Analysis of Micro-Scale Milling

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Faculty:
J. Ni

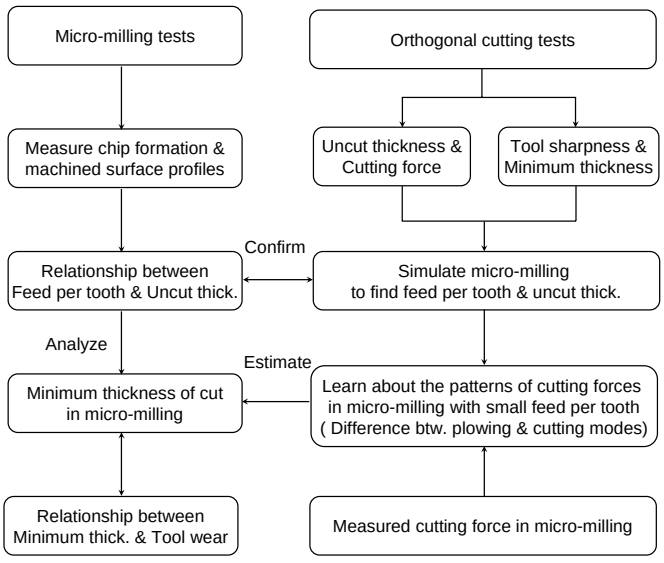
Objectives

- To understand the mechanism of chip formation and surface generation in micro-milling.
- To create a model for cutting forces in micro-milling.
- To investigate the effect of material micro-structure on chip formation and cutting forces in micro-milling.

State-of-the-Art

- Research on the cutting mechanics and surface generation in micro-scale cutting has been limited to orthogonal cutting and turning.
- Due to the roundness of the cutting edge, there exists a minimum thickness of cut exists, below which plowing occurs.
- Chip formation and the variation of the uncut chip thickness in milling has been studied, but the effects of material plowing and the minimum thickness of cut have not been considered.

Approaches

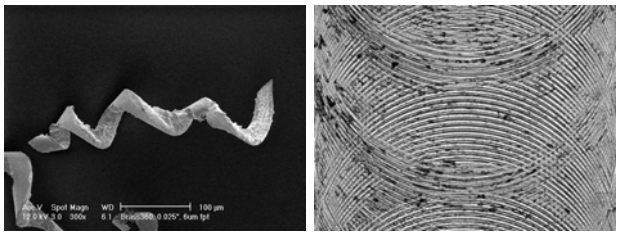


Accomplishments

- Chip formation in cutting with depths of cut smaller than the radius of the cutting tool has been studied using the molecular dynamics simulations.

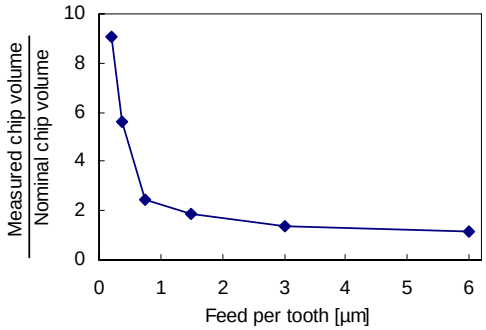
Depth/Radius = 0.125 Depth/Radius = 0.25 Depth/Radius = 0.5

- Machining tests have revealed some important information about chip formation and surface generation in micro-milling.



Brass chip (Left) and Bottom surface profile (Right)
Feed per tooth: 6 μm, Spindle speed: 80,000 rpm

- Observations on the experiments indicate that the tool rotates several times without performing any cutting, until the accumulated uncut thickness surpasses the minimum thickness of cut.



Future Work

- Create a model for chip formation and cutting forces that considers the minimum thickness of cut.
- Find the effects of material micro-structure on the variation of cutting forces and surface roughness.

