Applications of energy saving in machine tools

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www.iwu.fraunhofer.de

Energy efficient production

Reduction of energy consumption as a political-ecological necessity:

- Limitation of temperature raise up to 2°C
- Reduction of emission

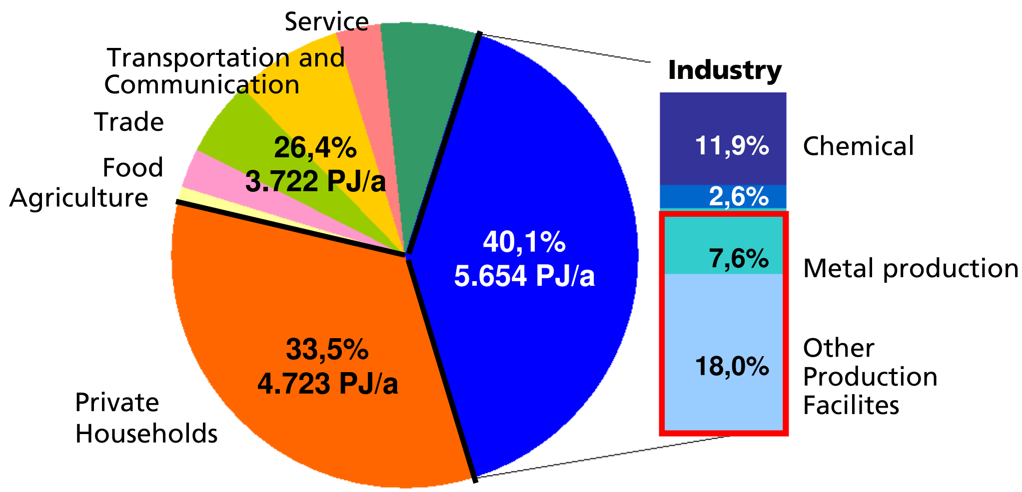
→ Reduction of total energy consumption

The total energy consumption in Germany: 14.101 PJ/a (2005)

Energy in the metal production and other industries per year: 3.609 PJ/a
18 %+ 7,6 %= 25,6 %

middle-term saving potential in industry: 30%(1)

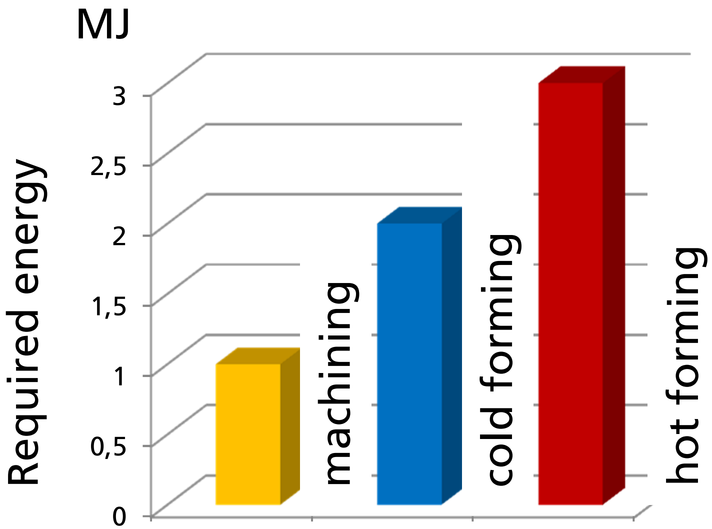
≙ 24 power stations, each one 1.4 GW



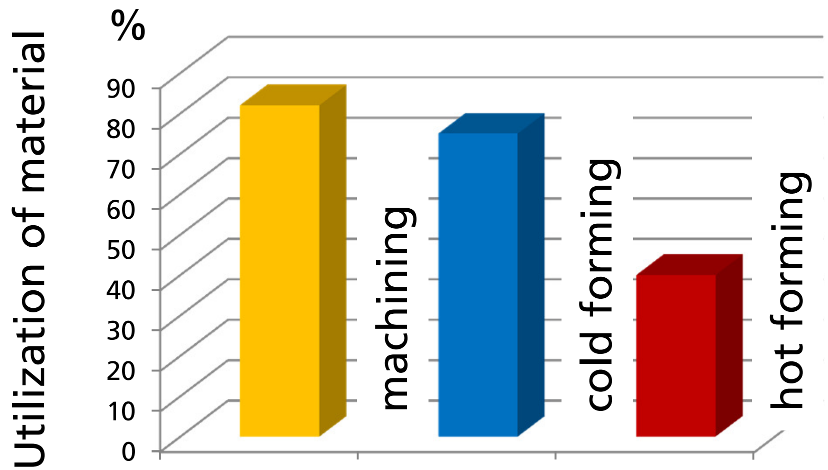
How can we influence industry, transportation and household to reduce energy consumption?

