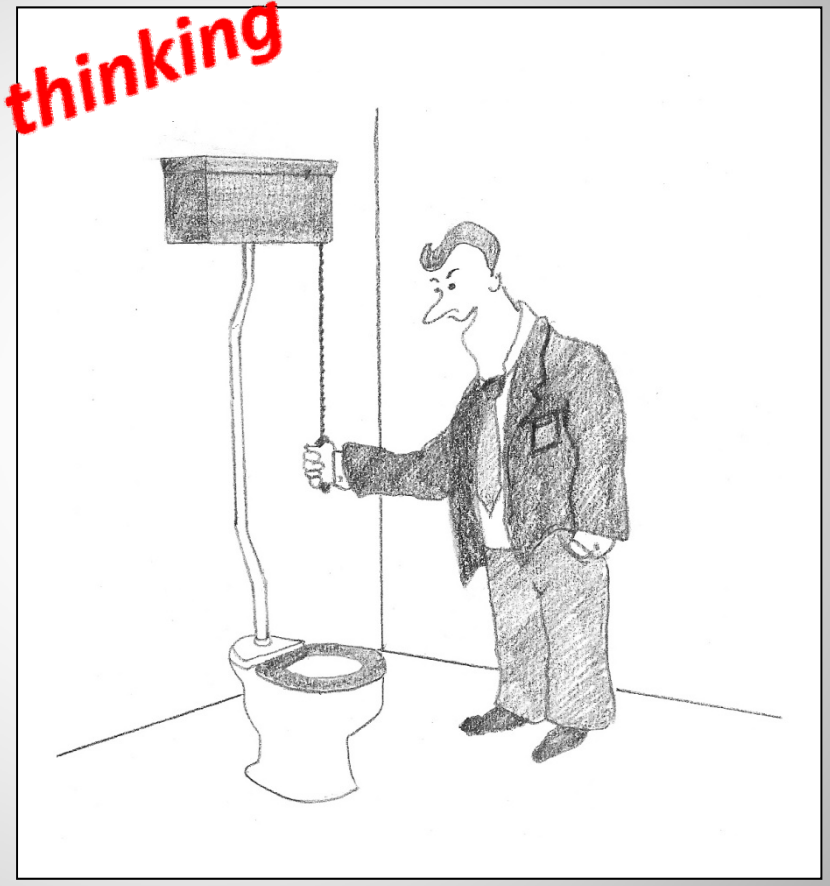
An Industrial Systematic Approach to Achieving the µm by Mechanical Engineering