Sponsor

- National Science Foundation

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Chip Formation and Surface Generation in Micro-milling

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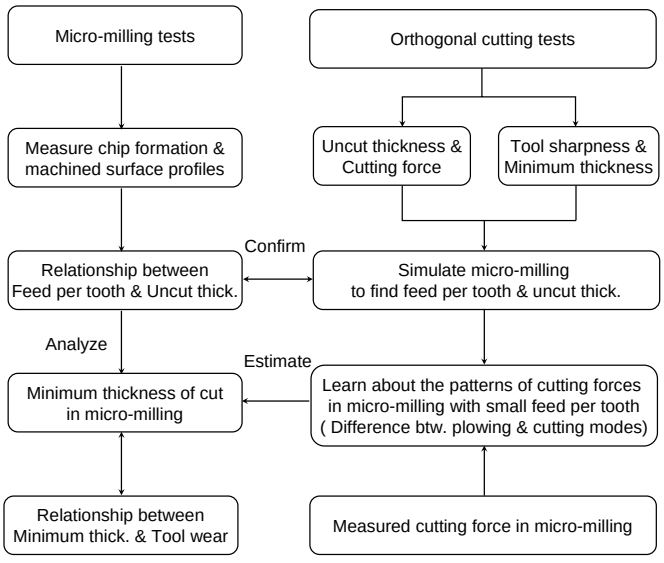
Objectives

- To understand the mechanism of chip formation in micro-milling
- To understand the relationship between chip formation and surface finish
- To investigate the effect of tool wear on chip formation and cutting forces in micro-milling

State-of-the-Art

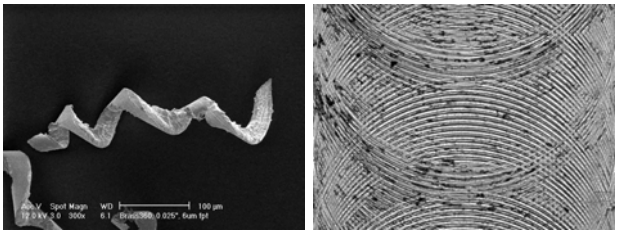
- Research on the cutting mechanics and surface generation in micro-scale cutting has been limited to orthogonal cutting and turning.
- Due to the roundness of the cutting edge, there exists a minimum thickness of cut exists, below which plowing occurs.
- Chip formation and the variation of the uncut chip thickness in milling has been studied, but the effects of material plowing and the minimum thickness of cut have not been considered.

Approaches



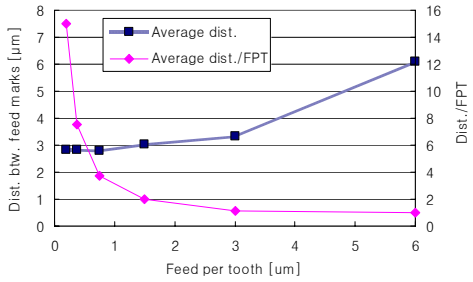
Accomplishments

- Machining tests have revealed some important information about chip formation and surface generation in micro-milling.



Brass chip (Left) and Bottom surface profile (Right)
Feed per tooth: 6 μm, Spindle speed: 80,000 rpm

- The relationship between feed per tooth and uncut thickness was measured and the effect of the minimum thickness of cut in micro-milling was analyzed.



Gap distance between feed marks vs. feed per tooth

- The observations indicate that the tool rotates several times without performing any cutting, until the accumulated uncut thickness surpasses the minimum thickness of cut.

Future Work

- Find the effect of tool wear on the uncut thickness by performing tests with worn tools.
- Create an uncut chip thickness model that considers the minimum thickness of cut and tool deflection.
- Estimate the minimum thickness of cut by analyzing cutting forces, measured chip thickness, and machined surface profiles.

