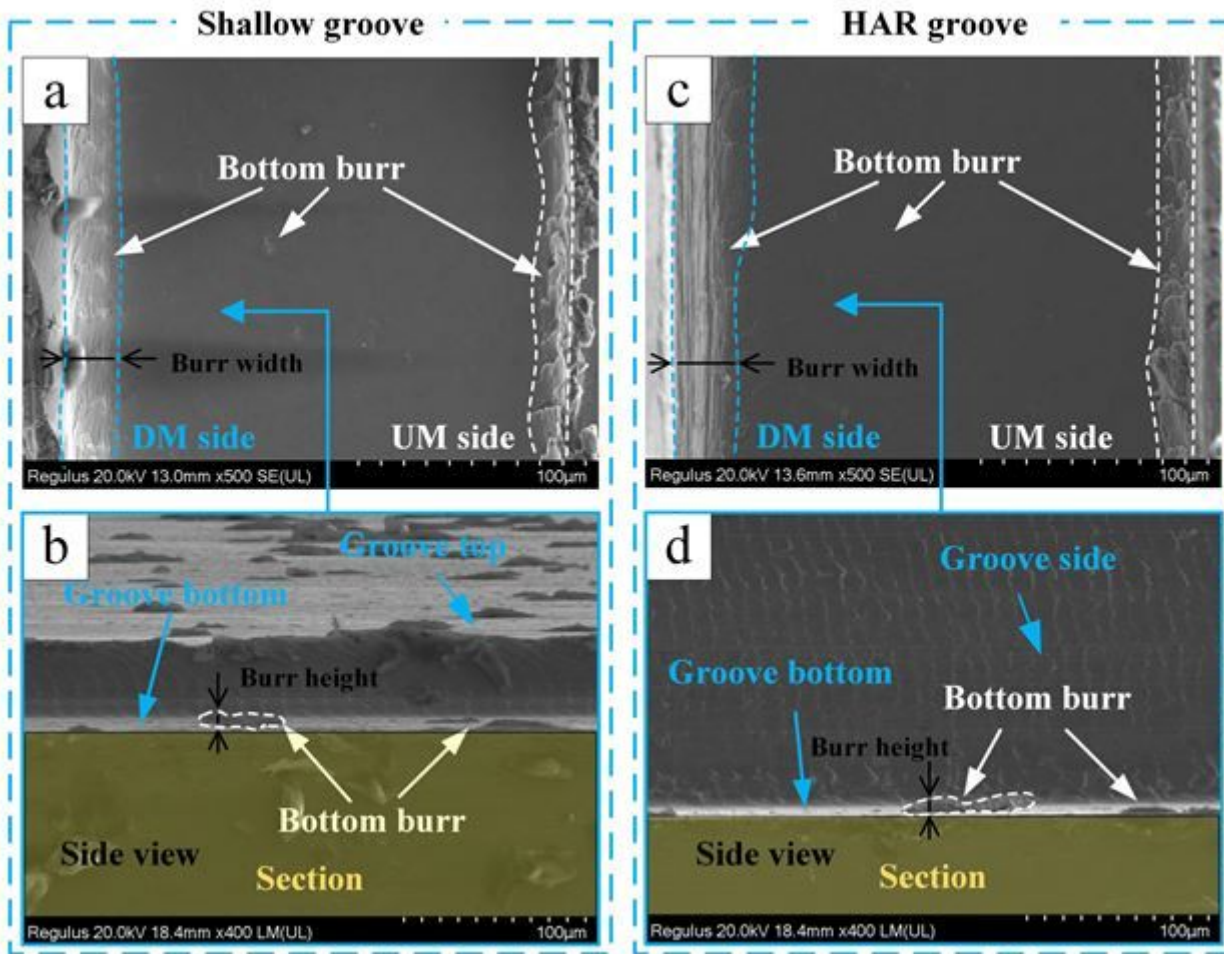


Figure 16

(a) Bottom burrs of shallow groove (SEM); (b) section view of shallow groove on DM side; (c) bottom burrs of HAR groove (SEM); (d) section view of HAR groove on DM side