Arthur Turner

The Secrets for Success in Micro Machining

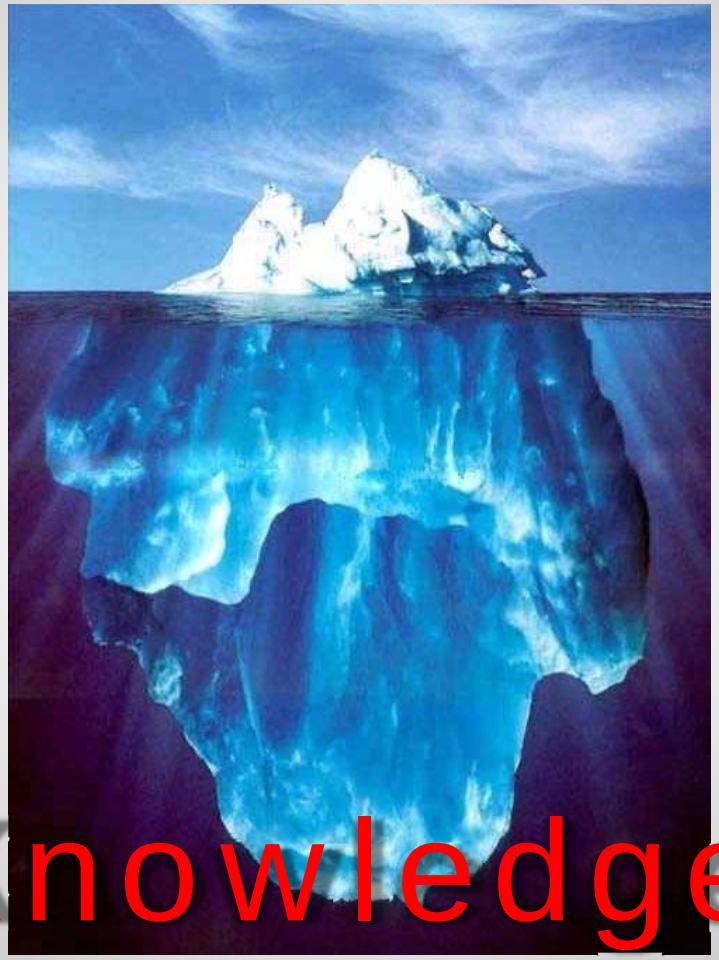
Flush away your old thinking



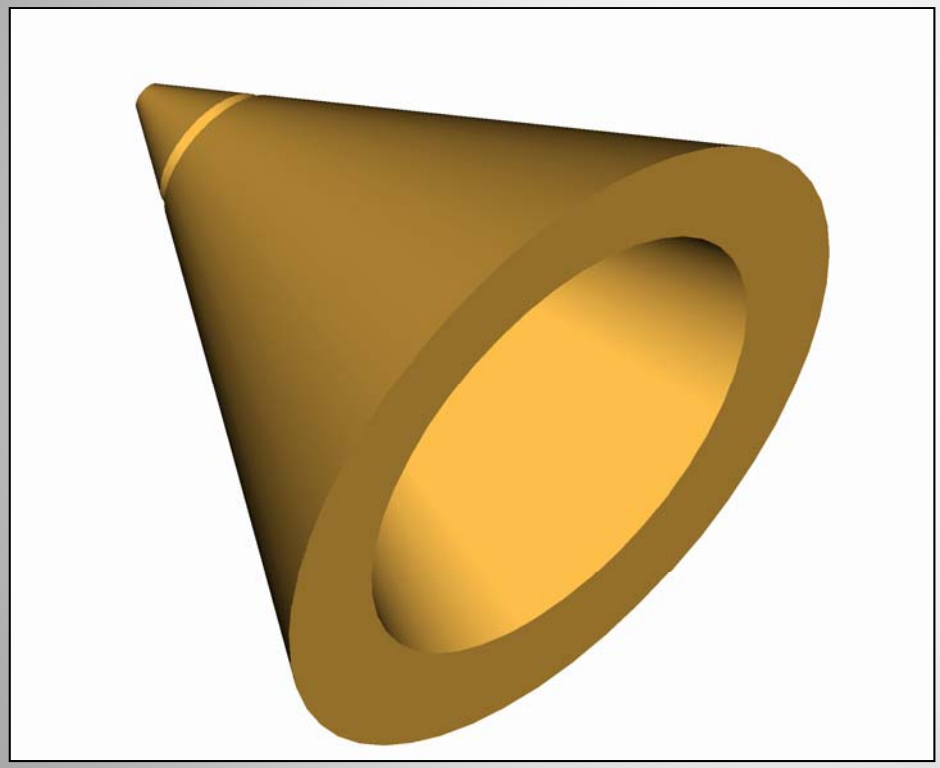
No Secrets

just plain common sense and sound engineering practice

Here we are



Looks interesting...



Height	1.50 mm
Base Diameter	1.60 mm
Tip Diameter	.05 mm
Wall thickness	.012 mm

Factors Influencing Precision:

PROCESS	MACHINE	ENVIRONMENTAL	HUMAN
Metrology	Design	Temperature	Management
CAD / CAM	Spindle	Sunlight	Operator
Cutting Tools & Tool Holders		Heating/Cooling	Designer
Workpiece Clamping		Foundations	
Workpiece Cooling			

Process Influences

Metrology CMM capabilities – vision systems or tactile ?

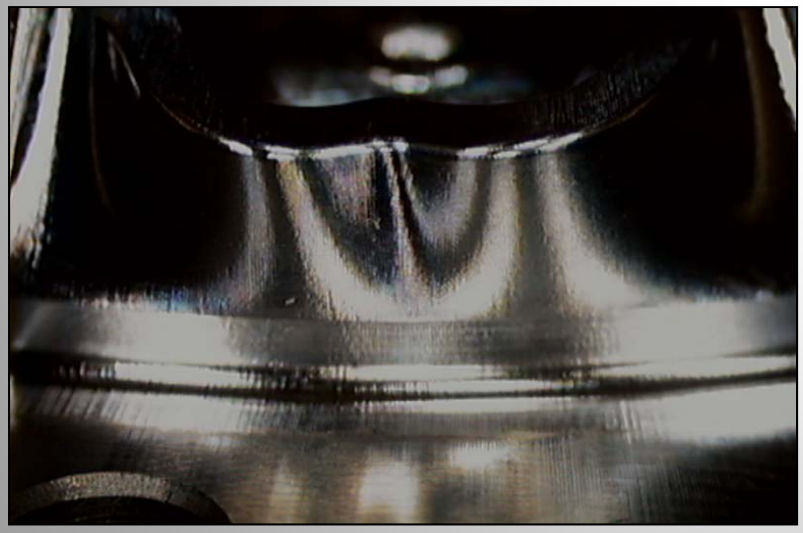
Accurate to 2 or 3 um ?

Accurate to 250 nm

Process Influences

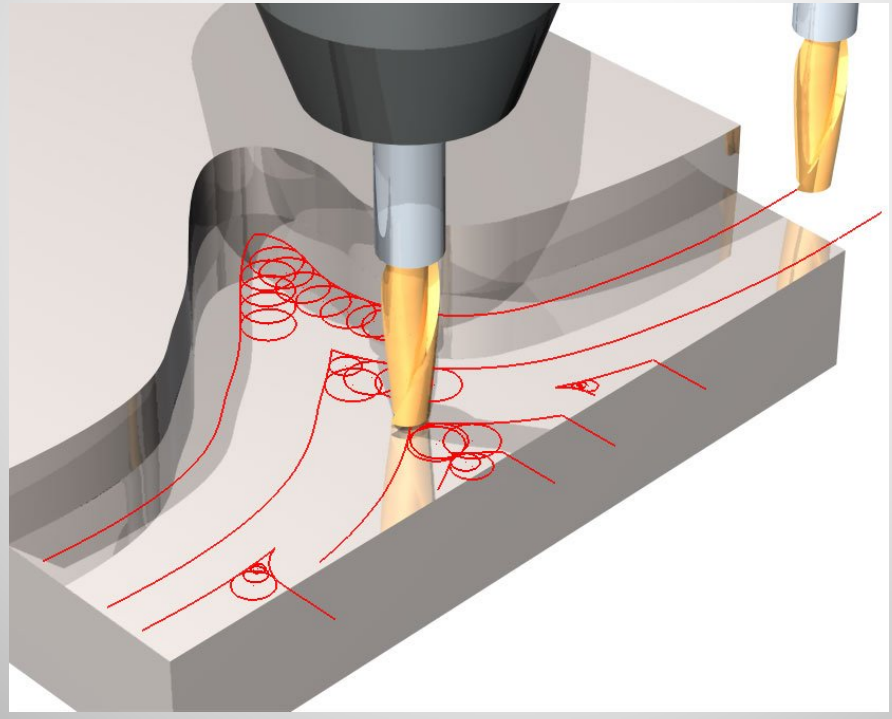
CAD /CAM cutter paths to produce the correct surface finish

Example: tooth mould



Process Influences

- CAD / CAM Machining strategy to enable small diameter cutters to be used without breaking



Process Influences

Cutting Tools

Material	HSS	Carbide	CBN	Diamond

Tolerance	diameter	from .005 to .050 mm
	radius	from .002 to .020 mm
	shank	from .005 to .050 mm

Process Influences

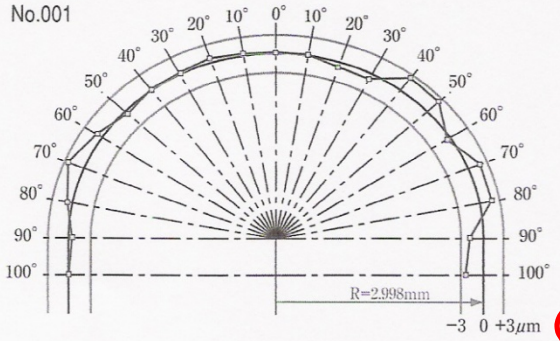
Cutting Tools Accuracy of form and guarantee of tolerance