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• National Science Foundation

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Modeling & Simulation of Micro/meso scale End-Milling Process

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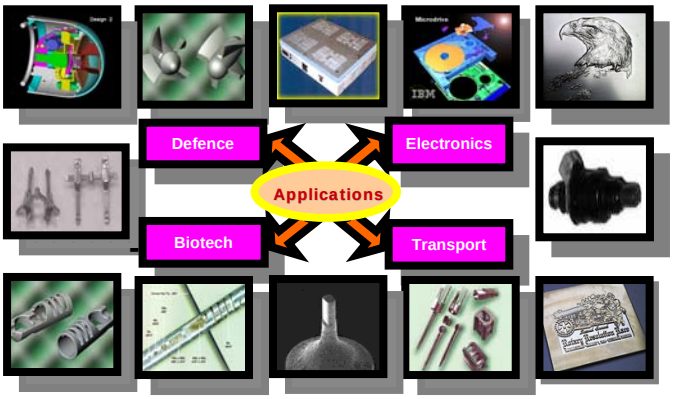
Objectives

- Build up micro milling machine and investigate size effects of micro/meso scale milling.
- Construct constitutive model for micro/meso scale materials and simulate cutting process using FEM.
- Model 3D cutting forces and predict the formation error of micro/meso milled surface.

State-of-the-Art



- Micro/meso milling has better capability of machining 3D complex products with high precision.
- Lower energy consumption and high machining stabilization.
- Lower machine-to-workpiece volume ratio.
- However, the technology has many difficulties in research area and commercial applications.

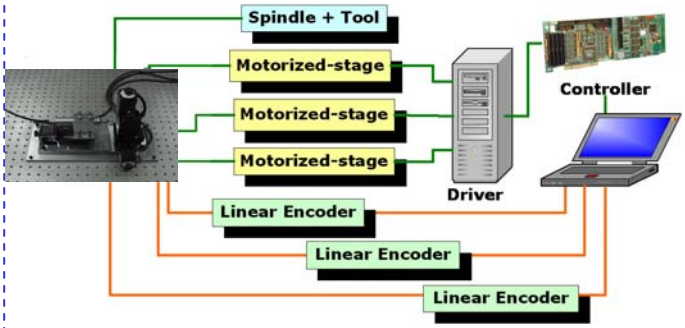
Approaches

Material constitutive model
- Develop constitutive relationship for micro/meso scale
- Validate the model with cutting experiments

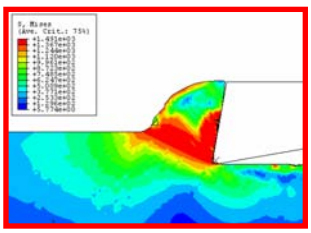
FE Simulation
- Implement constitutive equations to Abaqus
- Simulate the cutting process
- Obtain process guidelines for milling process

Experimental Work
- Design and fabricate cutting experiments
- Validate simulation results

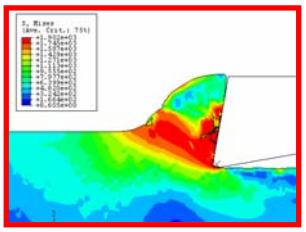
Accomplishments



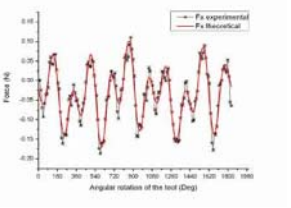
Developed Micro Milling Machine System



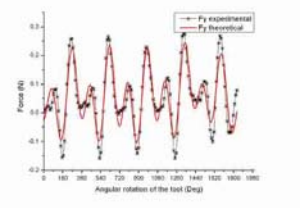
w/o size effect



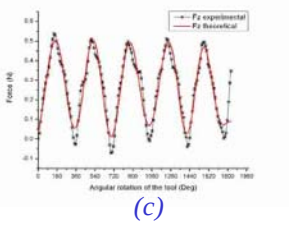
w size effect



(a)

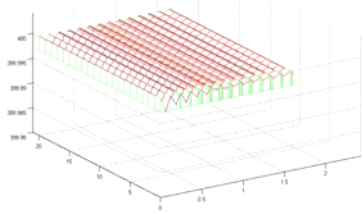


(b)



(c)

Simulated 3D cutting forces



Simulated formation of milled surface

Future Work

- Investigate effect of grain size on the milling characters.
- Study process design & optimization.

Sponsors

- National Natural Science Foundation of China

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