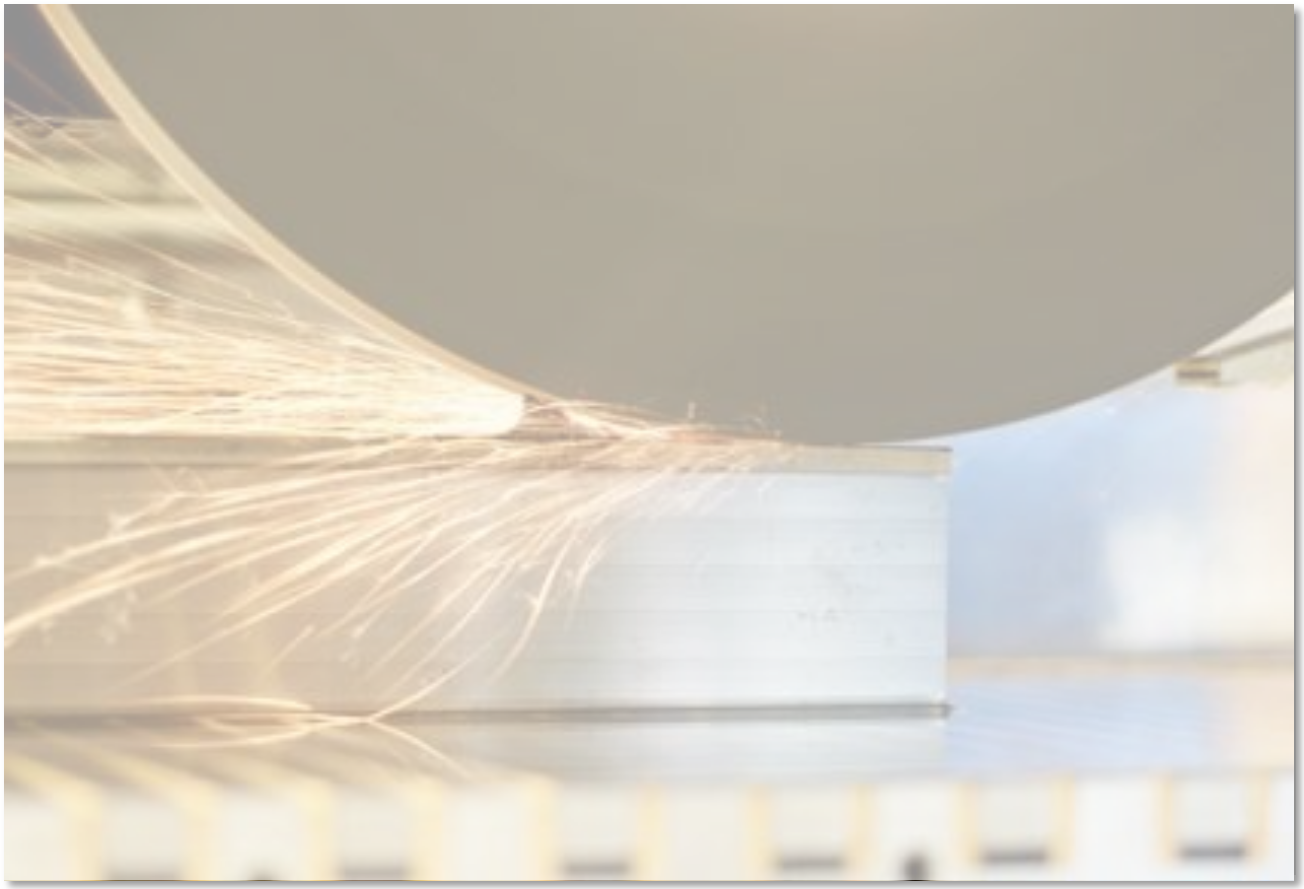
Superior Surface Integrity by Knowledge-based Manufacturing – Recent Advances