ボールエンドミルR精度測定 Measurements of Ball Type End Mill R Accuracy

型番 Model ：高精度Rボールエンドミル（R3）Higher precise R Ball End Mill

Lot. No.:7720011

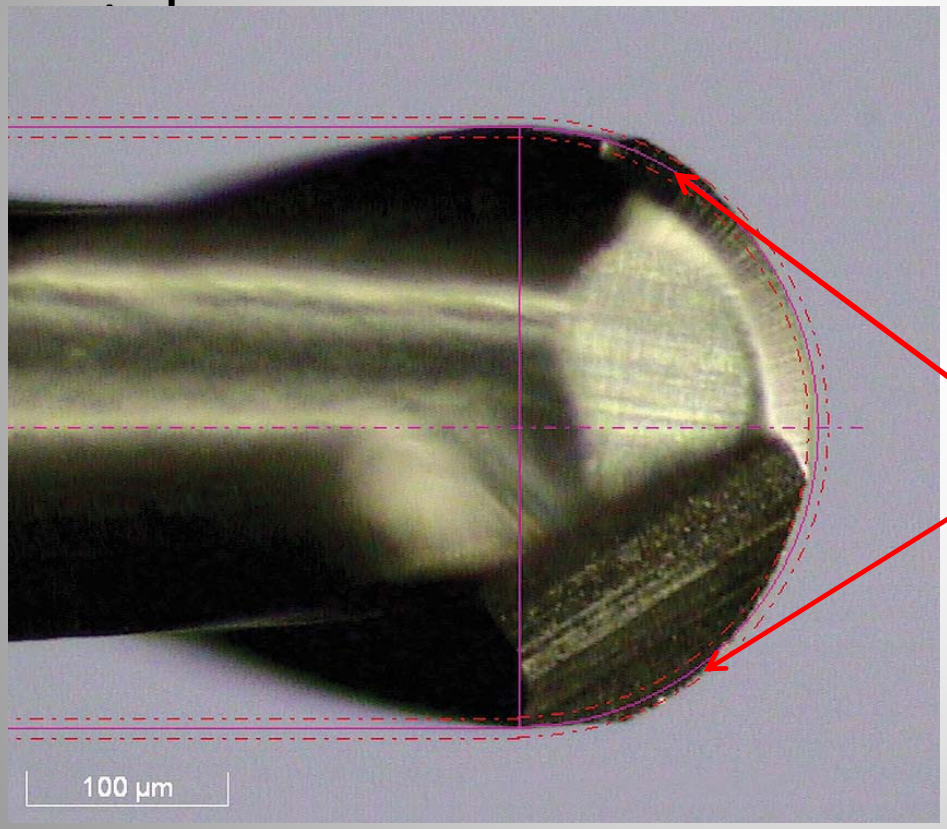
No.001



角度 Angle (°)	L 側 L side	R側 R side
0°	2.998	2.998
10°	2.998	2.998
20°	2.999	2.997
30°	2.998	2.997
40°	2.998	3.000
50°	2.997	3.000
60°	2.999	2.997
70°	3.000	3.000
80°	2.999	3.000
90°	2.997	2.997
100°	2.998	2.996
R 精度 R Accuracy	R=2.998 $^{+0.002}_{-0.002}$	
実測外径 Actual Outer Diameter	φD=5.996	

Tool Geometry -Milling Influences

New ballnose endmill with +/-.005 mm radius



Radius out of tolerance

Process Influences

- Tool holders
  - EX/ESX Collet chuck
  - Collet chuck
  - Heat shrink system
  - Zero-fit chuck

Process Influences

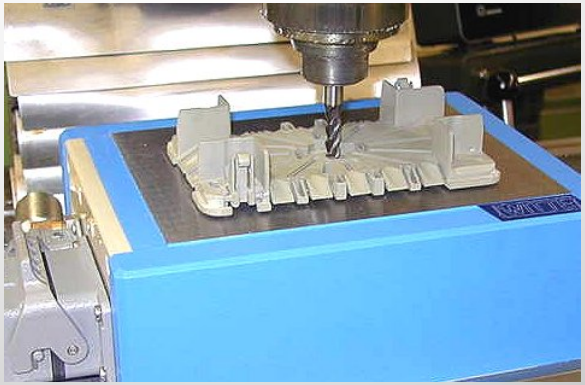
<u>Workpiece clamping</u>

Micro vices & clamps

Resin, wax

Ice chucks

Vacuum chucks



Process Influences

Workpiece Cooling or Lubrication Systems

Minimum Lubrication

Air Blow

Spray Mist

Cold Air

Volume Systems

Flood Coolant

Dielectric Systems

Temperature Controlled

Factors Influencing Precision:

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Correct machine for the job

Machine

Rigidity of build

Not influenced by heat or vibrations

Spindle concentricity

Finesse of movement

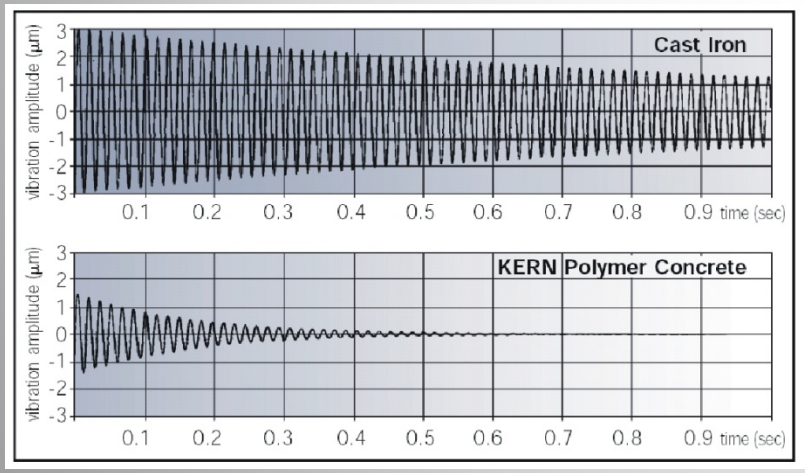
The control is up to the job

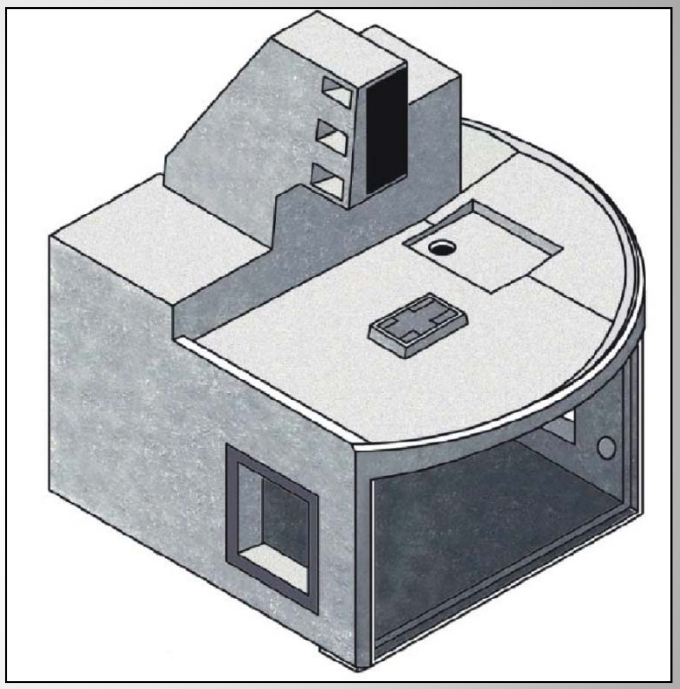
Machine Influences

Rigid design

Resistance to thermal growth

Vibration dampening





Polymer Concrete
or Granite bed

Machine Influences- Spindle

Is your spindle concentricity good enough?

Two simple checks

- Clock the inside of the spindle nose
- Use a test bar to measure run-out

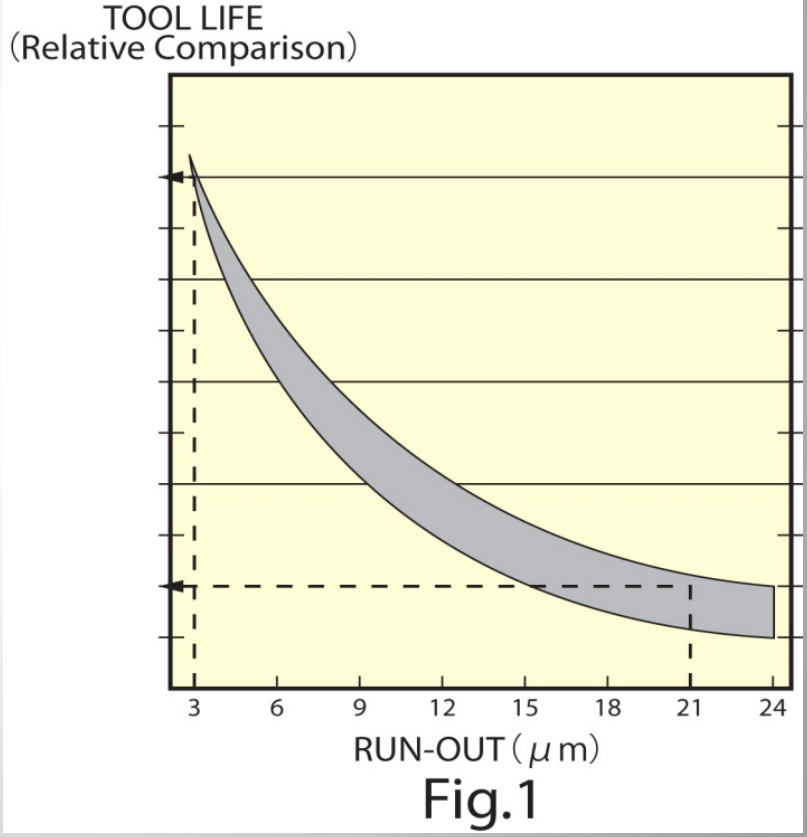
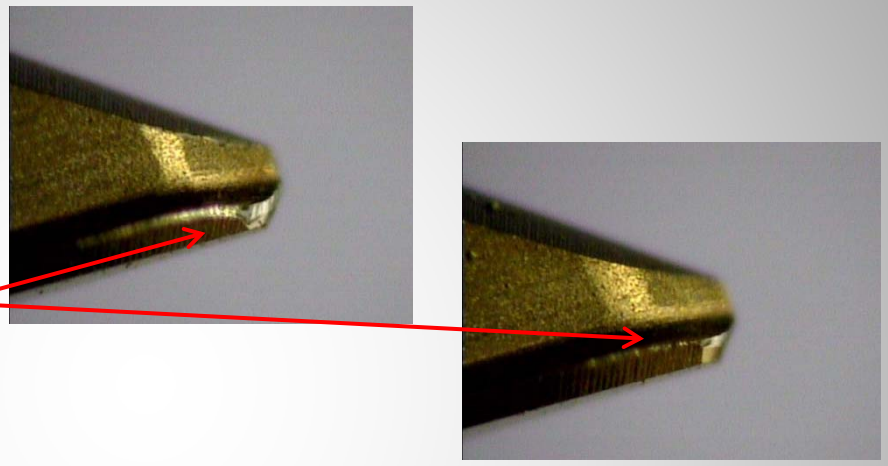


