euspen's 18th International Conference & Exhibition, Venice, IT, June 2018
www.euspen.eu

On-machine precision form truing of hemispherical diamond wheel

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Abstract
The accurate control of tool shape is essential for arc envelope grinding. In this study, precision form truing of resin-bonded semispherical diamond wheel is conducted by a diamond roller dresser. A laser displacement sensor is adopted to detect the wheel profile error. The results show that the semispherical diamond wheel (50 mm in diameter) can be trued with profile error less than 5 μm by this method. The grinding wheel surface scattered uniform abrasive grains after truing, the density and protrusion height of which increased significantly compared with the initial surface.

Keywords: semispherical diamond wheel, form truing, profile error, diamond roller

1. Introduction

Ball-end grinding wheel is applicable to spherical, aspherical and freeform surface grinding, especially suitable for envelope grinding of inner surface with large depth-to-width ratio[1]. On-machine precision form truing of grinding wheel is an essential condition to achieve fine ground surface figure accuracy. The sphericity error of grinding wheel can be replicated to the ground surface, resulting in surface shape error[2]. Therefore, it is necessary to select an efficient precision form truing method based on the characteristics of grinding wheel.

Form truing of grinding wheel is to eliminate the rotation error and profile error caused by manufacturing, installation and wear. Different grinding methods have different dimension and shape accuracy requirements for grinding wheels. Form grinding, such as some moulds and microstructure surface, requires that the grinding wheel has both high dimensional accuracy and shape accuracy[3]. While the dimension of grinding wheel can be compensated in arc envelope grinding of complex surface, where shape accuracy is more important.

Three typical ball-end grinding wheels are shown in Figure 1, the selection of grinding wheel shape depending on the workpiece geometric feature, grinding system and grinding path. Selection of form truing method relys on the grinding wheel shape, bonded material and grain size. In this study, resin-bonded hemisphere diamond grinding wheel, as is shown in figure1(b), was trued by a disc-shaped diamond roller dresser. Resin-bonded grinding wheel shares advantages of low grinding force and fine gound surface quality, but more prone to wear. Efficient on-machine precision form truing is able to decrease the influence of grinding wheel wear on grinding surface shape accuracy.

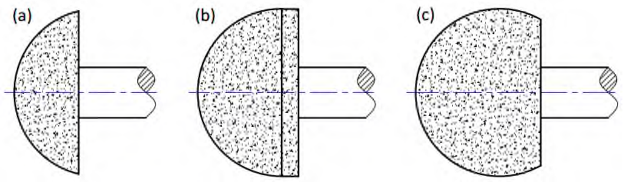

Figure 1. Typical shapes of ball-end grinding wheels: (a) hypo-hemisphere, (b) hemisphere, (c) hyper-hemisphere.

2. On-machine form truing system and process

The diamond roller dresser used in this study is a coarse-grained diamond wheel, and the truing process is accomplished by both grinding and rolling. Although diamond roller truing shares large truing force and requires high stiffness of tool spindle and slide guides of machine tool, it has advantages. On the one hand, the diamond roller truing system is flexible to wheels with different size and shape. On the other hand, the truing process is efficient and the shape accuracy of the trued grinding wheel is easy to control, because the diamond roller is resistant to wear and the truing is a deterministic material removal process.

Figure 2 illustrates the schematic diagram of the on-machine form truing system, which is constructed based on an inclined-spindle grinding system with hemispherical diamond wheel. The hemispherical diamond wheel is drived by tool spindle and trued by truing spindle with a diamond roller dresser. The laser displacement sensor is used to detect the profile error of the diamond wheel. The tool spindle tilt relative to z axis, truing spindle and laser displacement sensor are located on both sides of the workpiece spindle and move along the x and y axis. Besides, the tool spindle is adjusted perpendicular to the truing spindle, and the laser beam from the laser displacement sensor is adjusted to parallel to the axis of tool spindle.

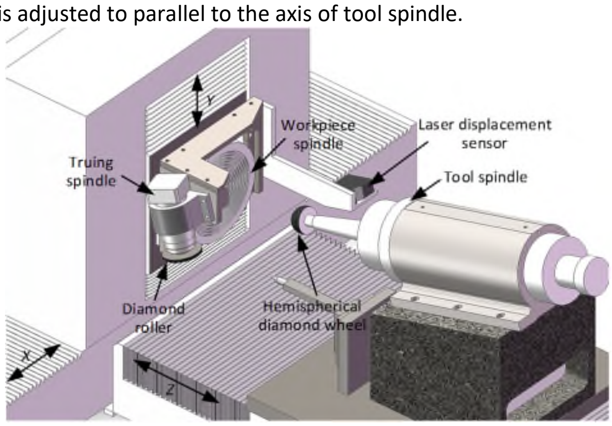

Figure 2. Components of the on-machine form truing system

Figure 3(a) shows the form truing process of hemispherical diamond wheel, where the tool spindle rotates at a speed of w_t and the diamond roller rotates with speed of w_d. The diamond roller cuts in along *x* axis at the top of diamond wheel, then *x*, *y*, *z* axes simultaneous motion keeps the diamond roller move along the generatrix of the diamond wheel. The detailed on-machine form truing process parameters are shown in table 1.

Figure 3(b) illustrates the detection of profile error of the hemispherical diamond wheel. The laser displacement sensor scan perpendicular to the axis of tool spindle and pass the center of the grinding wheel. The independent sampling points are the surface height information of the diamond wheel, while the scanning and continuously sampling constituted the profile of the diamond wheel, based on which the profile error was obtained by numerical fitting.