2017 GAFOE Symposium, Evendale, Ohio, 31.03.17-02.04.17



IWT
Stiftung Institut für Werkstofftechnik
Bremen

ECO Centrum

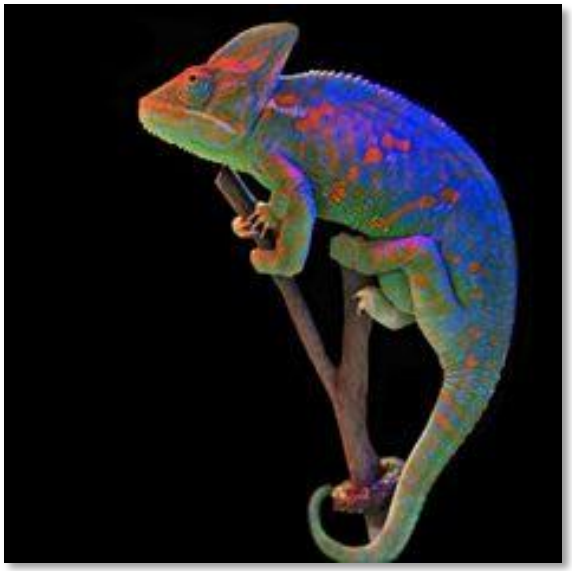
LFM
Labor für Mikrozerspanung

Outline

Recent frontiers of machining

The Loch Ness Monster „Nessie“

- Below the surface
- Not well described
- Famous (thus kind of important)



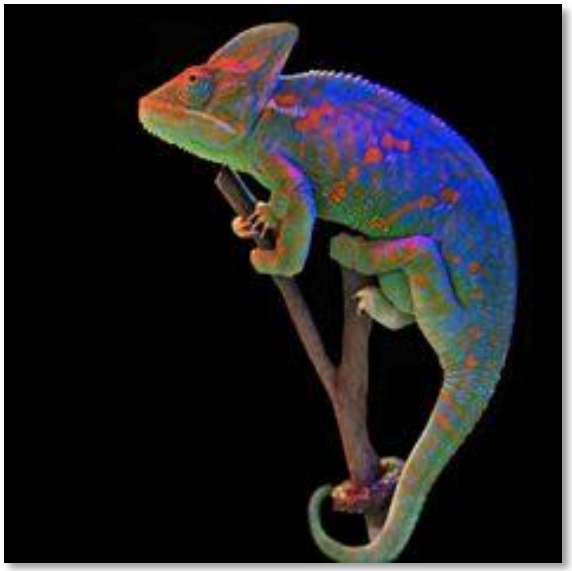
A Chameleon

- Changes color
- Complex mechanism
- Interacts with its environment using „code“

Pictures: thegreenhead.com, nationalgeographic.com

Outline

Recent frontiers of machining



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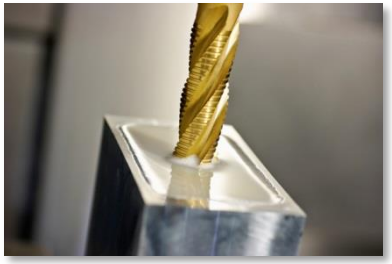
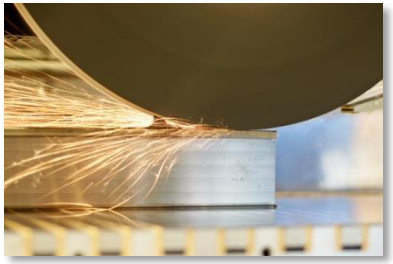
Highly relevant to interdisciplinary challenges in manufacturing

Pictures: thegreenhead.com, nationalgeographic.com

Manufacturing Technologies

What exactly are we doing?






Processes

Pictures: IWT Bremen

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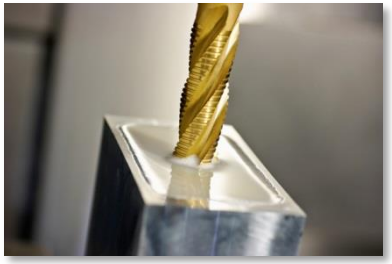

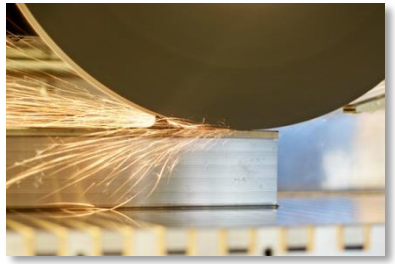
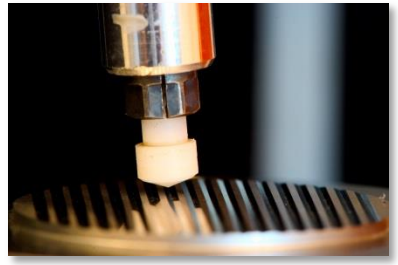