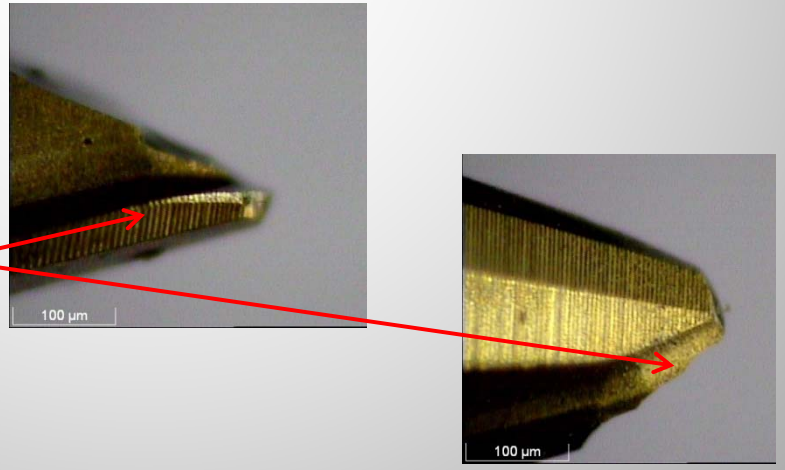
Fig.1

Machine Influences- Spindle

Tool not running concentrically shown by uneven wear

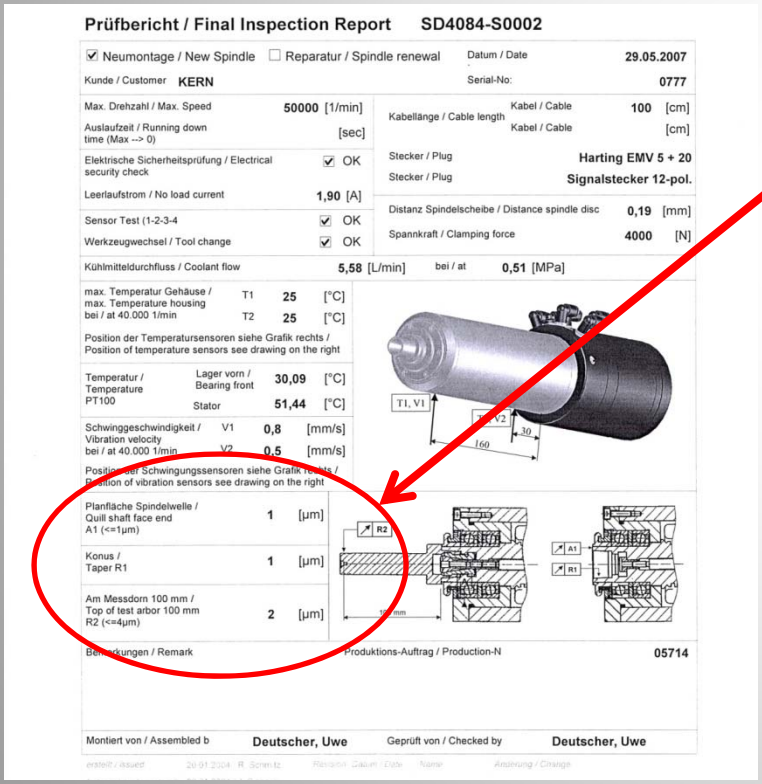


Tool not running concentrically shown by tool breakage



Machine Influences

Spindle concentricity



Prüfbericht / Final Inspection Report **SD4084-S0002**

☑ Neumontage / New Spindle ☐ Reparatur / Spindle renewal		Datum / Date	29.05.2007
Kunde / Customer KERN		Serial-No:	0777
Max. Drehzahl / Max. Speed	50000 [1/min]	Kabellänge / Cable length Kabel / Cable	100 [cm]
Auslaufzeit / Running down time (Max --> 0)	[sec]	Kabel / Cable	[cm]
Elektrische Sicherheitsprüfung / Electrical security check	☑ OK	Stecker / Plug	Harting EMV 5 + 20
Leerlaufstrom / No load current	1,90 [A]	Stecker / Plug	Signalstecker 12-pol.
Sensor Test (1-2-3-4)	☑ OK	Distanz Spindelscheibe / Distance spindle disc	0,19 [mm]
Werkzeugwechsel / Tool change	☑ OK	Spannkraft / Clamping force	4000 [N]
Kühlmitteldurchfluss / Coolant flow	5,58 [L/min]	bei / at	0,51 [MPa]
max. Temperatur Gehäuse / max. Temperature housing bei / at 40.000 1/min	T1 25 [°C]		
	T2 25 [°C]		
Position der Temperatursensoren siehe Grafik rechts / Position of temperature sensors see drawing on the right			
Temperatur / Temperature PT100	Lager vorn / Bearing front 30,09 [°C]		
	Stator 51,44 [°C]		
Schwinggeschwindigkeit / Vibration velocity bei / at 40.000 1/min	V1 0,8 [mm/s]		
	V2 0,5 [mm/s]		
Position der Schwingungssensoren siehe Grafik rechts / Position of vibration sensors see drawing on the right			
Planfläche Spindelwelle / Quill shaft face end A1 (<=1µm)	1 [µm]		
Konus / Taper R1	1 [µm]		
Am Messdorn 100 mm / Top of test arbor 100 mm R2 (<=4µm)	2 [µm]		
Bemerkungen / Remark		Produktions-Auftrag / Production-N	05714
Montiert von / Assembled b	Deutscher, Uwe	Geprüft von / Checked by	Deutscher, Uwe

Planfläche Spindelwelle / Quill shaft face end A1 (<=1µm)	1	[µm]
Konus / Taper R1	1	[µm]
Am Messdorn 100 mm / Top of test arbor 100 mm R2 (<=4µm)	2	[µm]

Spindle run-out causes:

1. Tool breakage
2. Excessive tool wear
3. Poor surface finish
4. Inaccuracy of component

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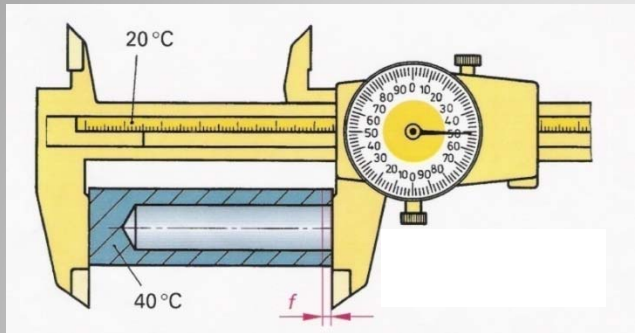
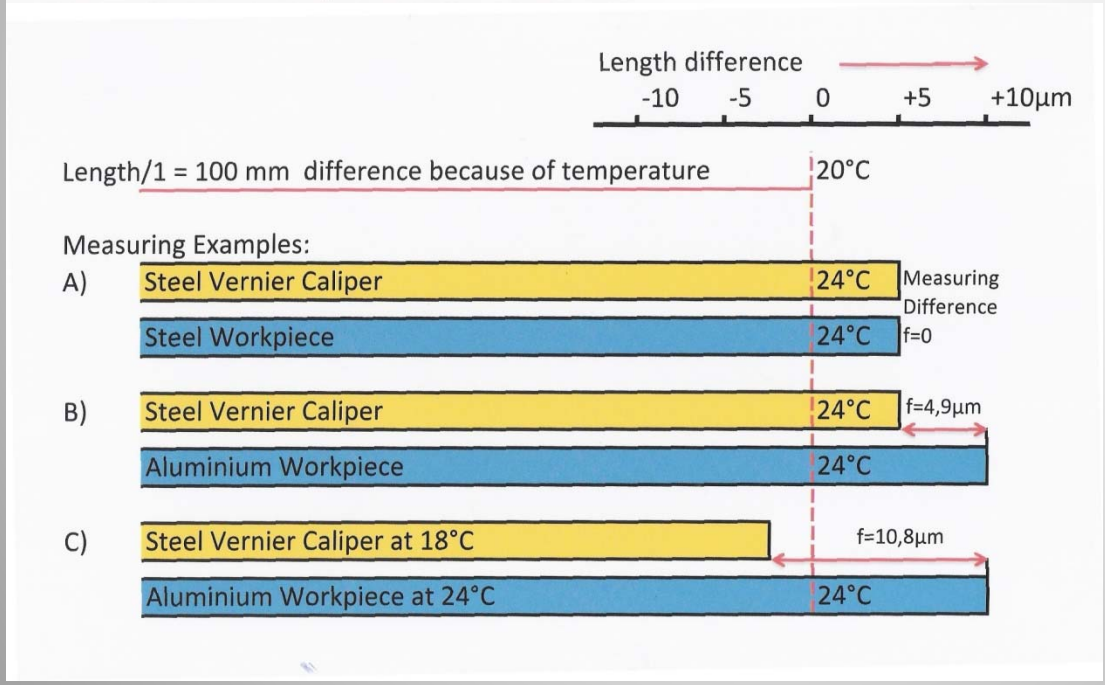
Environmental Influences