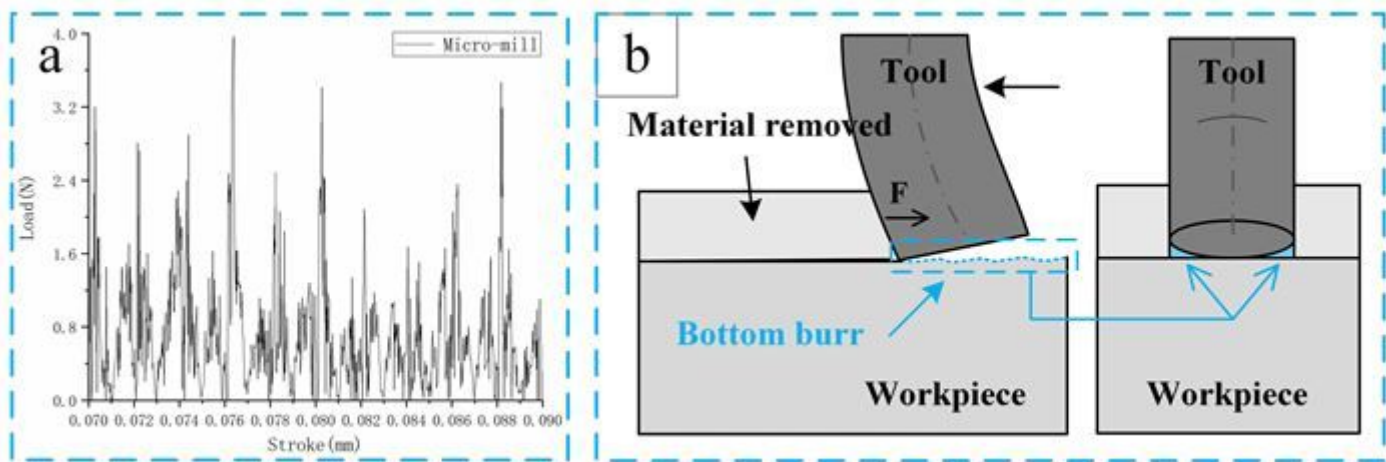


Figure 17

(a) The variation of cutting force in the micro-milling of micro-mill (HAR groove); (b) bottom burr forming principle

