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Prediction of undeformed chip thickness distribution and surface roughness in ultrasonic vibration grinding of inner hole of bearings

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Grain-workpiece interaction mechanism

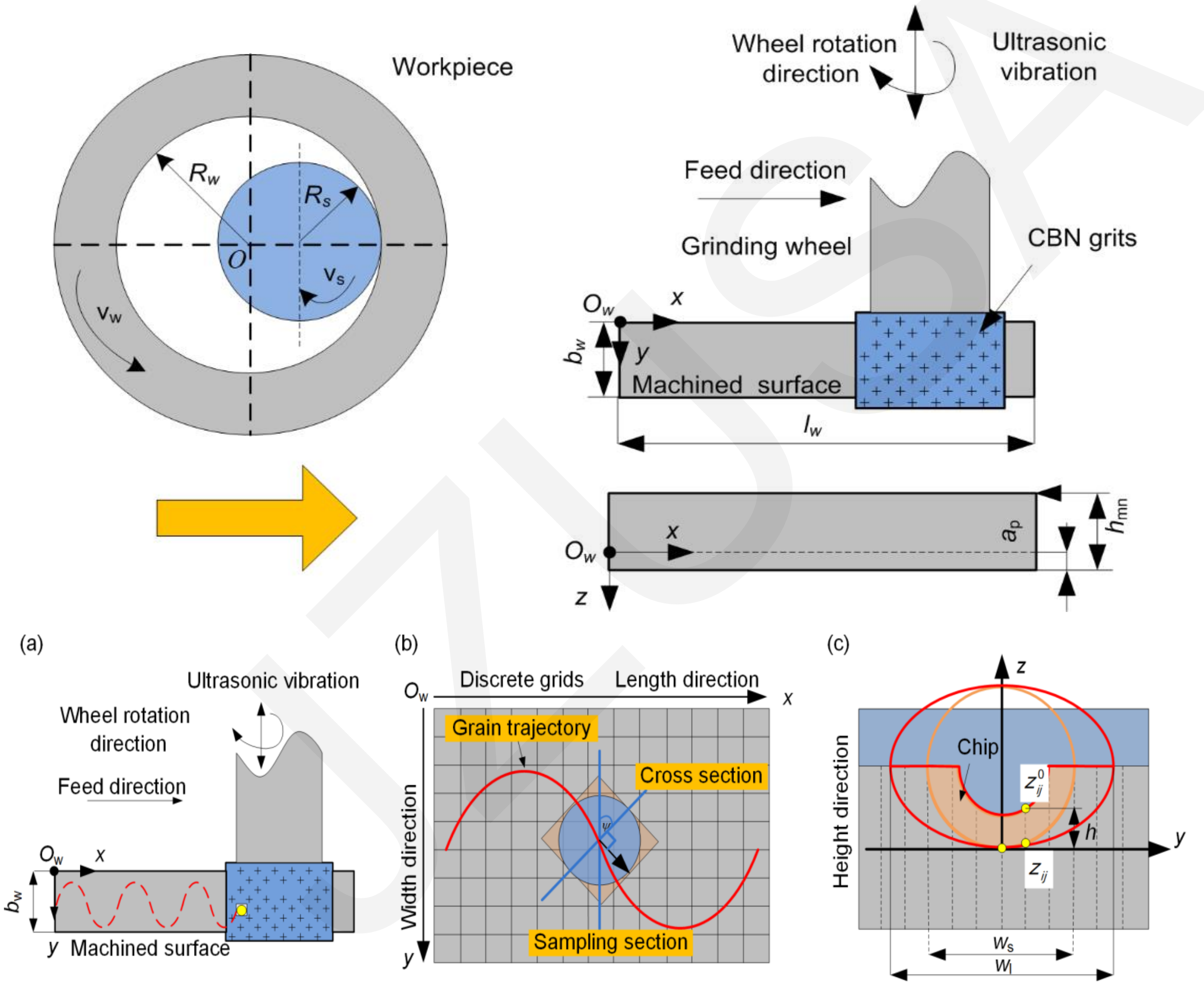


Fig. 1. Chip generation mechanism illustration: (a) ultrasonic grinding diagram; (b) workpiece grids; (c) UCT and width