Influences of temperature with different materials



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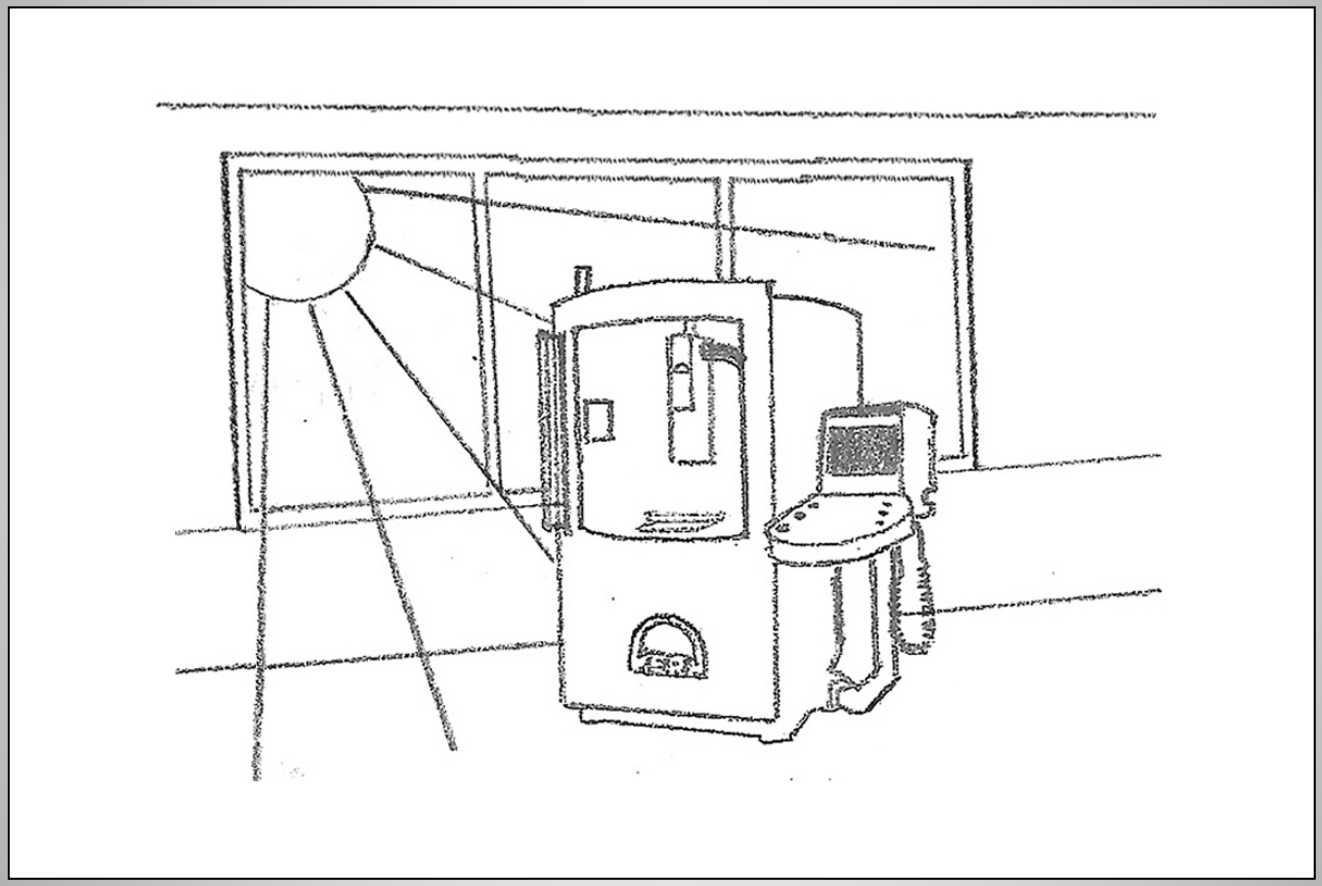
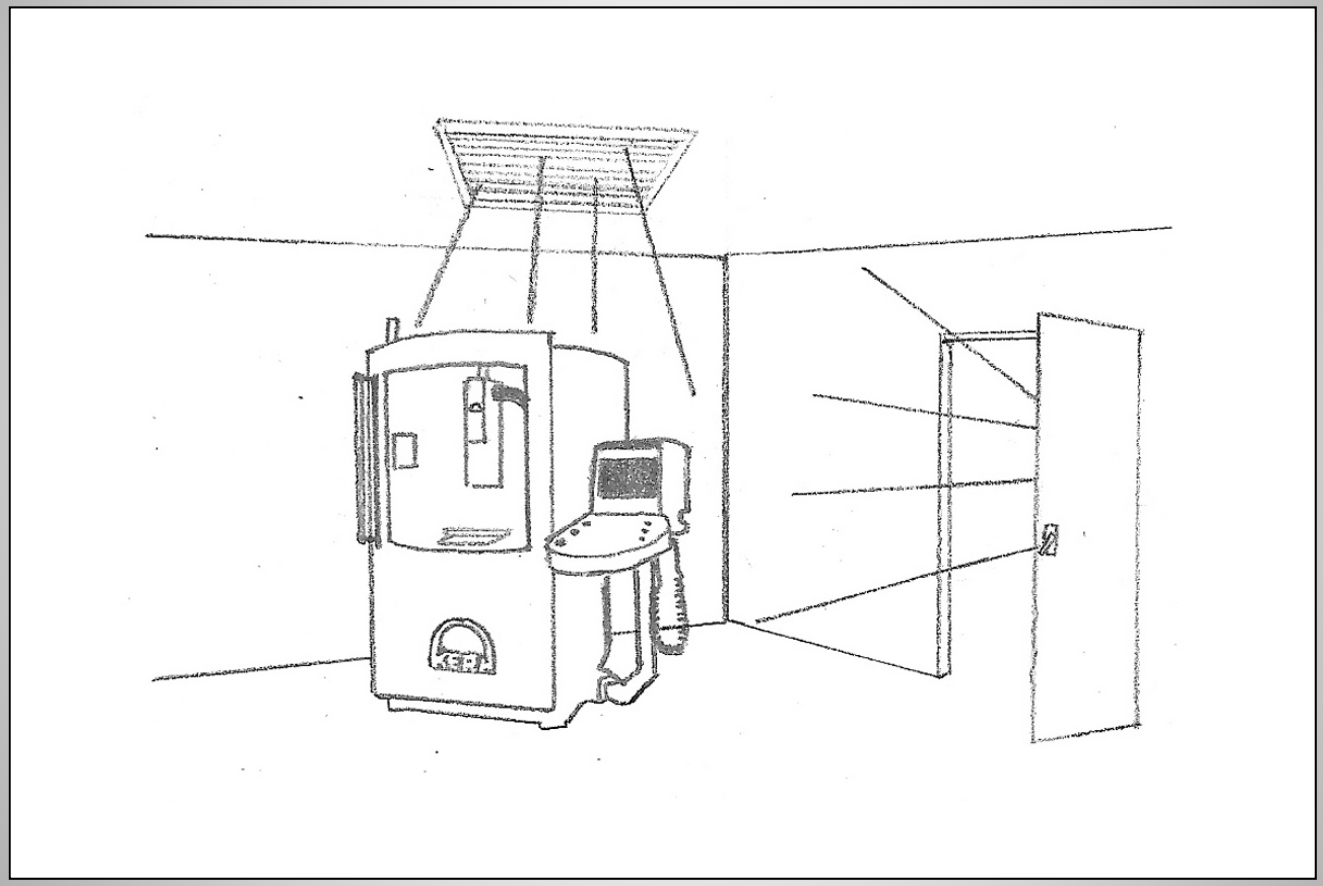