Energy utilization

Energy required



Utilization of material



Energy required (raw material): steel **15 MJ**

Example: finish part 1 kg

Machining: 2 kg = 30 MJ + 1 MJ = **31 MJ**

Cold forming: 1,2 kg = 18 MJ + 2 MJ = **20 MJ**

Analysis of energy flow in machine tools

- **Analyzing the electrical-energy flow** is essential to energy efficiency
- **electrical energy** (100% exergy) is converted through several transformations **into thermal energy** (nearly 100% anergy) during the machining process

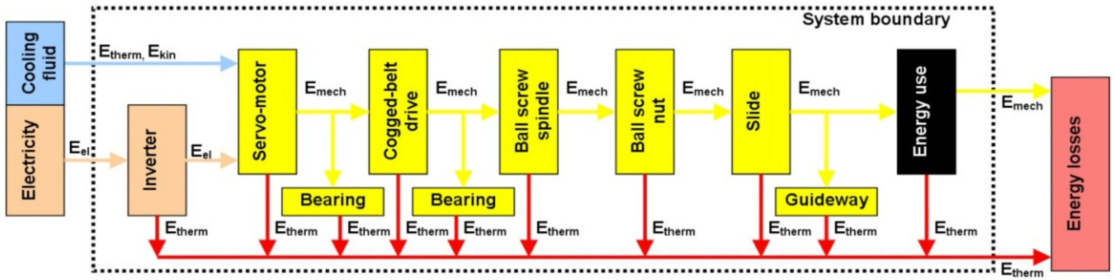
machine tool subsystems		P_{nom} [kW]	P_{nom} [%]	stand-by	ready for production	production: tool change	production: positioning	production: machining
servo drives	main drives	5,00	6,98		○	◑	◑	●
	support drives	51,50	71,93		○	●	◑	◑
auxiliary drives	coolant	11,99	16,75				●	●
	cooling	0,64	0,90	◑	●	●	◑	●
	hydraulics	0,96	1,35		●	●	●	●
	chip conveyor	0,25	0,35		◑	●	●	●
	air cleaner	0,53	0,74		◑	●	●	●
	tool changer	0,20	0,28			●		
controller	CNC	0,24	0,34	●	●	●	●	●
others		0,40	0,39	◑	◑	◑	◑	◑
installed nominal power		71,60	100,00					
compressed-air	sealing air	8,75		●	●	●	●	●
	clamp-systems					●		

Sub-systems and operation modes of a milling centre

- energetic and functional Classification sub-systems
- definition of operation modes and typical machining processes
- measurement of energy consumption

  ➔ calculation of energy consumption in Live cycle

- modeling of the Energy flow systems
- detailed measurement promotes information for simulation, calculation and design



Example for an energy flow system in a machine tool support drive

Energy power consumption

5 axis machining center

200 kWh/ day
x 220 days (2 shifts)

44 000 kWh/ year

10 x

Based on CO_2 emissions
km/year: 10 000 km

12 x

3600 kWh/year

227 x

193 kWh/year

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Machine tools

Possible energy savings

- ⇨ 78 % of whole power is basic load
- ⇨ 22 % of energy consumption takes machining
- ⇨ time utilization of machine
  - 38 % mass production
  - 15 % small series

