CIRP UK Meeting 8th May 2009

Fundamental Study of Corrective Abrasive Machining Technology

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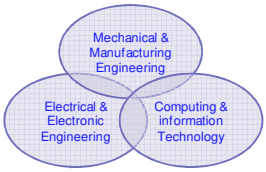
Advanced Machining Technology Group
Centre for Precision Technologies
School of Computing and Engineering

Precision machining technology

Unique pioneer challenge in developing

next generation machining technology

Current Research Themes



- Precision machining
  - Abrasive machining
  - Diamond turning
  - Finite element analysis and molecular dynamics
- Intelligent process monitoring and control
  - Contact detection using acoustic emission
  - Abrasive machining monitoring using AI techniques
- Knowledge support systems

  Database / Knowledge warehouse

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Educating tomorrow's professionals

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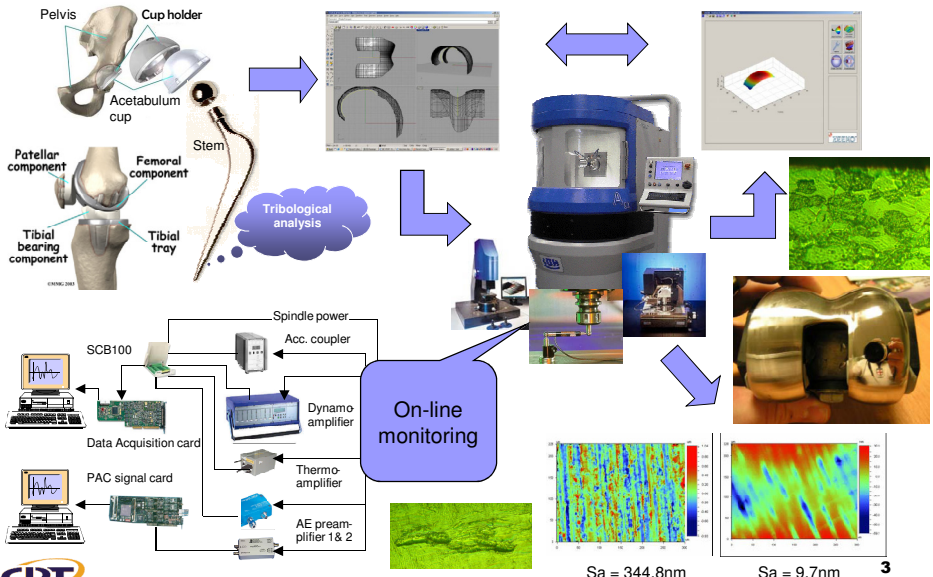
Basic principle of precision corrective machining



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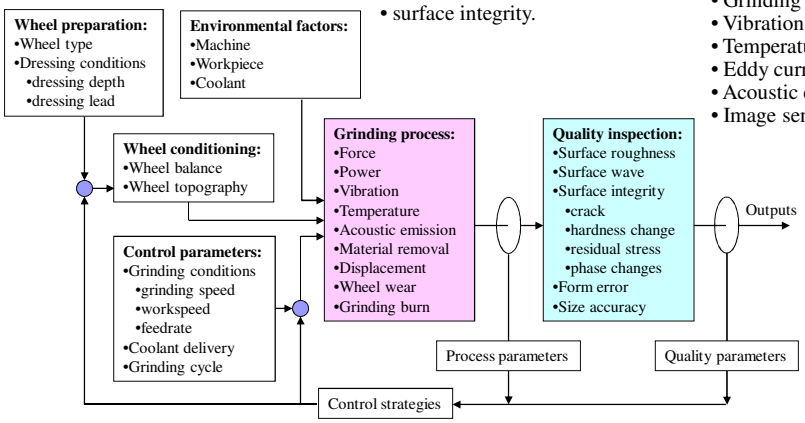
Framework of a grinding process control

Control methods
- adaptive control,
- constraint control.

Three major measures of grinding qualities
- accuracy of size and form,
- surface roughness,
- surface integrity.

Sensors:
- Power and torque
- Forces
- Size gauging
- Grinding force
- Vibration monitoring
- Temperature sensing
- Eddy current sensing
- Acoustic emission
- Image sensing



Monitoring & control; Surface integrity; Coolant delivery; Wheel dressing

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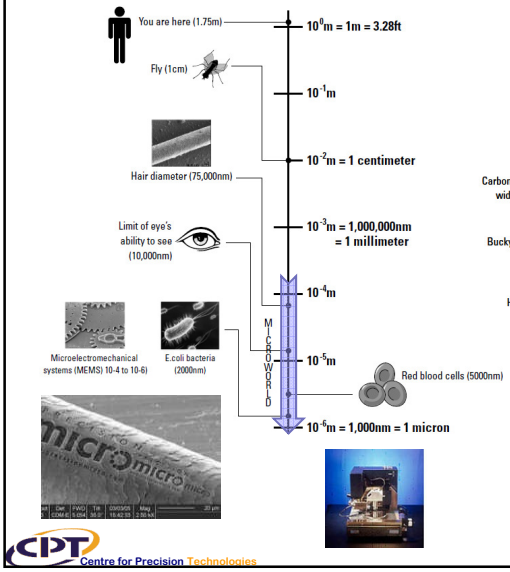
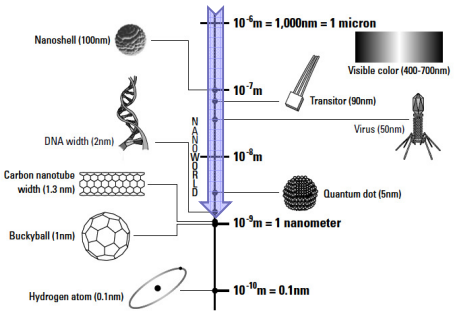
From the macroworld to the nanoworld