Workpiece surface modeling

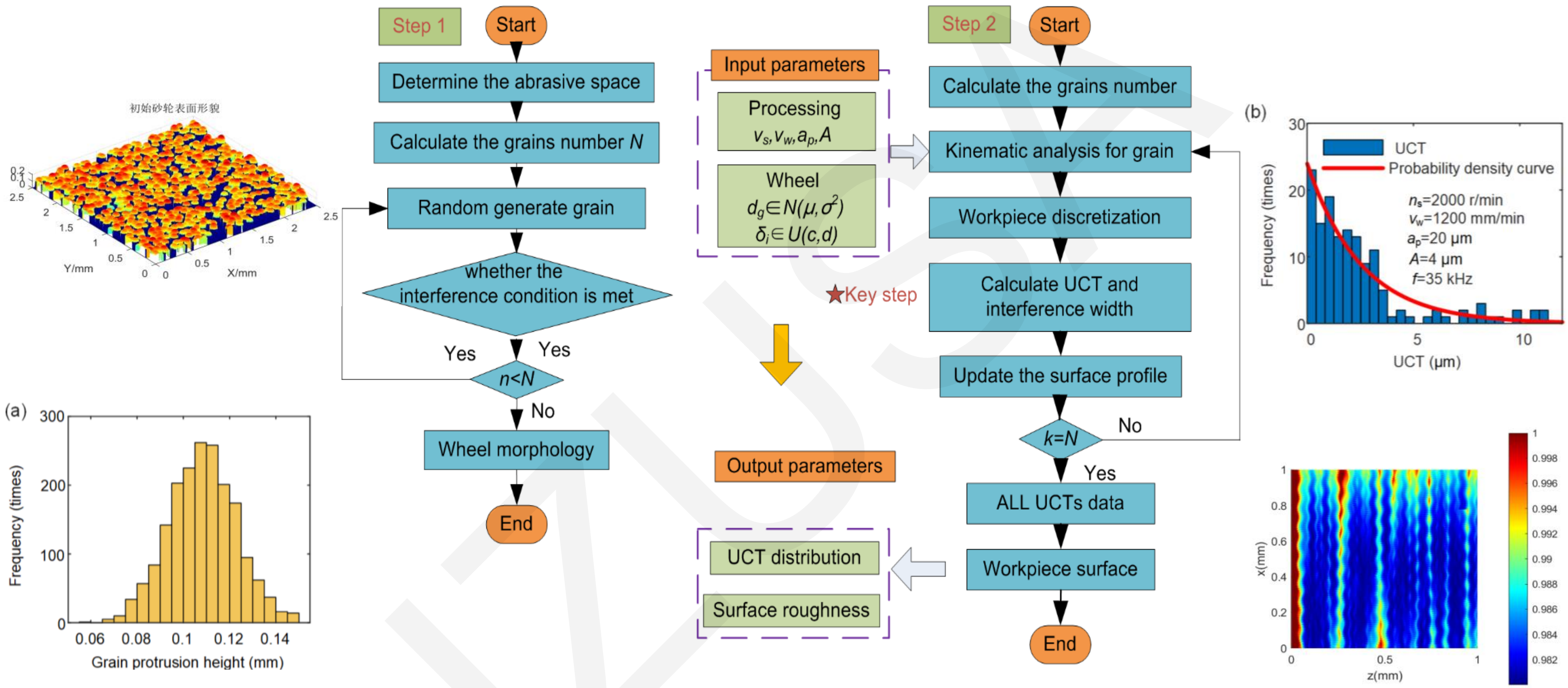


Fig. 2. Flowchart of workpiece surface topography and UCT distribution generation algorithm