exhaust

spindle

feeder

workpiece cooling

light

sealing air

cooling

hydraulic

machine control

chip conveyor

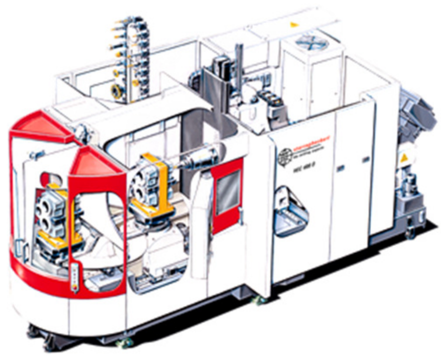
clamping unit

22% machining

78% basic load

Energy utilization

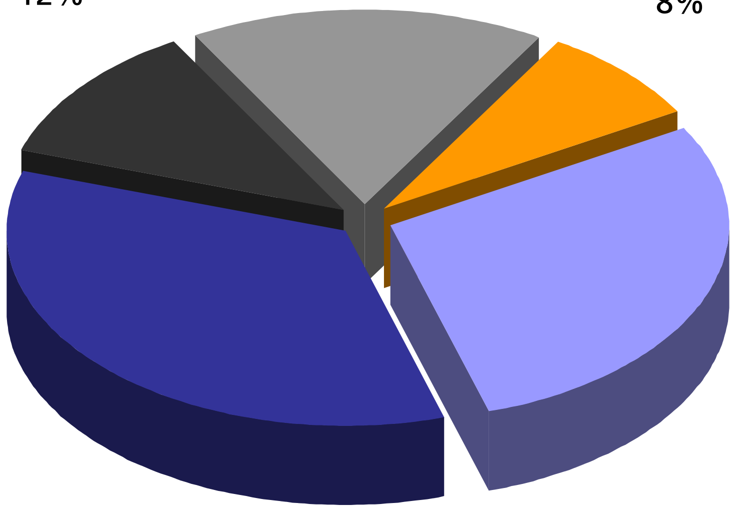
Energy distribution by HEC400D machining centre



Machining of aluminium engine

- milling of functional surface
- drilling of bores
- thread machining
- grating of bores
- milling of crank shaft shells

- process time: 4 minutes
- wet-machining

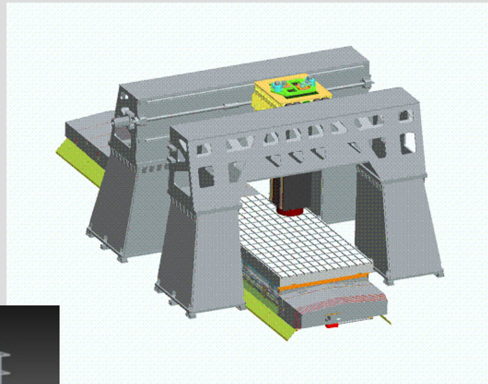


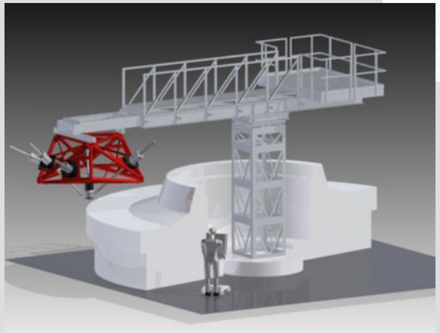
Bionics in Machine Tool Design

Locomotion bionics

→ energetic optimum
f(mass, stroke)

Redundancy in movement generation





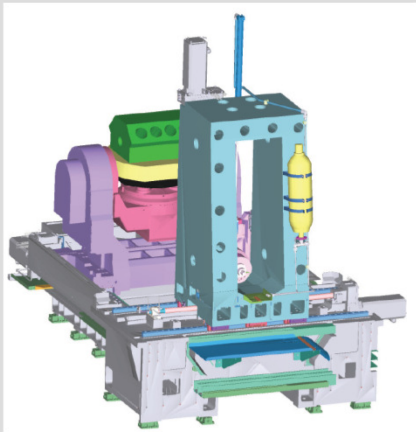
Mobile machining

Structure bionics

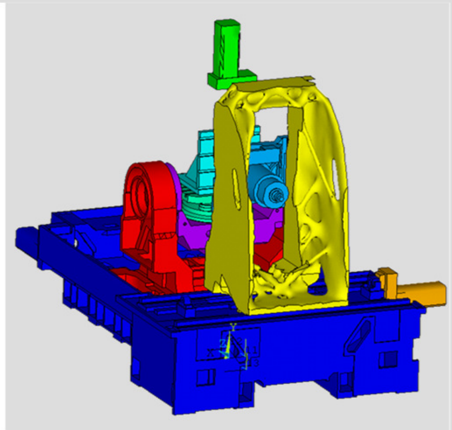
→ load oriented structural design
(on micro/macro level)

