# Intelligent Machining

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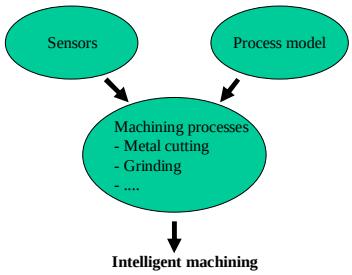
## What does intelligent machining means?




## Why intelligent machining

**Machining Process**

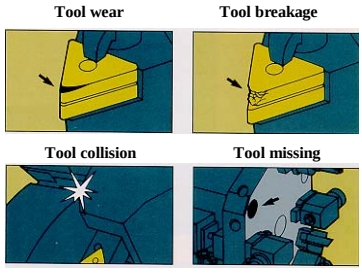
- Open loop system
- Stochastic
  cutting tool fracture
- Non-stationary
  tool wear, plastic deformation
- Correlated

**Machining Equipment**

- Expensive
- Highly automatic



## Typical events in machining process





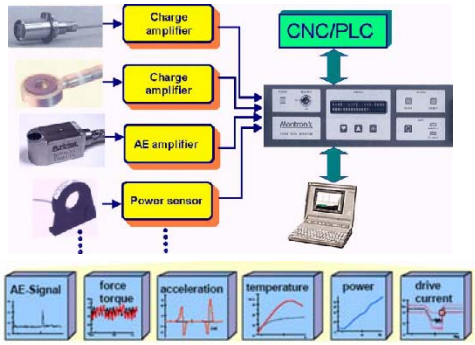

## Issue of intelligent machining

- 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

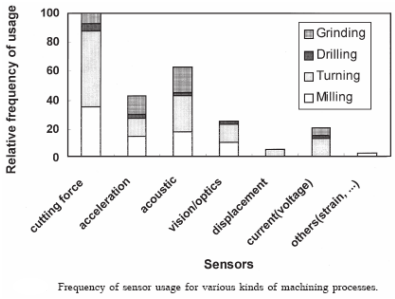
## What can you benefit from intelligent machining?

- Enhance reliability
- Increase efficiency
- Prevent fatal damage

## Sensors used in intelligent machining

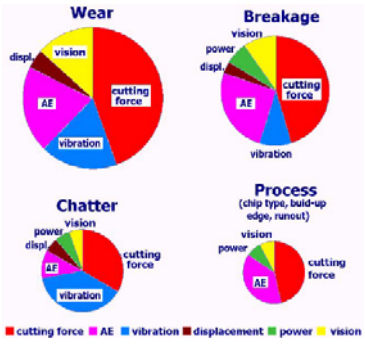



## Sensors used in intelligent machining

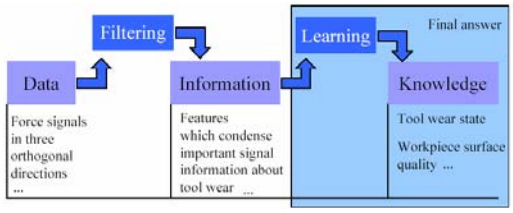



Frequency of sensor usage for various kinds of machining processes.

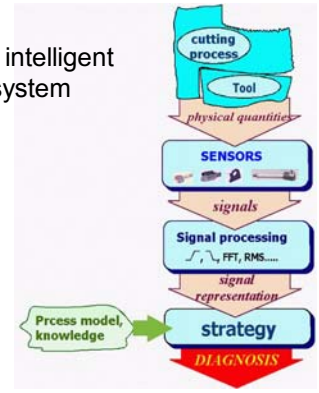
## Sensors used in intelligent machining



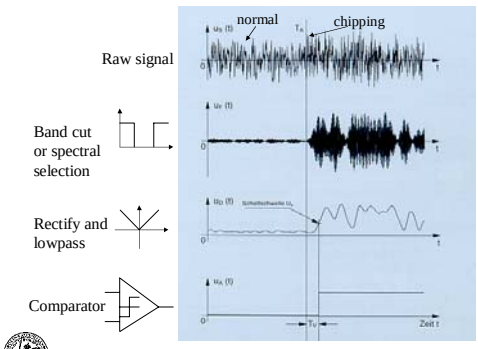

## Software structure of intelligent machining system




## Structure of intelligent machining system




## Feature extracting in intelligent machining



## General structure of intelligent machining

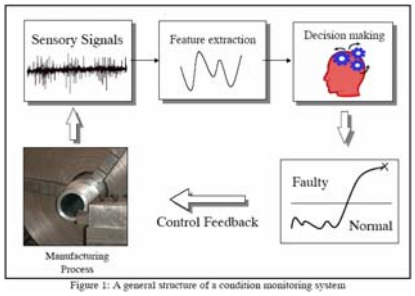
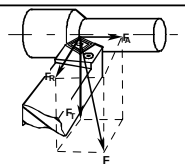


Figure 1: A general structure of a condition monitoring system

## 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 Force

**Cutting forces:** induced in the three deformation zones

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

**Measurement**: strain gage cell, poezoelectric transducer
motor current.



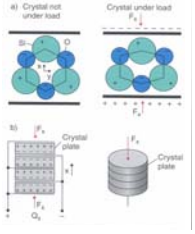
## Force Dynamometer

- Force dynamometer based on strain gauge transducer
- Force dynamometer based on piezoelectric transducer
- Sensor integrated tool holder based on microsensor