(The Hitchhiker's Guide to Nanotechnology, 2006)





Micro-machining is considered to cover the production of minute components and features from a wide range of materials, generally in the size range of 200 microns to a few nanometres and may also be known as micro drilling, micro cutting, micro milling, micro grinding and micro etching.

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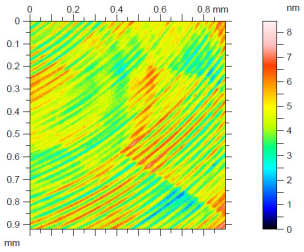
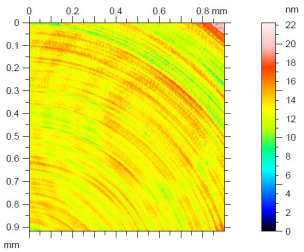
Challenge of nanometre scale machining

Sa < 1 nm
Form error < 0.1 µm



Aluminum (Al) Sa = 0.742 nm

- Spindle RPM: 2000
- Finish Feedrate: 7.5 mm/min
- Finish Depth of Cut: 2 µm
- Coolant: Odorless Mineral Spirits



Nickel (Ni) Sa = 0.924 nm

- Spindle RPM: 3000
- Finish Feedrate: 5 mm/min
- Finish Depth of Cut: 4 µm
- Coolant: Odorless Mineral Spirits

Grain boundary indicates the limitation of the conventional turning operation limitation.

What can be done?

It was claimed that grinding has no minimum depth of cut.

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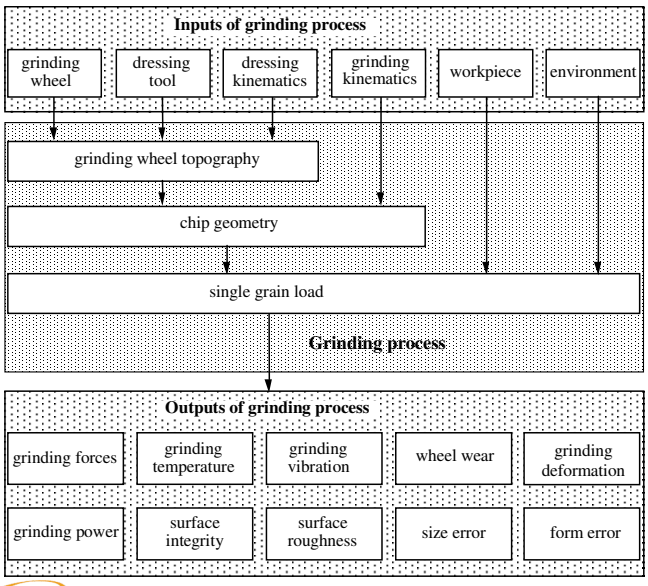
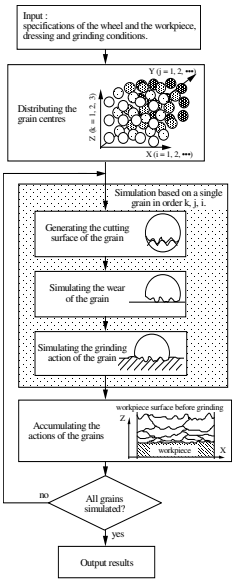
Basic Relationships of a Grinding Process and Simulation





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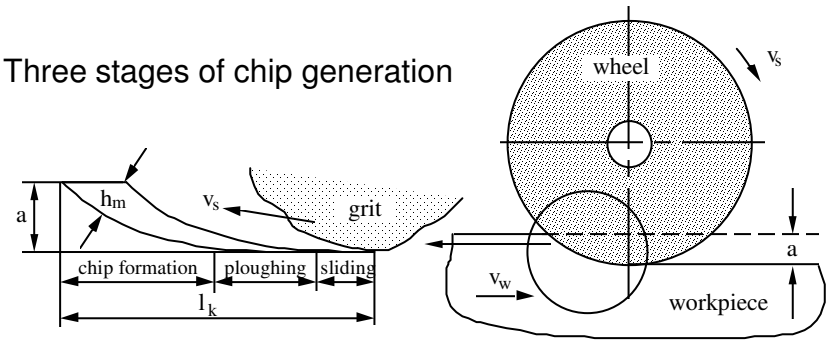
Fundamental Mechanism of Grinding

Three stages of chip generation



AE signals would have certain features that present three stages of chip generation.