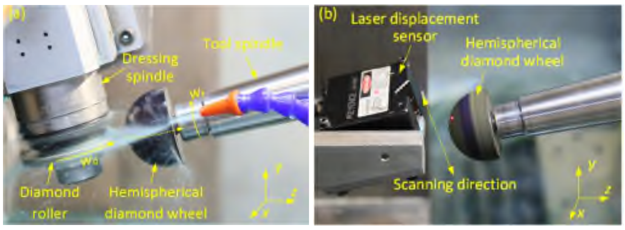

Figure 3. Form truing of hemispherical diamond wheel by diamond roller (a), and detecting of the wheel profile error (b).

Table 1 Truing parameters of hemispherical diamond wheel

Parameters	value
Truing spindle RPM w_d (rpm)	7200
Tool spindle RPM w_t (rpm)	900
Depth of tuding (μm/pass)	5-20
Feed rate (mm/min)	10
Diameter of grinding wheel (mm)	50
Grain size (μm)	20-30
Coolant (Challenge 300-HT)	3 vol% in water

3. Result and discussion

Profile error of grinding wheel referrs to the deviation between the actual profile and the ideal profile on the cross section that vertical to the rotating direction. Manufacturing and wear of diamond wheel is the main source of profile error, while installation resulted in run-out error.

Figure 4(a) and (b) show the profile error distribution of the hemispherical diamond wheel before and after form truing, respectively. It can be found that the error distribution before truing shows "W" shape, about 170 μm in amplitude. In the truing process, compensation of centering error along the *x* axis direction was finished based on in-situ detection of profile error distribution. A series of truing experiment results show that the profile error of hemispherical diamond wheel that is trued with diamond roller dresser can be stably less than 5 μm, as shown in Figure 4(b). Besides, the run-out error is completely disappeared, ideal profile accuracy is achieved after precision from truing.

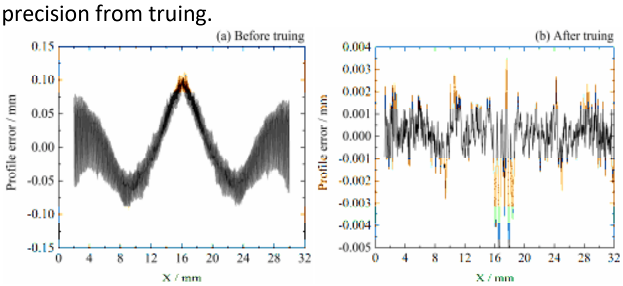

Figure 4. Profile error of the resin-bonded hemispherical diamond wheel before (a) and after (b) truing

Figure 5(a) and (b) show the surface topography of the resin-bonded hemispherical diamond wheel before and after diamond roller truing, respectively. It can be easily found from the initial wheel surface shown in Figure 5(a) that the grooves and pits distribute with no directionality, and the sparse abrasive grains (indicated by the circle regions) almost buried in the bonding material totally. The grinding wheel surface is flat and regular after diamond roller truing, as shown in Figure 5(b). The truing surface appears dence pits (indicated by the yellow arrows), the size of which is similar to the size of diamond grains, indicating a series of abrasive grains pulling out occurred under the diamond roller truing process. Besides, the consistent grooves in the direction of truing are derived from the rolling and scratching of the drawn abrasive grains. By comparing the detail view of the grinding wheel surfaces before and after truing, it can be found that the surface of the grinding wheel after truing still distributed uniform abrasive grains, the density and protrusion height of which increased significantly, confirming the excellent truing result of diamond roller.

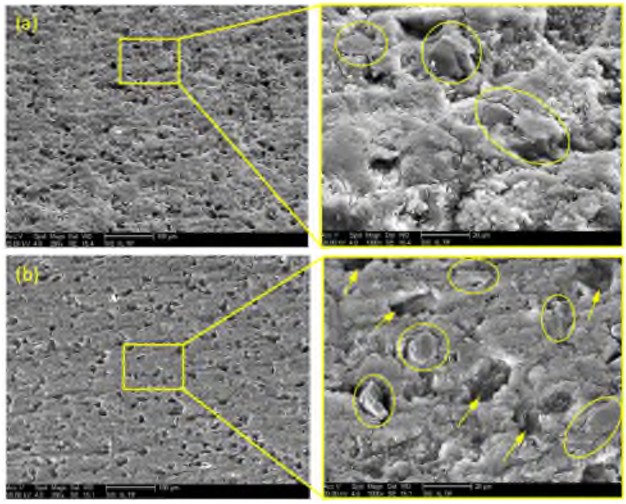

Figure 5. Surface topography of resin-bonded hemispherical diamond wheel before (a) and after (b) truing.

4 Summary and conclusions

Based on the achieved results and discussion, the main conclusion could be summarized as follows:

(1) On-machine truing of Φ50mm resin-bonded semispherical diamond wheel was conducted with diamond roller, the achieved profile error is less than 5 μm.

(2) The surface of the grinding wheel after diamond roller truing distributed uniform abrasive grains, the density and protrusion height of which increased significantly.

Therefore, It is considered that the diamond roller truing of resin-bonded diamond wheel obtained ideal effect, which is helpful to promote the grinding efficiency and improve the ground surface quality as well as accuracy.

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