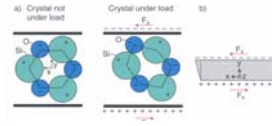
## Principle of Piezoelectric Transducer

Under longitudinal load



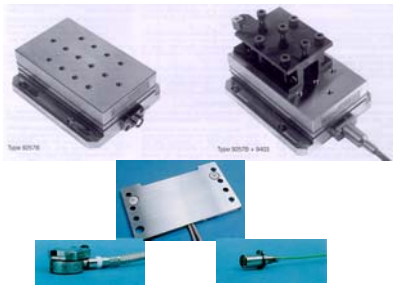
- "Piezo" is a Greek term which means "to squeeze."
- When strained, piezoelectric elements create a charge
- Crystalline quartz, is a stable and sensitive piezoelectric material

Under shear load

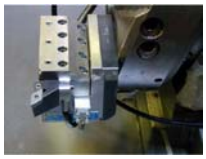


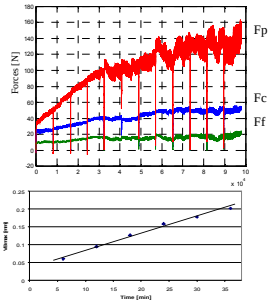


## Three component dynamometer with piezo-electric transducer



## Monitoring Three Cutting Forces with 3-D Force Dynamometer in Hard Turning Process

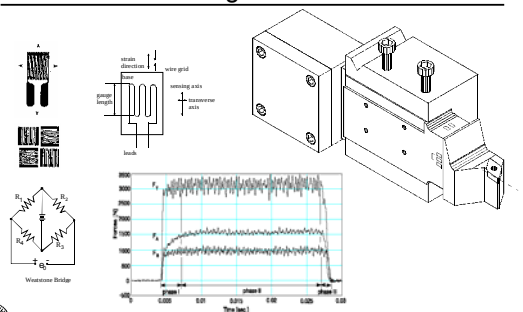





Workpiece: 100Cr6, Bainitic, 57-60HRC
Cutting parameter: v=160m/min, s=0.05mm, a=0.05mm
Cutting time 38min, VBmax=0.2mm

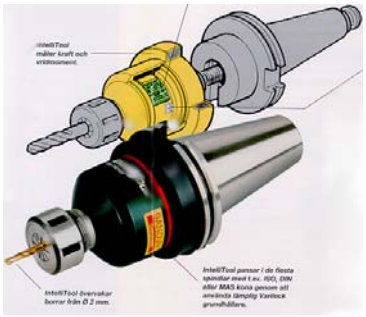


## Cutting Force Dynamometer Based on Strain Gauge Transducer



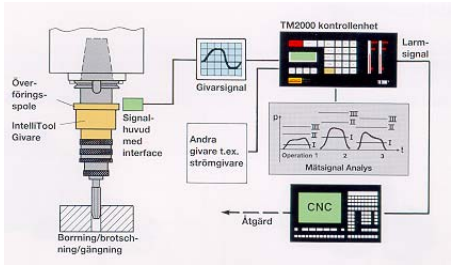



## Intelligent Tool





## Drilling Process Using Intelligent Tool



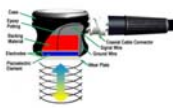



## Acoustic Emission

**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

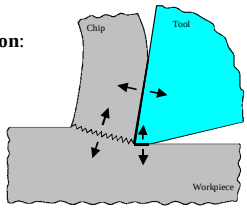
Convenntional and high speed machining process
- Wear
- Fracture
- Collision

Sheet metal forming
- Friction
- Cracking

## Source of Acoustic Emission

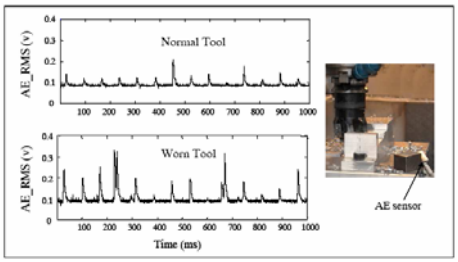
**AE** generates from friction on the rake face and flank, plastic deformation in the shear zone, crack formation and propagation, impact of the chip breakage.

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



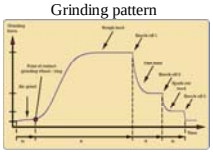



## AE application in milling process

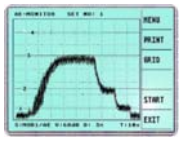


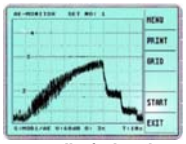

## Application AE in grinding

Grinding pattern

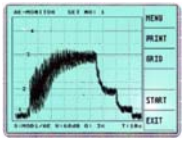


Normal

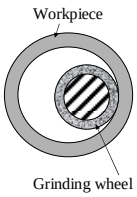




Too small infeed resulting longer grinding cycle



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