Grinding Process Modeling and Cycle Design

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PROJECT OBJECTIVES

- Develop a grinding model to predict the main process outputs such as power, forces, and part surface roughness.

- Use the grinding model to find the optimal process settings to produce the desired part quality subject to machine capability constraints.

- Implement and test the final cycle design in a cylindrical grinding machine with an open architecture system.
MODEL 1 – THE GRINDING CHIP

The chip is idealized as a long slab with constant thickness, \( h \), and a triangular cross section.

The chip thickness is assumed to take a Rayleigh probability density function.

Figure 1. Idealized chip geometry

Figure 2. Probability density of function of the chip thickness

The chip thickness is assumed to take a Rayleigh probability density function.
MODEL 2 – GRINDING WHEEL CHARACTERIZATION

- Print the wheel surface in a soft material
- 3-D surface topography scanning by Zygo
- Image processing to characterize: grit geometry and static cutting edge density
- Dynamic cutting edge calculation \( \rightarrow \) Chip thickness model

Figure 3. 3-D wheel topography

Figure 4. Static grain density
The model is a closed-loop system by considering dynamic effects produced by the total normal force and the normal force per grain.
The model was calibrated and validated using the normal and tangential force in surface grinding and also using the grinding power in cylindrical grinding.

Figure 6. Model calibration and validation using the grinding power
The surface profile is generated by the grooves left by the grains on the part surface. The depth of the grooves is assumed to be equal to the chip thickness.

By probabilistic analysis

\[ E \left( R_a \right) = 0.37 \ E \left( h \right) \]

Empirically adjusted as

\[ E \left( R_a \right) = 0.32 \ E \left( h \right) \]
CYCLE DESIGN - CONSTRAINTS

Stock removal: Machine capability and part surface burn
Final stage: Surface roughness and out-of-roundness

Power control
Feed control

Figure 8. Constraints in the plane workpiece velocity vs. depth of cut
Material removed
First layer: power control
Second layer: feed control
Third layer: spark-out or remaining material

Figure 9. Workpiece cross section

Figure 10. Power and infeed response
CONCLUSIONS

- Development of a grinding model based on the probabilistic nature of the grinding chip.

- Design of a grinding cycle based on the grinding model with the constraints of machine capabilities and part quality.

- Cycle implementation in an open architecture system