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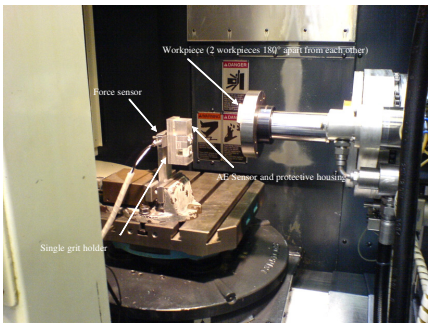
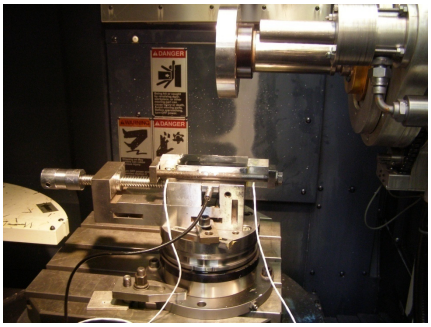
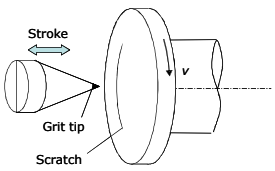
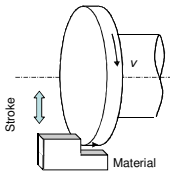
Rigs for single grit grinding tests









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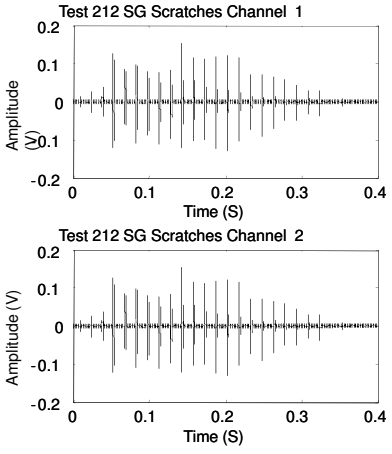
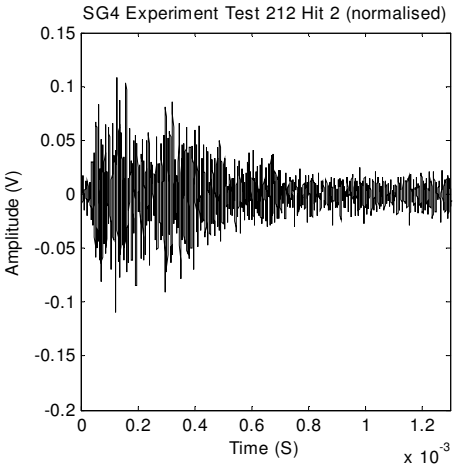
AE signals of single grit scratch





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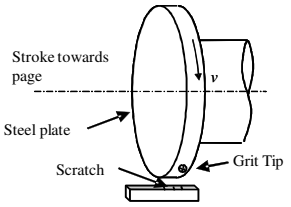
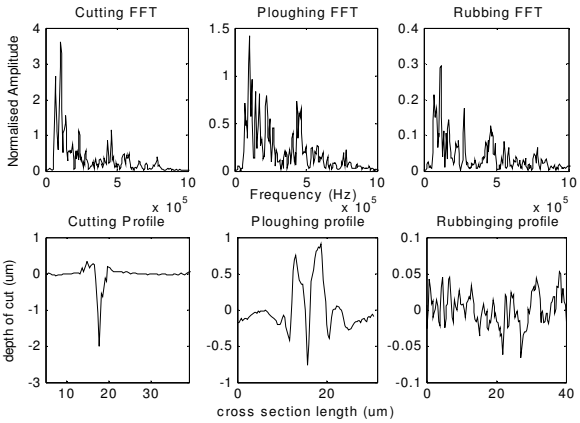
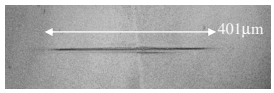
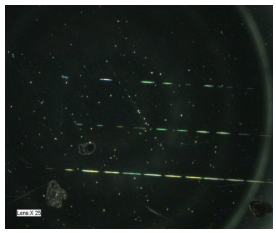
Single grit scratch test









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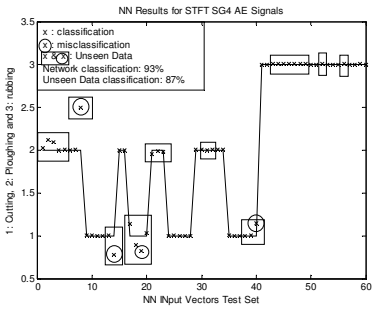
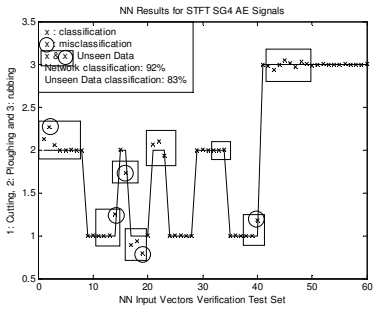
Grinding mechanism classification using Neural Networks





Wheel rotational speed = 4000 rpm, Feedrate = 4 m/s.