Numerical simulation result

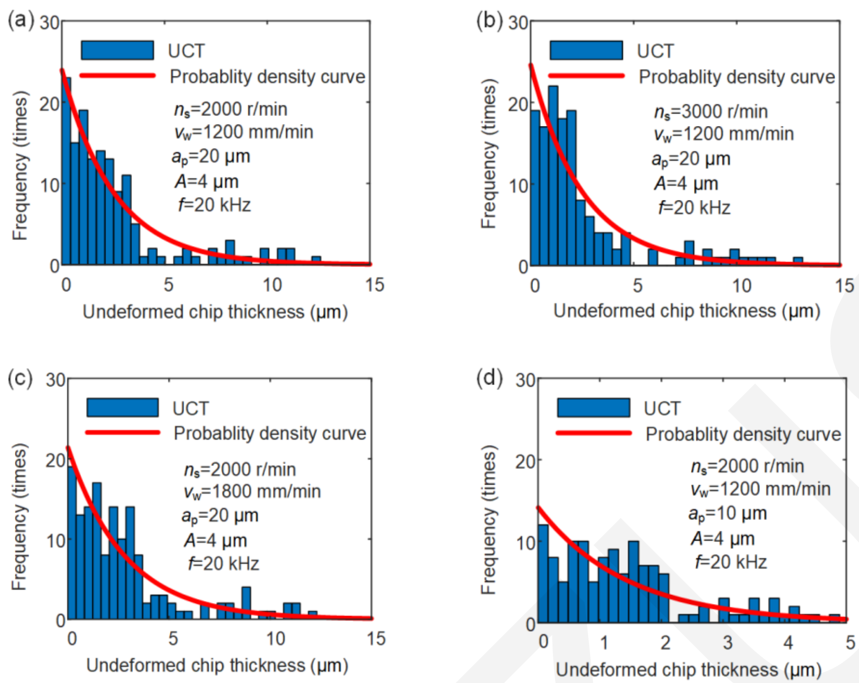


Fig. 3. UCT distribution histograms under different machining parameters

UCT分布的特征评价参数

分布均值

$$h_{mean} = \frac{1}{N}\sum_{i=1}^{N} h_{\max i}$$

分布最大值

$$h_{max} = \max(h_i)$$

分布方差

$$var = \frac{\sum (h_{\max} - h_{mean})^2}{N}$$

有效磨粒数 Ne

Regression model of surface roughness

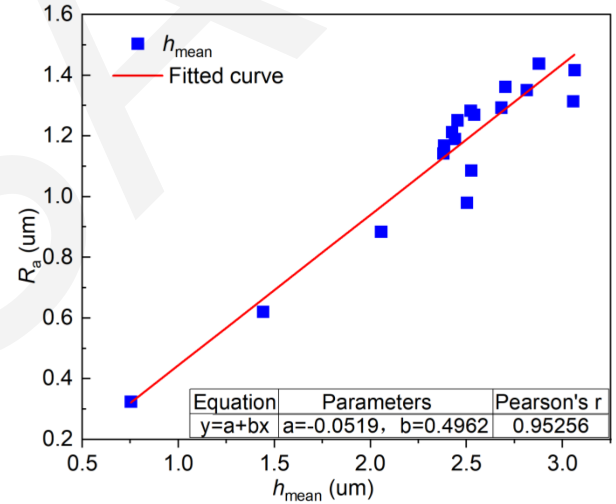


Fig. 4. Relationship between h_{mean} and R_a

$$R_a = -0.0519+0.4962x$$

The Pearson correlation coefficient is 0.95256. In statistics, the Pearson correlation coefficient is used to evaluate the correlation between two variables. A value between 0.8 and 1.0 is regarded as indicating a strong correlation.