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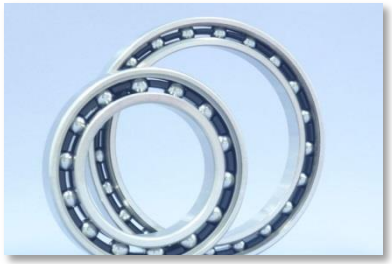
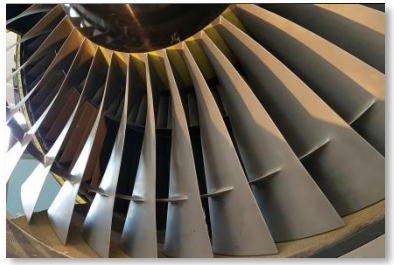

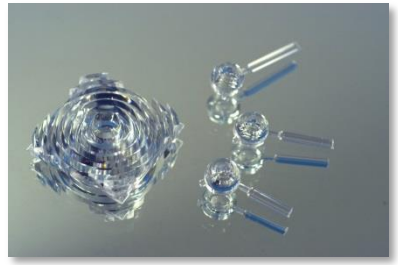

Components

Pictures: IWT Bremen, FAG, xylon.de

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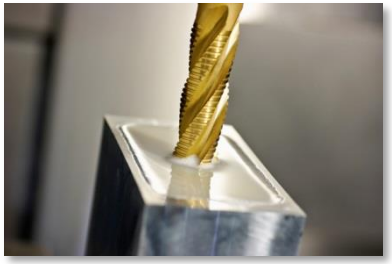

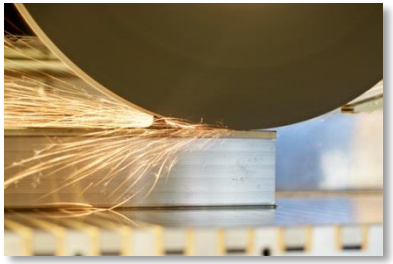


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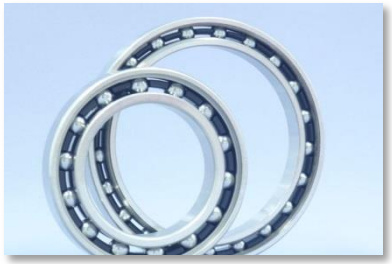
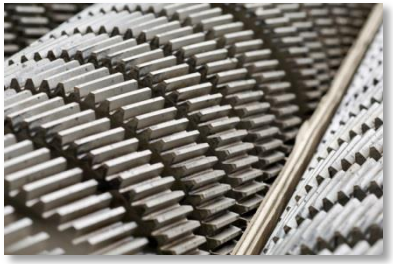
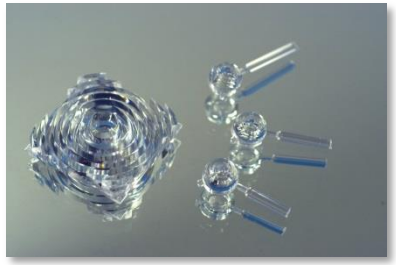