Workpiece materials: CMSX4

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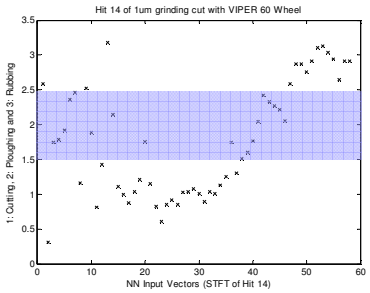
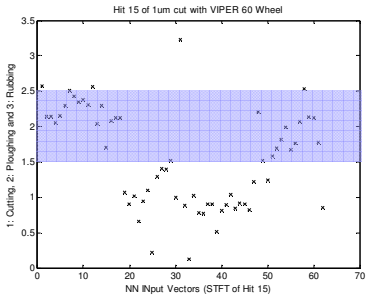
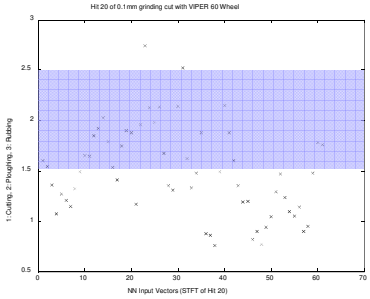
Feature extraction of AE in grinding



Wheel rotational speed = 4000 rpm,
Feedrate = 4 m/s,
Workpiece materials: CMSX4.

	C%	P%	R%
1 μm cut	45	29	26
1 μm cut	45	47	8
0.1 mm cut	57	40	3





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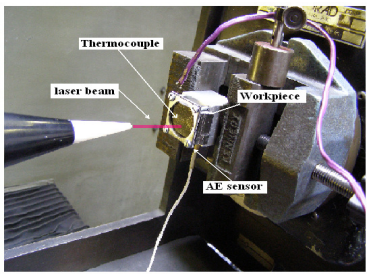
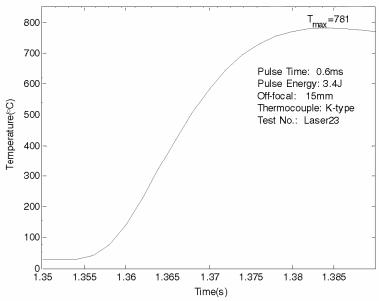
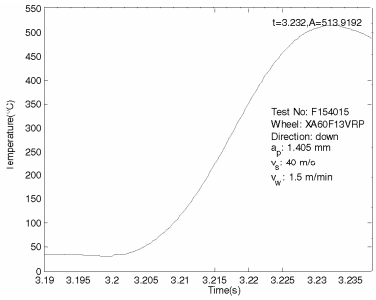
Laser irradiation imitating grinding thermal behaviour

Laser machine	Lumonics:JK704 Nd:YAG
Wave length	*1.06 ηm*
Pulse energy	*1.36J*
Maximum peak power	*2.5kW*
Laser irradiation time	0.06 ms
Focal length	120 mm
Light beam diameter	12 mm
Off-focal length	34~46 mm





(a)



(b)

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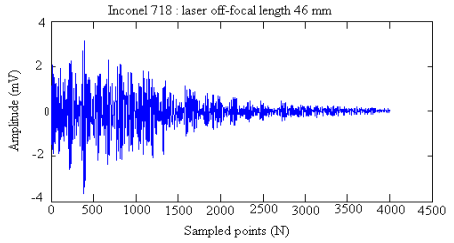
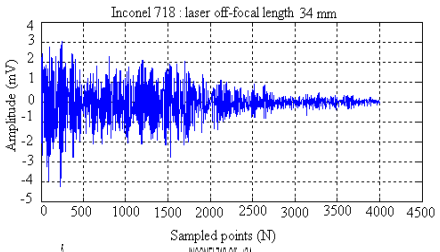
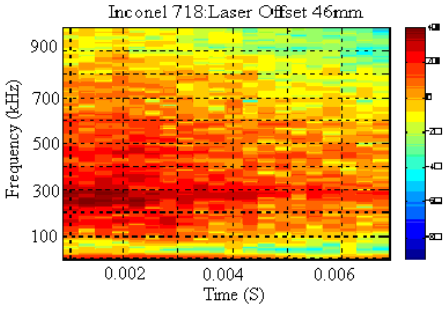
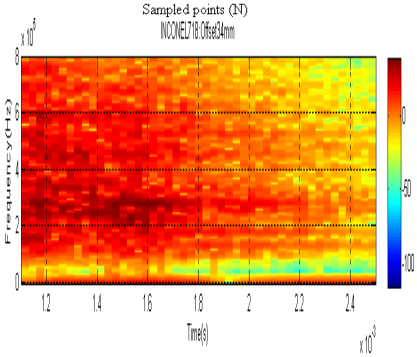
Features of thermal stress induced AE signals