Experimental verification

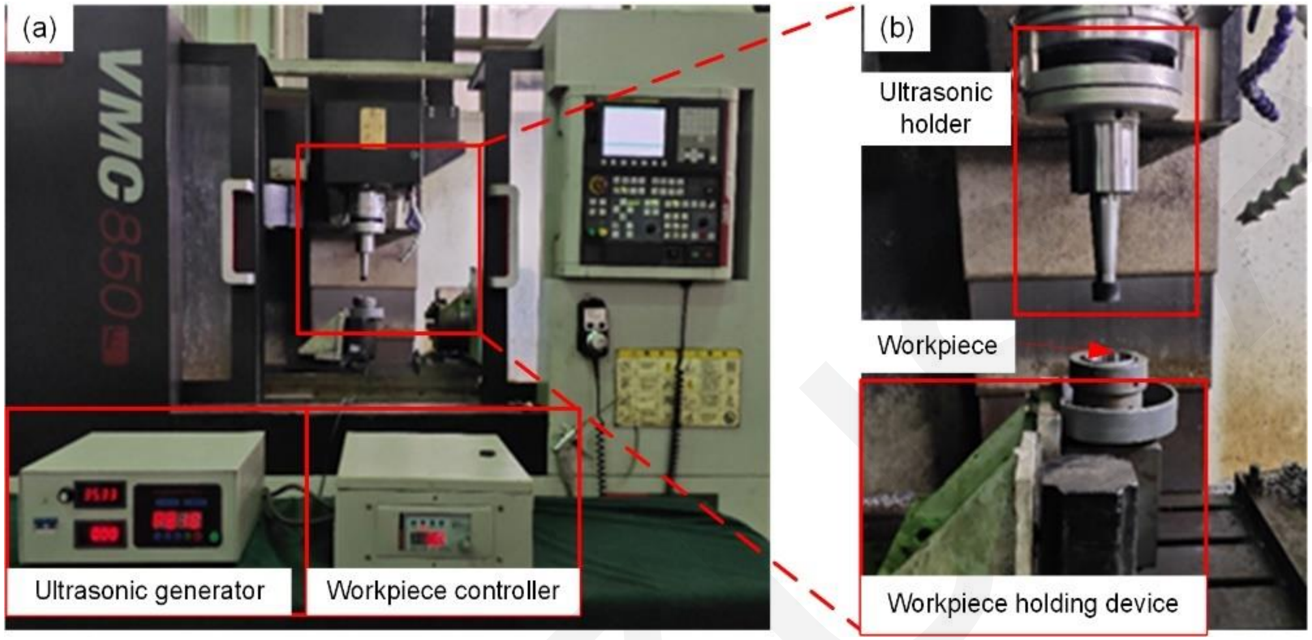
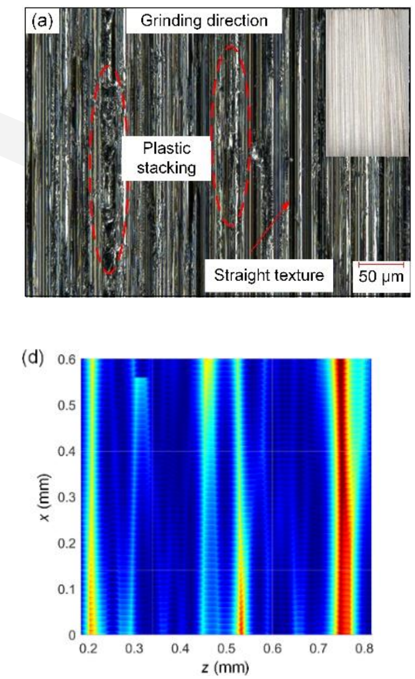


Fig. 5. Diagram of the ultrasonic grinding experimental platform (a) and platform details (b)



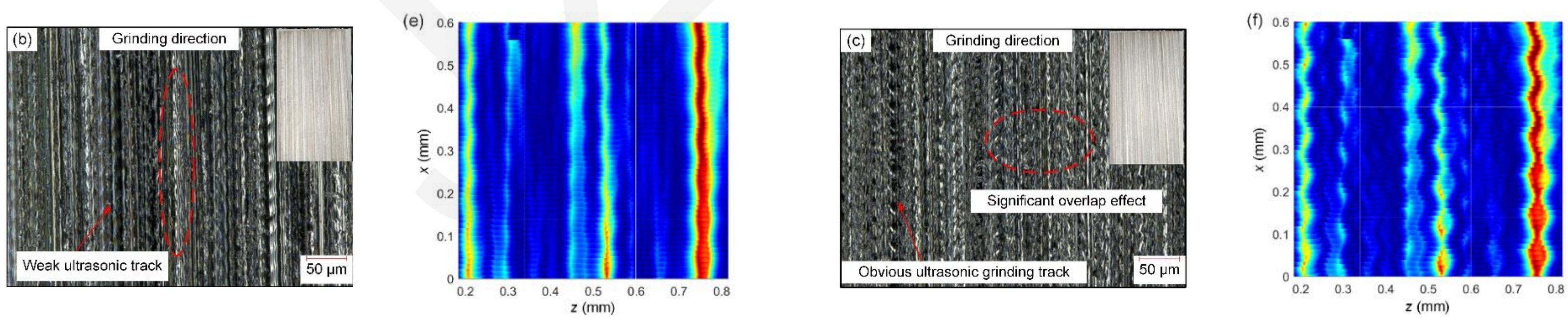


Fig. 6. Surface morphology under different ultrasonic amplitudes: (a–c) measured morphology with *A*=0 μm (a), *A*=2 μm (b), and *A*=4 μm (c); (d–e) simulated morphology with *A*=0 μm (d), *A*=2 μm (e), and *A*=4 μm (f).