Components

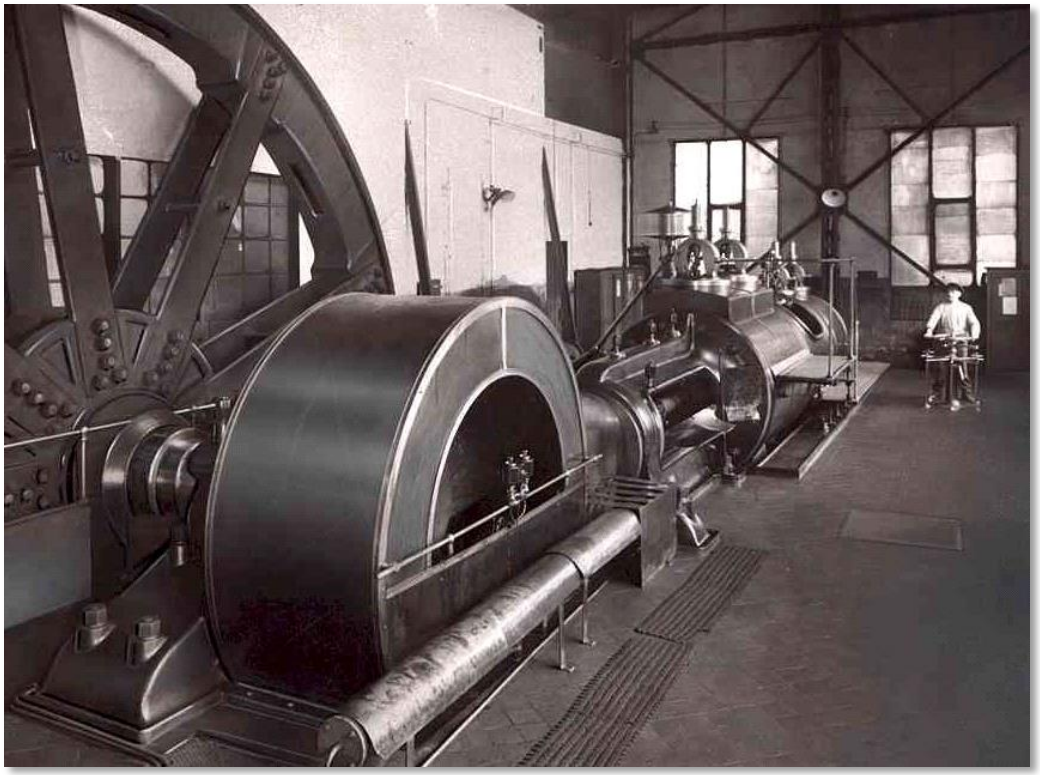


Products

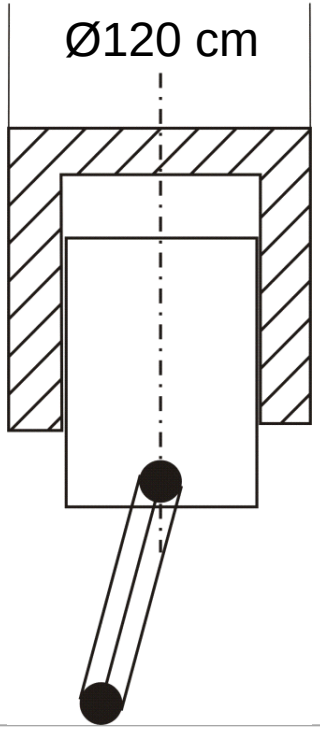
Pictures: IWT Bremen, FAG, xylon.de, Daimler, Airbus, GE, Apple

Manufacturing Technologies

and their accuracy around 1900



2.33 mm



Pictures: huettenmuseum-thale.de

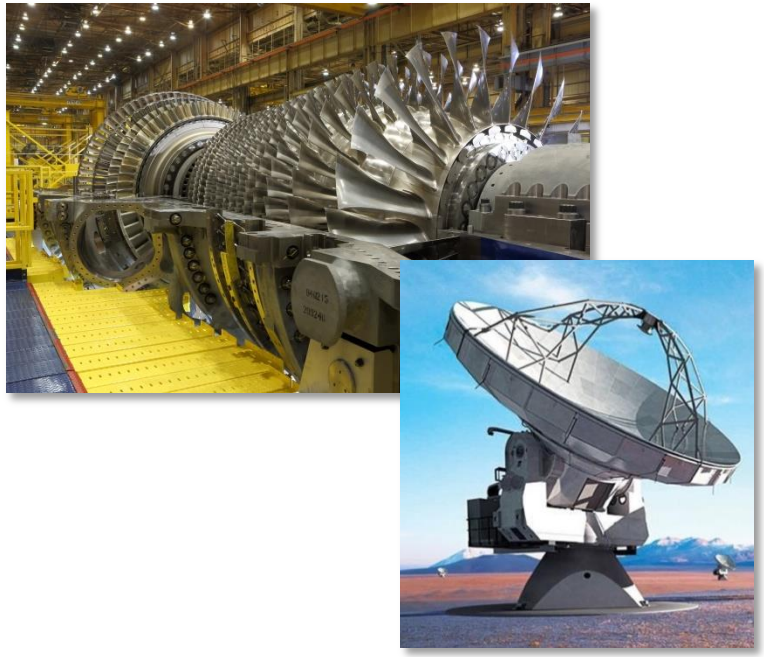
Manufacturing Technologies

their accuracy and tasks today

Geometrical accuracy

- Conventional machining (turning, milling, grinding, …)
  - accuracy of ca. 1 µm
  - Ø of a human hair ≈ 70 µm