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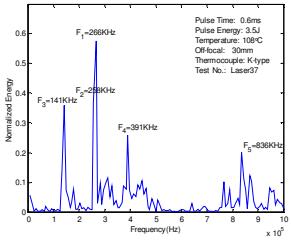
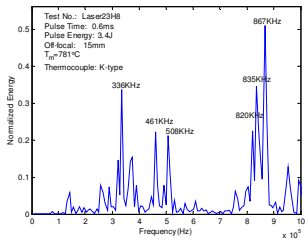
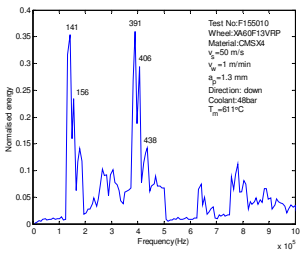
Comparison of AE signals generated by laser and grinding

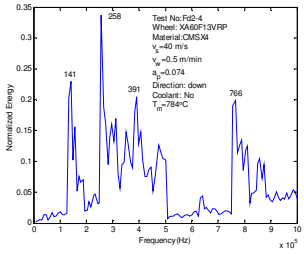
Laser





Grinding





Low temperature

High temperature

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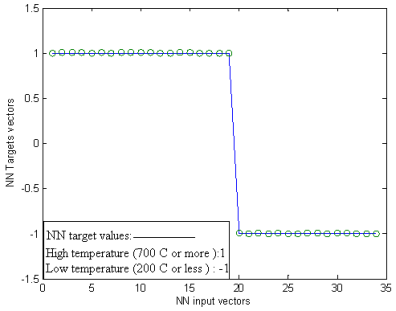
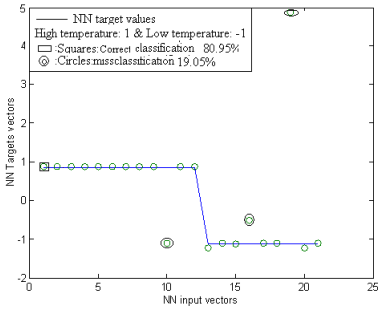
Grinding thermal behaviour monitoring by using thermal AE signatures



The NN created using AE signatures from laser irradiation



Grinding burn identification using the NN from thermal AE signatures

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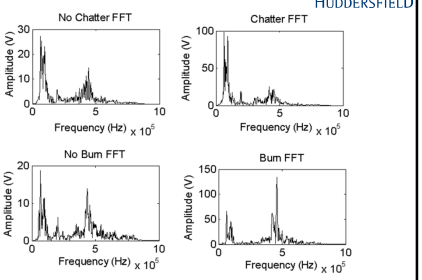
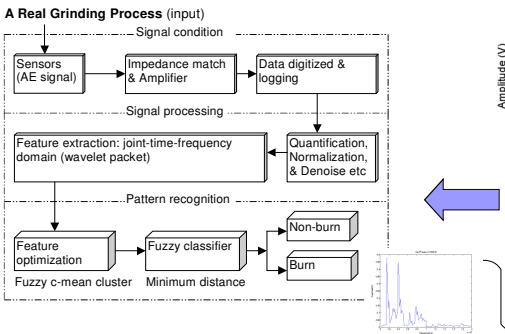
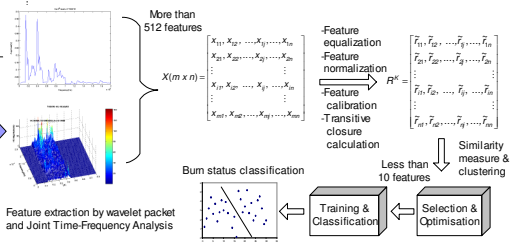
Pattern recognition for grinding defects





Fuzzy recognition block diagraph

Fuzzy recognition procedure



- Success rate 92.3%

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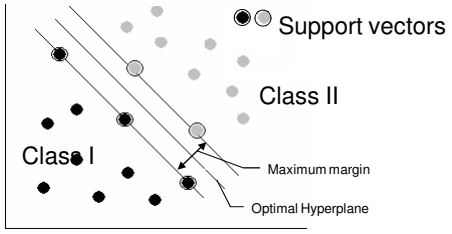
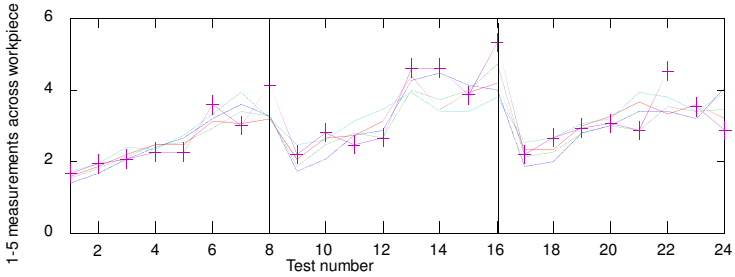
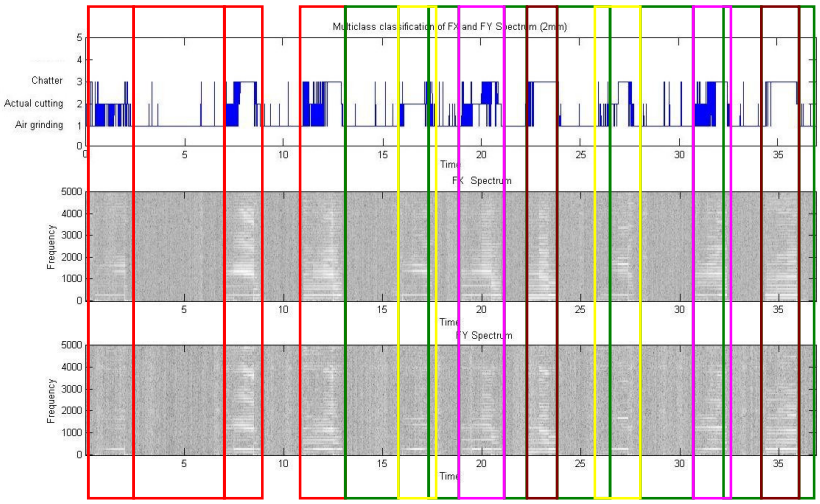
Support vector machine classification