Topology optimization of structure

Initial design



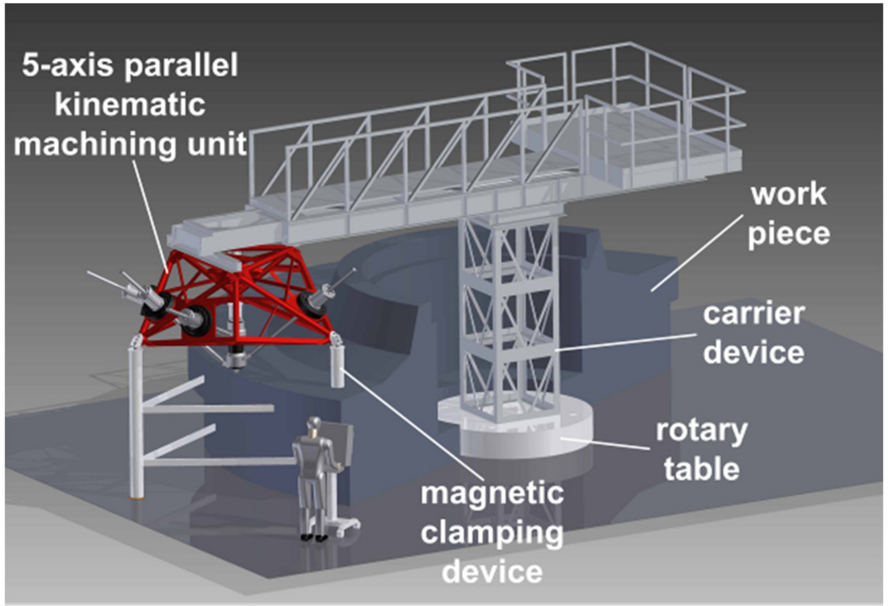
Optimized design



Locomotion Bionics – Mobile Machine Tools

Application Example

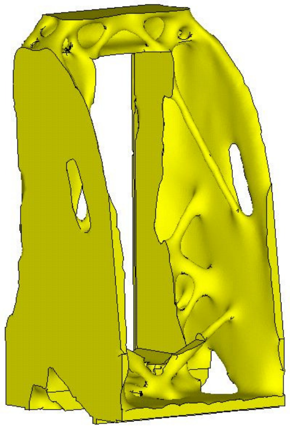
- use of **supporting frame structure** and rotary table for global movement
- **Allocation** by tactile measuring of reference geometries
- **Interface** Machine Tool/Work piece using magnet clamping device and a supporting frame structure



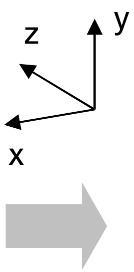
Structure Bionics

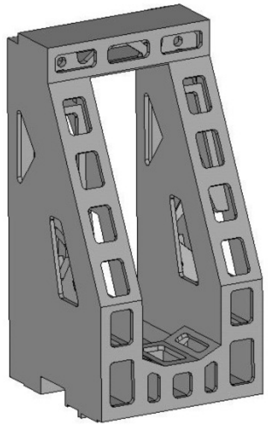
Optimization of Moved Machine Stand

Lightweight structural design
Steel structure



Topology optimization

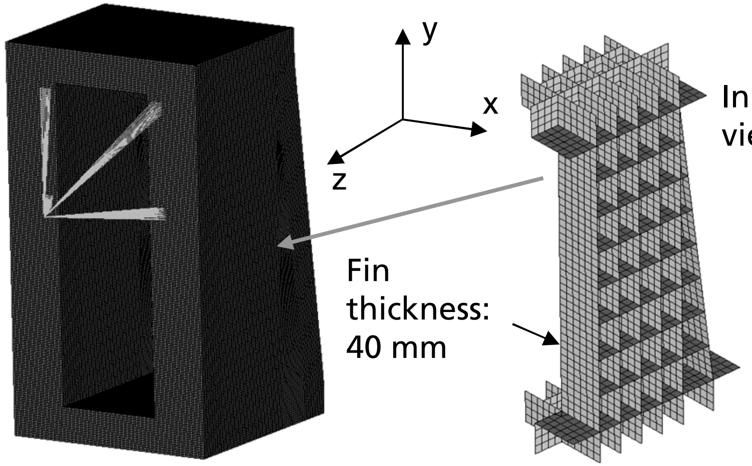




Design interpretation

Mass	-19%
Stiffness x	+25%
Stiffness y	+0,5%
Stiffness z	+10%

Lightweight structural- and material design
Carbon fibre composite (CFC)