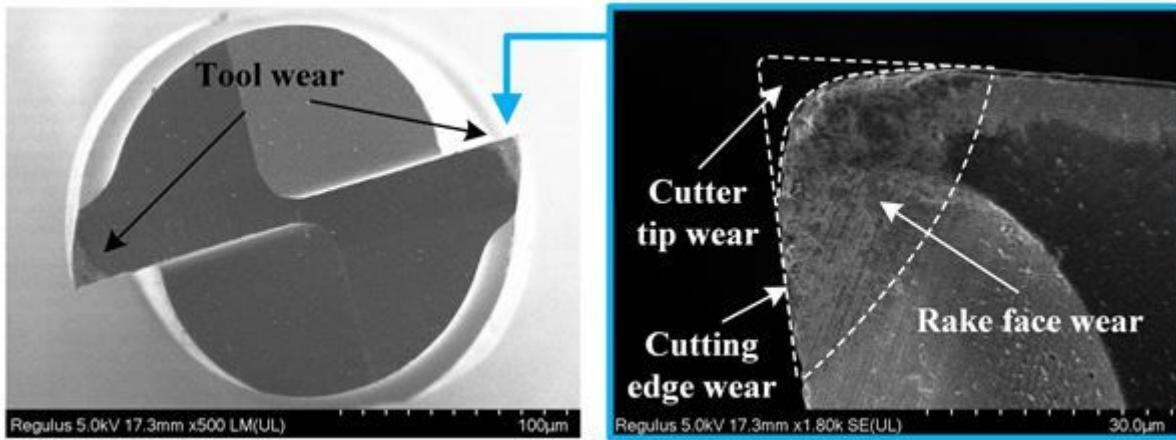


Figure 18

Influence of tool wear area on bottom burr

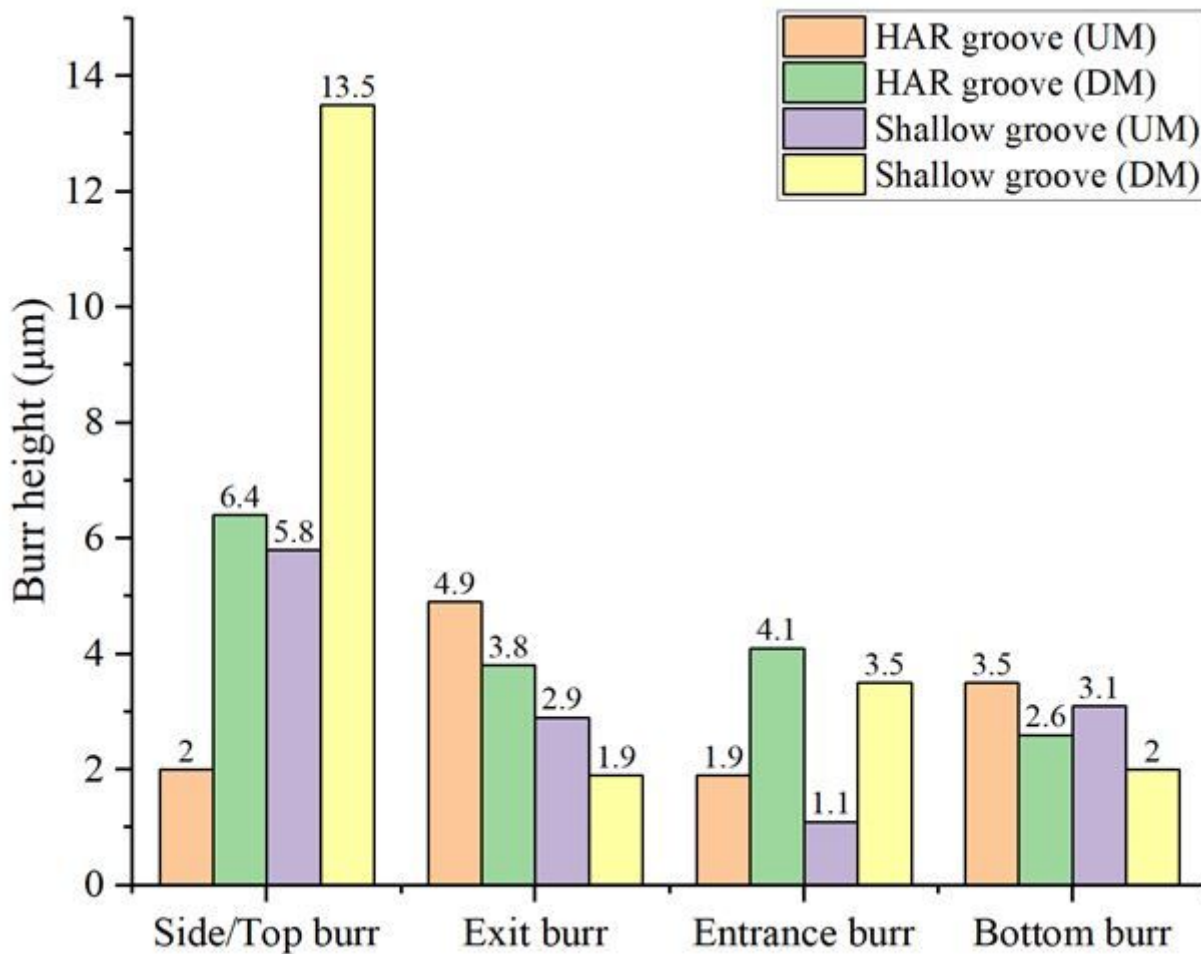


Figure 19

Burr height of HAR and shallow grooves