Ra measurements for each cut (3 Trials separated by lines)

SVM classification



Benefits of SVM:
- ❑Small amount of training data required
- ❑Small amount of classifying time

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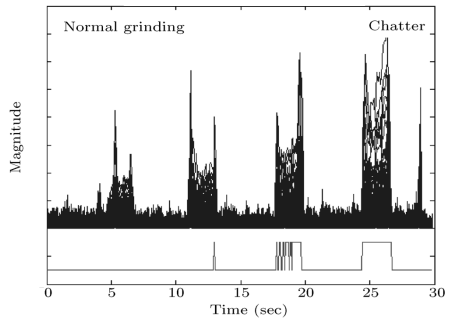
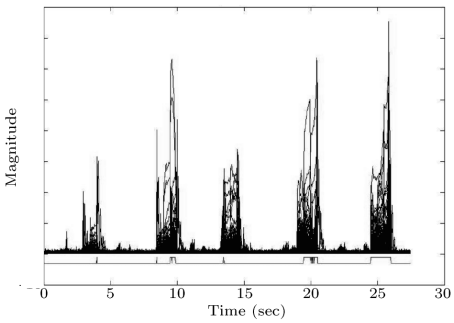
SVM Classification





Machine: Makino A55 CNC machine centre.
Workpiece: Inconel 718.
Wheel: VIPER wheel.
Depth of cut: 1 mm;
Grinding speed: 35 m/s;
Workspeed: 1000 mm/min.

Machine: Makino A55 CNC machine centre.
Workpiece: Inconel 718.
Wheel: VIPER wheel.
Depth of cut: 1 mm;
Grinding speed: 55 m/s;
Workspeed: 1000 mm/min.

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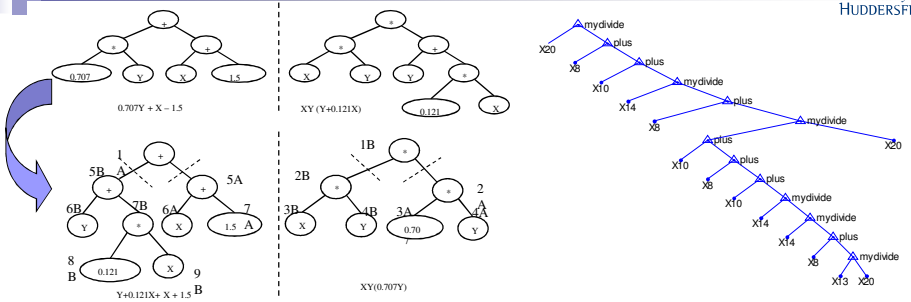
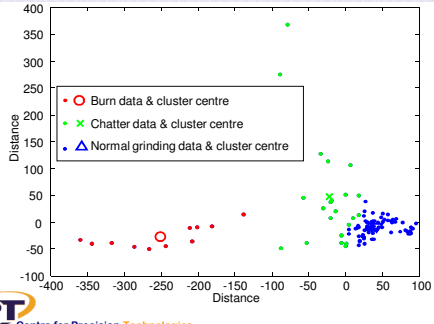
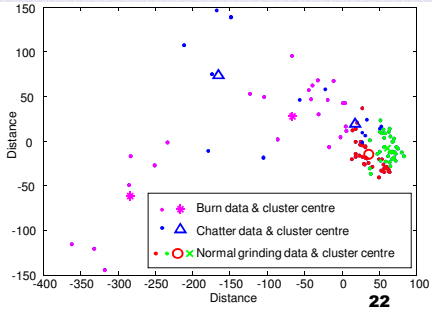


Multi-classification of normal grinding, grinding chatter and burn using the GP





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Classification of grinding anomalies using genetic programming