Differential design

TU Chemnitz, SLK

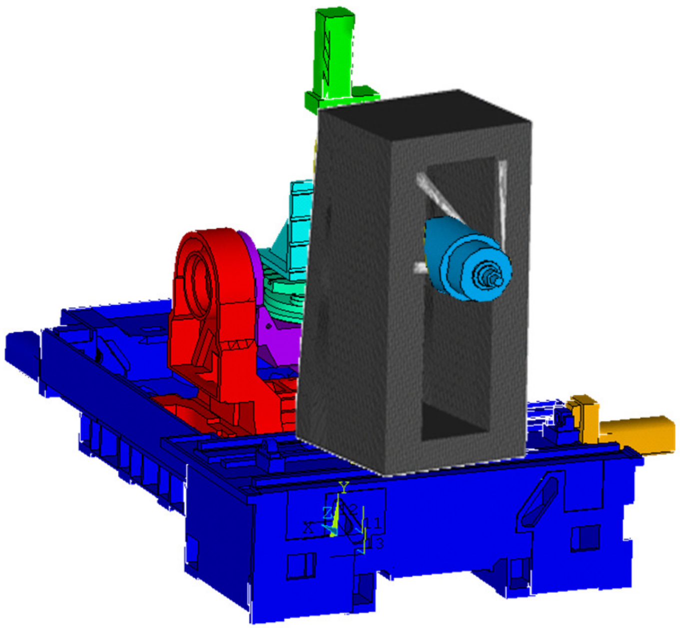
Mass	-52%
Stiffness x	+14%
Stiffness y	+96%
Stiffness z	-19%

Structure Bionics

Resulting Benefits in energy savings and cycle time

Mass (incl. attaching parts) **= 3850 kg**

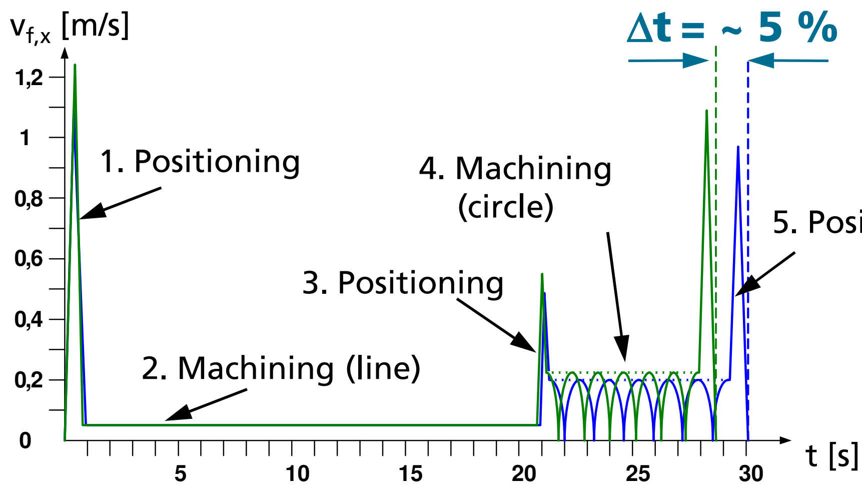
Reduction by 30 % ≈ 2700 kg



Reduction of electric losses in drive chain by **42 %**

Reduction of cycle time by **5 %**

➔ **Reduction base load share** through **reduced machining time T_B**



➔ **Less energy consumption** through **reduction of machining time**

IWP WERKZEUGMASCHINEN UND PRODUKTIONSPROZESSE

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Structure Bionics

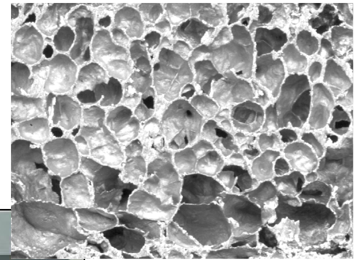
5-axes-machining centre: **aluminium foam**

Composition principle:

11 steel-aluminium foam sandwiches

Effects of aluminium foam:

- **28% lighter** by **identical stiffness**

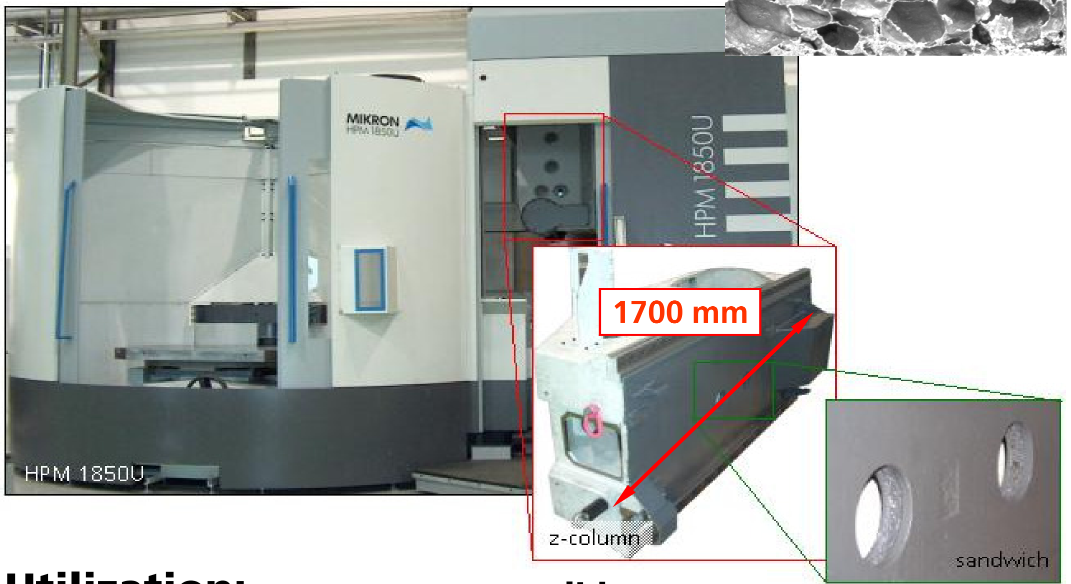


Potential CFC-composite:

- **45% lighter** by **identical stiffness...**

...but 2,5times higher costs!

Concept CFC



z-slide

Sandwich

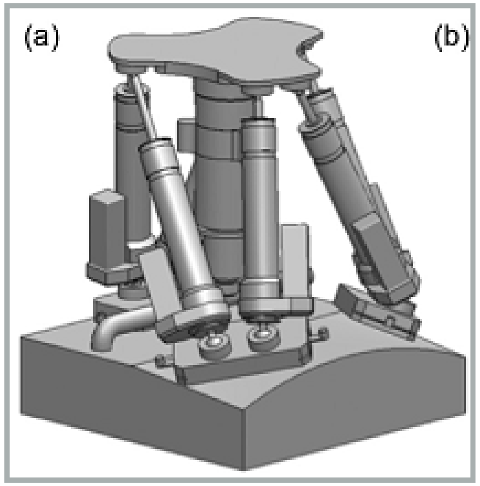
Utilization:

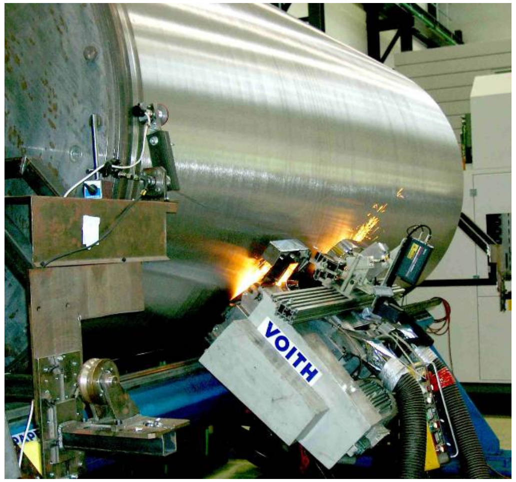
Production since 2004

(ca. 15 machines/year) Source: Fraunhofer IWU/NILES-SIMMONS

Mobile Machine Tool

Mobile **milling unit** for maintenance (Rolls-Royce UTC)





Mobile **grinding unit** for roll maintenance in paper industry (Voith Paper Services/ Fraunhofer IWU)

Challenges: - **Position allocation** towards work piece coordinate system

- Work piece as part of **machine structure**
- **high-dynamic,** energy efficient machining technologies with **low reaction forces**