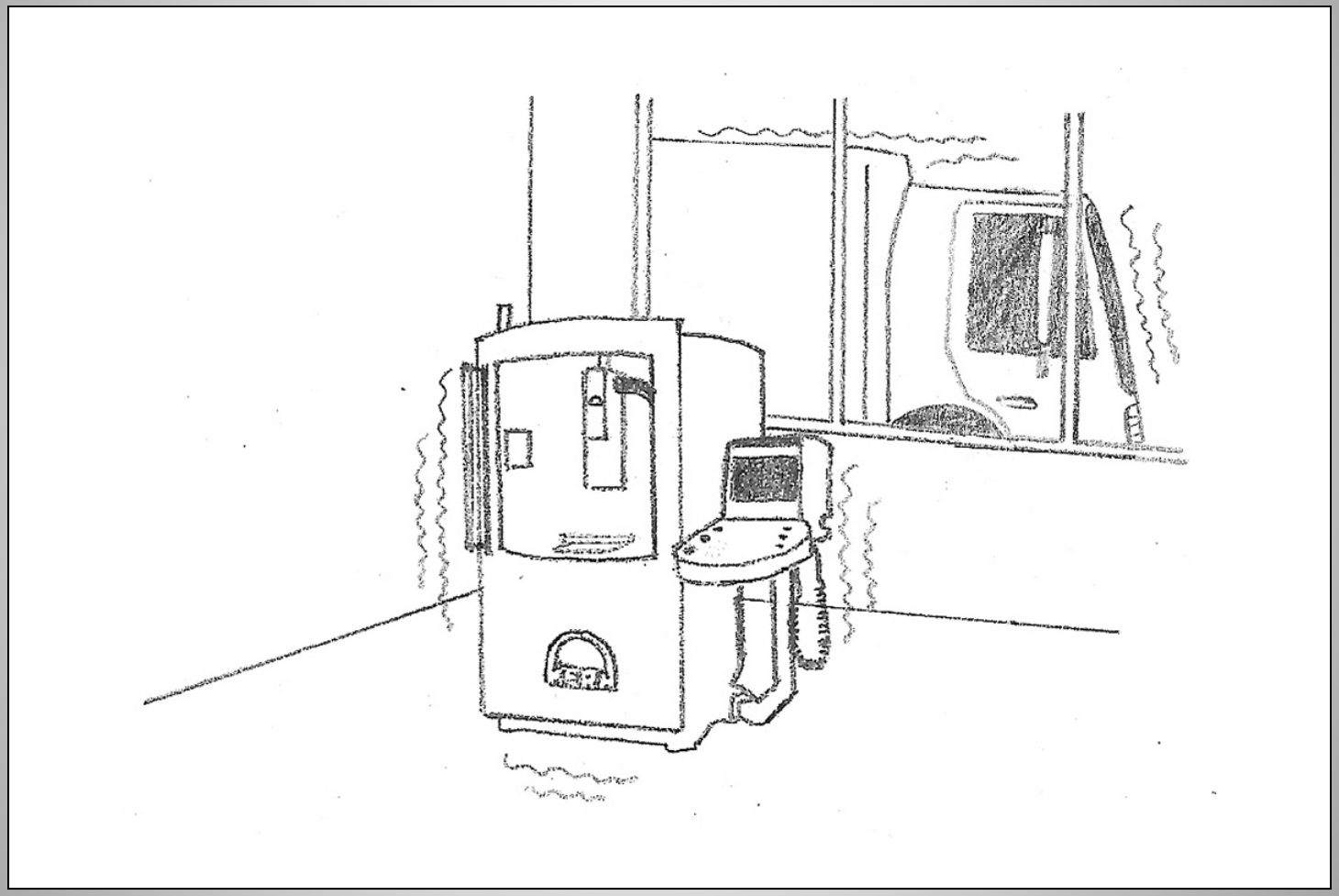
Environmental Influences



Environmental Influences

Not next to a heating system or under targeted air conditioning

Environmental Influences



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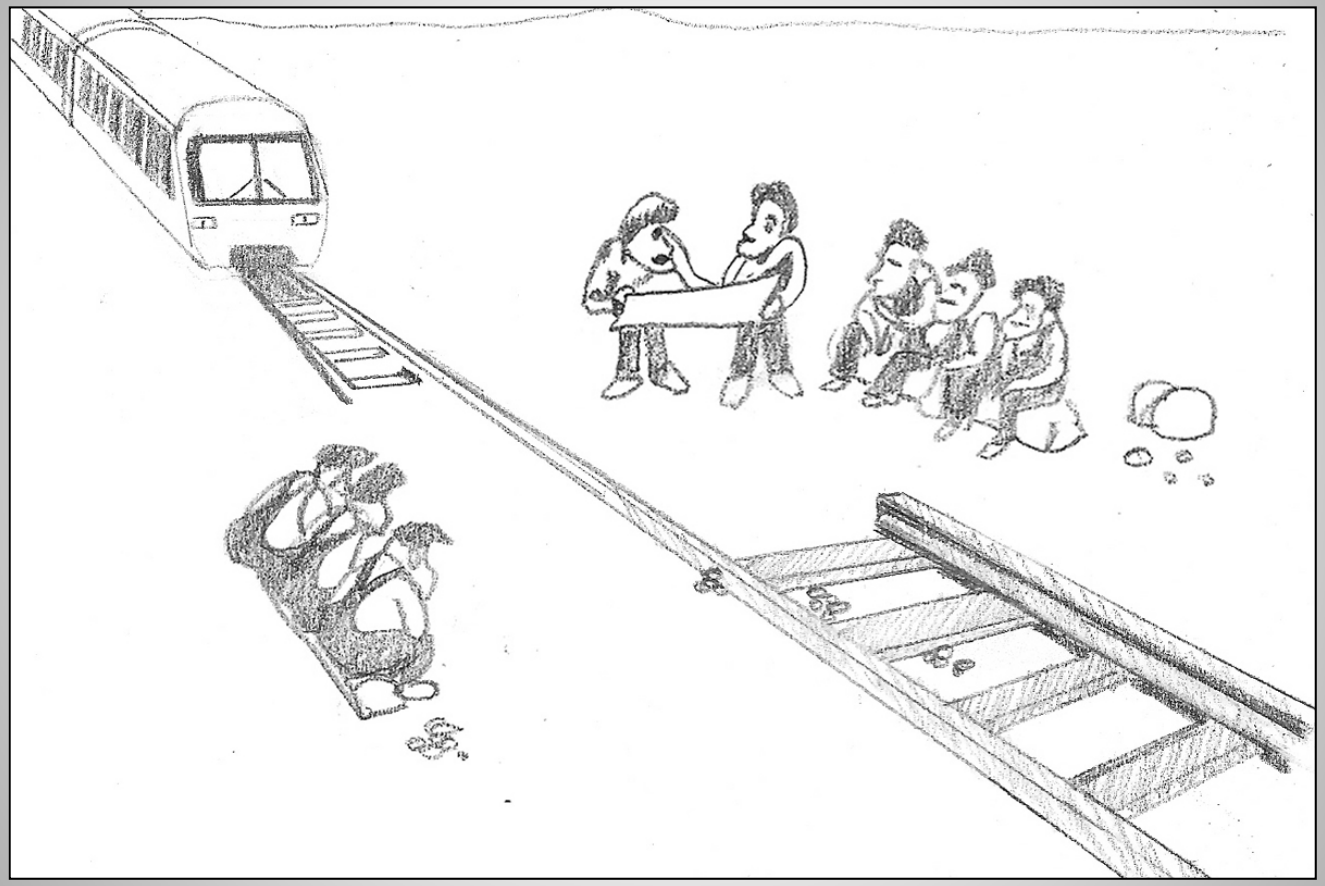
Human Influences

Management	- Organisational skills
	- Understanding of what is required (Totally)
Operator	- Skills
	- Passion for the challenge of the job
Designer	- Understanding of the machining process and the available machines and tools
	- Realistic designs

Human Influences



Poor communications

What's the next job?

How well do you know your manufacturing environment?

Do you use .002 mm dial indicators?

Check

Temperature range in your workshop Maximum to Minimum

Temperature range of the coolant systems used

Accuracy of the measuring machine

Diameter tolerance on endmills and drills

Concentricity of machine spindles and cutting tool holding systems

With Thanks to the following

Thank you

Any Questions ?