No.	GP fitness function	Data set	Function Nodes	Test Score	Accuracy %
1	sum diff fitness	ICA Chatter and burn	+,' -, '/, '*	32/40	80
2	sum diff fitness	*reduction: burn and no burn	+,' -, '/, '*	36/40	90
3	sum diff fitness	*reduction: burn and no burn	=<, '=>, if	36/40	90
4	sum diff fitness	*reduction: burn and chatter	+,' -, '/, '*	36/40	90
5	sum diff fitness	*reduction: burn and chatter	=<, '=>, if	38/40	95
6	classes overlap	ICA Burn and no burn	+,' -, '/, '*	33/40	82.5
7	classes overlap	ICA chatter and no chatter	+,' -, '/, '*	32/40	80
8	classes overlap	ICA chatter and no chatter	+,' -, '/, '*	40/40	100
9	sum diff fitness	ICA chatter and no chatter	+,' -, '/, '*	36/40	90
10	classes overlap	ICA Burn and no burn	+,' -, '/, '*	40/40	100
11	classes overlap	*reduction: burn and no burn	+,' -, '/, '*	40/40	100
12	classes overlap	*reduction: chatter & no chatter	+,' -, '/, '*	40/40	100
*reduction: is based on the statistical window n-dimensional reduction technique					

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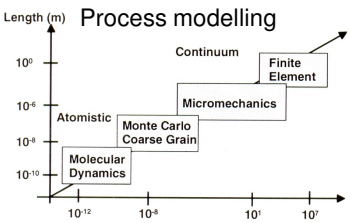
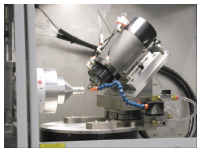
Micro and nano scale corrective abrasive machining

Process modelling





Two-body and three-body erosions

Grinding Lapping Polishing

Grolishing

Models Suitable conditions Process monitoring On machine probing

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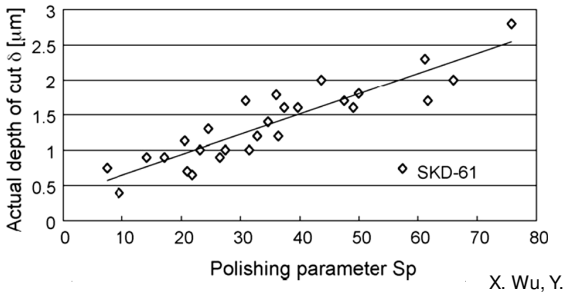
Grolishing Process Tools

Models of material removal

Preston material removal rate model $$\frac{dz}{dt} = C_p p v_r$$

Archard material removal volume model $$V_w = K\frac{F_n s}{H}$$

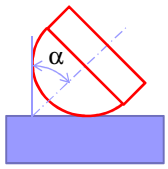


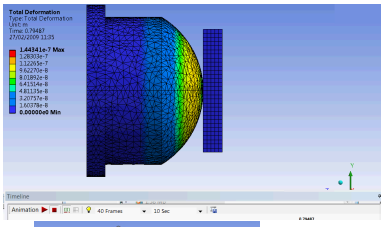
$$S_p = \frac{(V+f)p}{f H_v}$$

X. Wu, Y. Kita, K. Ikoku (2007)

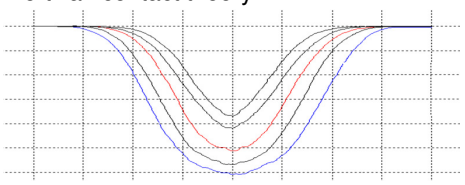
Grolishing material removal

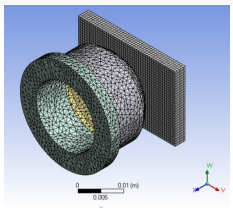
Modelling of Zeeko *gr*olishing tools
Simulation of Deformations and Stresses



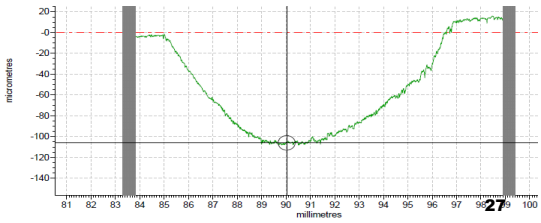


Hertzian contact theory





Real result



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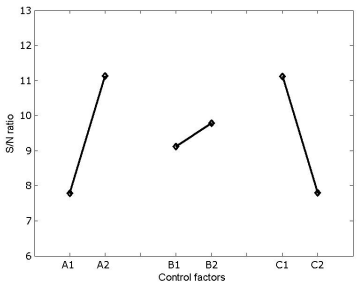
Taguchi test results

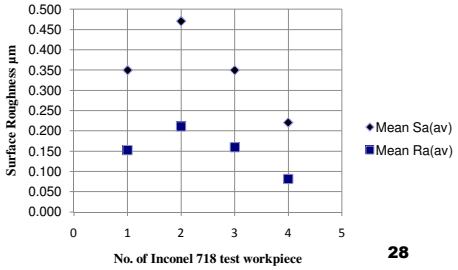
Representation	Control Factors	Levels 1	2
A	Head speed (rev/min)	1000	2000
B	Tool Angle (°)	0°	10°
C	Grit Size (µm)	7	25

Test No.	Control Factors A	B	C	Mean $S_{a(av)}$	S/N ratio
1	A1	B1	C1	0.350	9.12
2	A1	B2	C2	0.470	6.45
3	A2	B1	C2	0.350	9.12
4	A2	B2	C1	0.221	13.12



The best result is A2, B2, C1

Further improvement could be achieved by using different pad.