Experimental verification

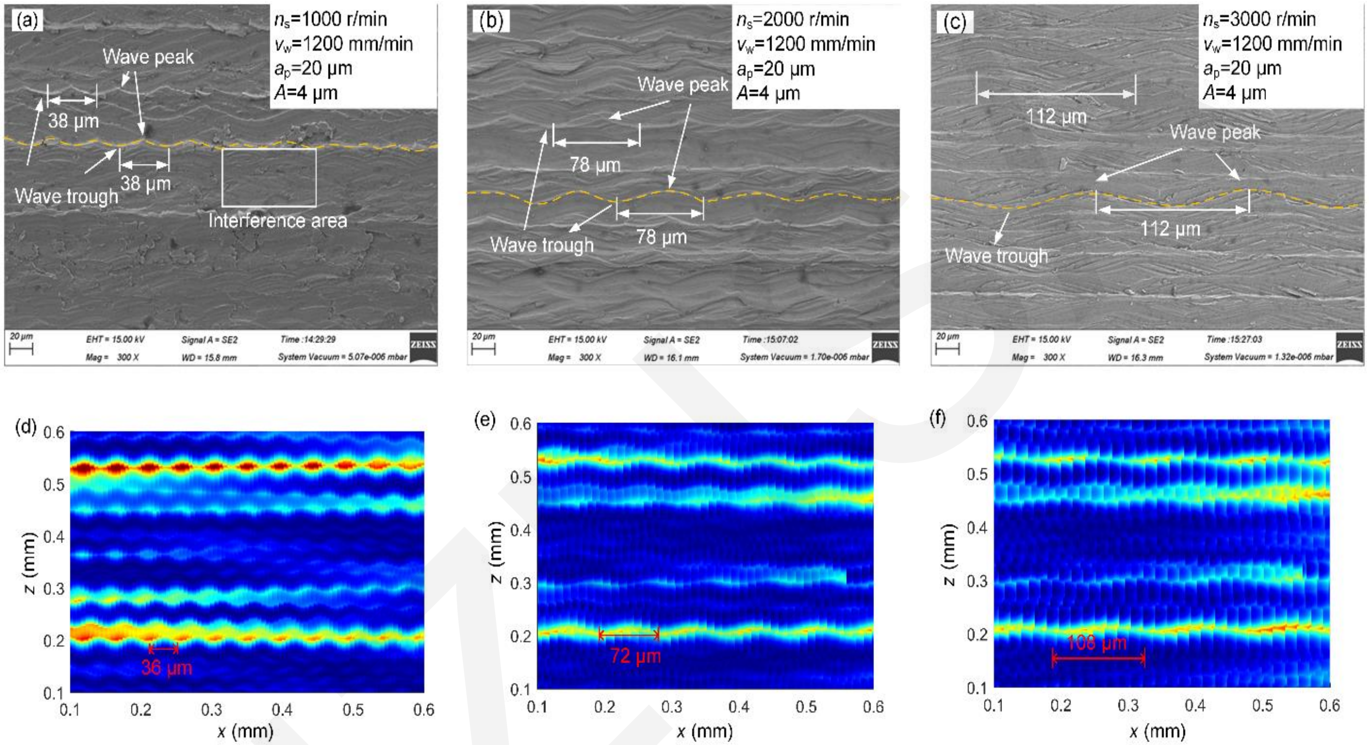


Fig. 7. Surface texture under different wheel speeds: (a–c) measured texture with n_s=1000 r/min (a), n_s=2000 r/min (b), and n_s=3000 r/min (c); (d–e) simulated texture with n_s=1000 r/min (d), n_s=2000 r/min (e), and n_s=3000 r/min (f).

Conclusions

1. Based on the grain moving trajectory during ultrasonic vibration grinding, a symbolic difference method was proposed to calculate UCT and width to raise the simulation efficiency.

2. The UCT distribution in the ultrasonic vibration grinding process follows an exponential distribution. The characteristic parameters of UCT distribution were extracted. The application of ultrasonic waves can change UCT and width, enhance the repeated interference effect, and reduce the surface roughness.

3. The influence rules of grinding parameters on the UCT distribution characteristics were analyzed. A linear relationship is found between R_a and h_{mean}. The experimental results show the same variation tendency as the simulated values, with a maximum deviation of 14.3%.

4. High grinding wheel speed, low workpiece speed, small grinding depth, and an appropriate ultrasonic amplitude are conducive to obtaining lower UCT, forming a smoother workpiece surface.