Intelligent Machining

Dr. J. M. Zhou

Avdelningen för mekanisk teknologi och verktygsmaskiner
Lund Tekniska Högskola

What does intelligent machining mean?

Sensors
Process model
Machining processes
- Metal cutting
- Grinding
Intelligent machining

Why intelligent machining

Machining Process
• Open loop system
• Stochastic cutting tool fracture
• Non-stationary tool wear, plastic deformation
• Correlated

Machining Equipment
• Expensive
• Highly automatic

Typical events in machining process

Tool wear
Tool breakage
Tool collision
Tool missing

Issue of intelligent machining

• Wear of cutting tool, grinding wheel
• Fracturing of cutting tool
• Cutting tool plastic deformation
• Temperature
• Vibration
• Chip formation
• Thermal expansion and error compensation
• Machining process optimization

What can you benefit from intelligent machining?

• Enhance reliability
• Increase efficiency
• Prevent fatal damage

Department of Production & Materials Engineering, Lund University, Sweden
Sensors used in intelligent machining

Software structure of intelligent machining system

Feature extracting in intelligent machining

Department of Production & Materials Engineering, Lund University, Sweden
General structure of intelligent machining

Cutting Force

- $F_T$: Tangential force or primary force
- $F_A$: Axial force or feed force
- $F_R$: Radial force or passive force

\[ F = \sqrt{F_T^2 + F_A^2 + F_R^2} \]

Cutting forces: induced in the three deformation zones

Connection with process phenomenon:
- Tool wear
- Tool breakage
- Cutting edge plastic deformation

Measurement: strain gage cell, piezoelectric transducer, motor current.

Principle of Piezoelectric Transducer

- "Piezo" is a Greek term which means "to squeeze."
- When strained, piezoelectric elements create a charge
- Crystalline quartz is a stable and sensitive piezoelectric material

Three component dynamometer with piezo-electric transducer
Monitoring Three Cutting Forces with 3-D Force Dynamometer in Hard Turning Process

Cutting Force Dynamometer Based on Strain Gauge Transducer

Intelligent Tool

Drilling Process Using Intelligent Tool

Acoustic Emission

Acoustic emission (AE): elastic stress waves which generated during cutting process. The wave propagates through machine structure.

Frequency range: from 100kHz to 1MHz

Measurement: Piezoelectric strain transducer

Application of AE in Advanced Manufacturing Process

High precision grinding operation
- Gap elimination
- Cycle analysis and optimization
Conventional and high speed machining process
- Wear
- Fracture
- Collision
Sheet metal forming
- Friction
- Cracking
Source of Acoustic Emission

AE generates from friction on the rake face and flank, plastic deformation in the shear zone, crack formation and propagation, impact of the chip breakage.

Connection with process phenomenon:
- Tool breakage generates high amplitude of AE signal
- Tool wear

AE application in milling process

Application AE in grinding

Too small infeed resulting in longer grinding cycle
Bad incoming quality with regard out of roundness

Summary

- Structure of intelligent machining system
- Sensors
- Intelligent machining based on cutting forces
- Intelligent machining based on AE