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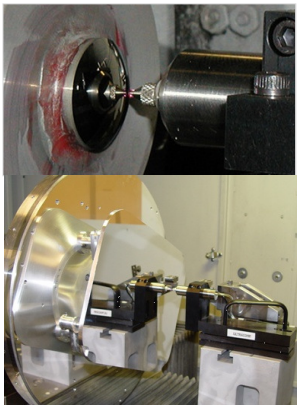
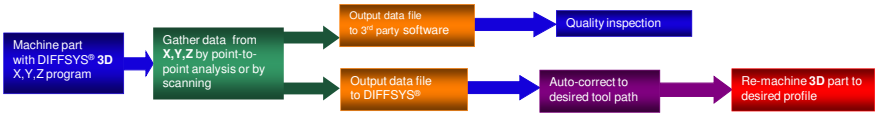
Error compensation On-Machine Metrology enhanced

2D and 3D Metrology

Utilizing **UltraComp's**™ LVDT, 2D and 3D data files of the part profile can be gathered including the machine axes

DIFFSYS® MC3 performs data import, graphically displays and auto-corrects the 3-dimensional part profiles from the LVDT measurement data to the desired part profile.





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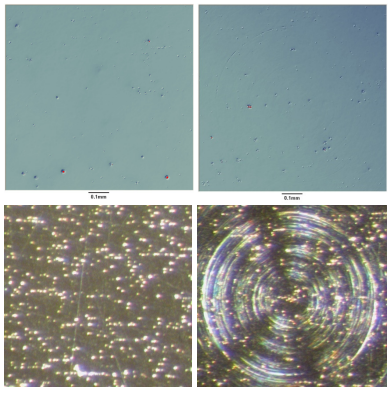
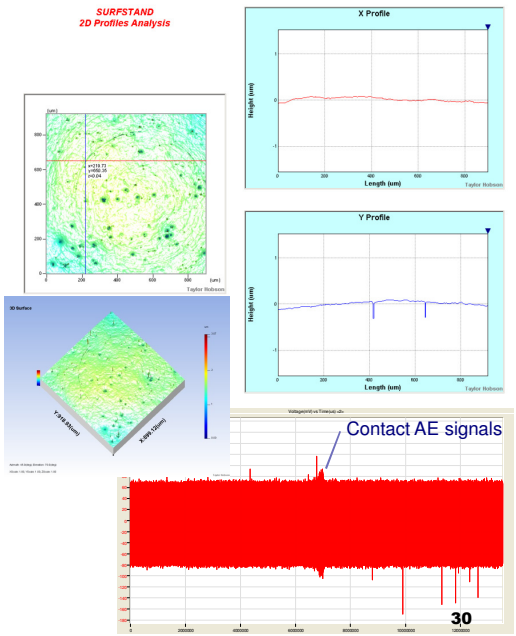
AE detection of contact

Before contact After contact





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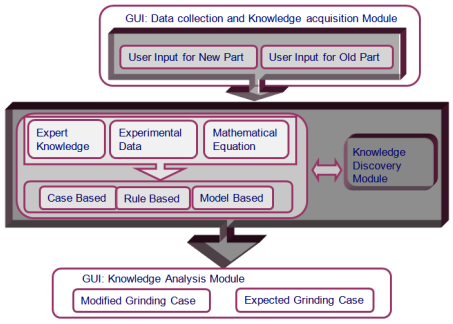
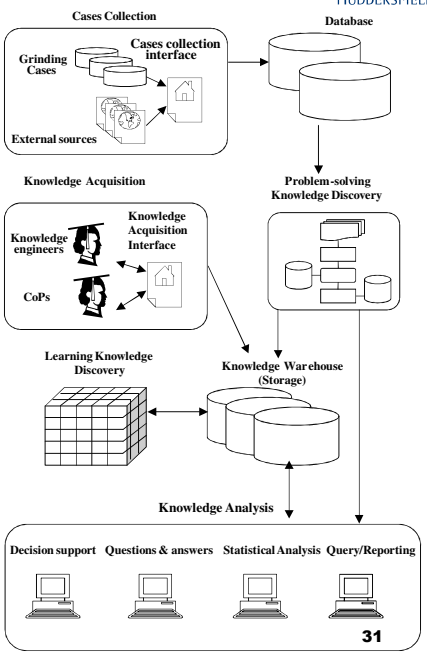
Manufacturing Knowledge Warehouse Development

Contents of communication in CoP
- Questions and answers.
- Passing documents or web links.
- Calling for events or conference.
- Sending news box.
- Others.

Framework of the warehouse
- date Input module
- database module
- problem solving module
- knowledge discovery module
- knowledge warehouse
- knowledge analysis module.





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Opportunities of further development

- Ultra precision corrective machining at nanometre scale (micro material removal).
- Intelligent machining monitoring and optimisation.
- Precision machining knowledge support system.

Thanks for listening

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