- Ultraprecision machining (diamond machining, polishing, …)
  - accuracy on a nm scale
  - mirrors for telescopes: shape deviation of < 8 µm over 1 m



Pictures: GE, ALMA

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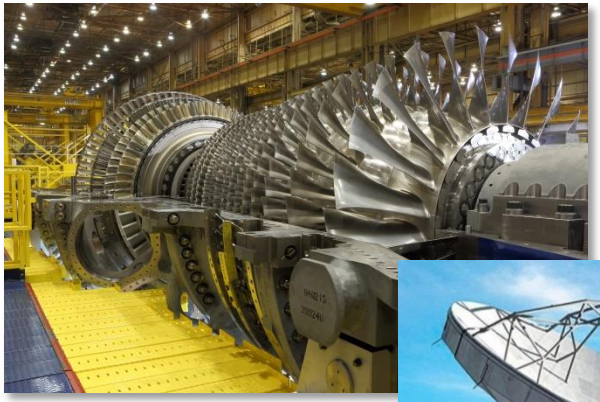
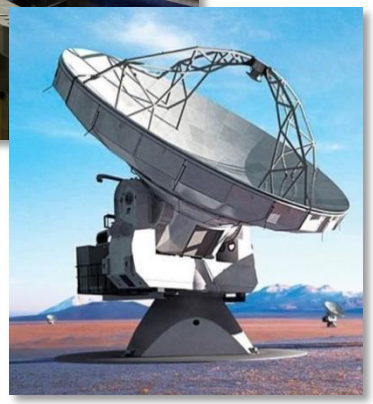
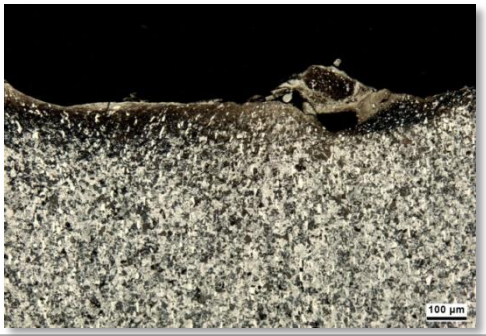




Consideration of the surface integrity

- Surface roughness
- Hardness
- Residual stresses
- Cracks and microcracks



Pictures: GE, ALMA, IWT Bremen

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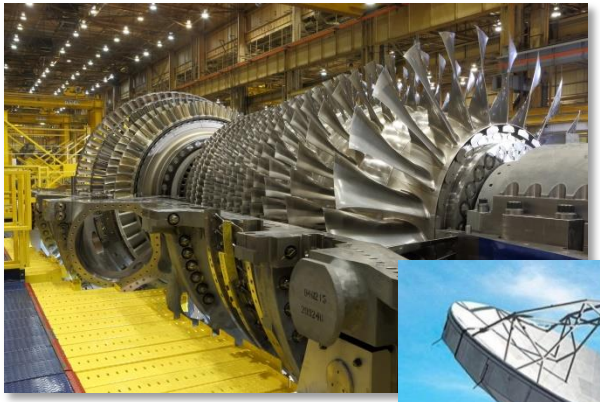

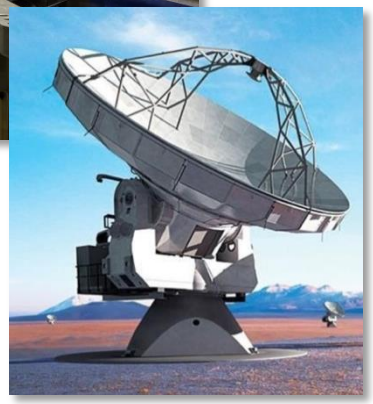

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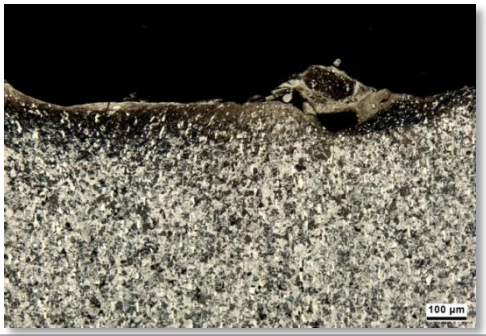
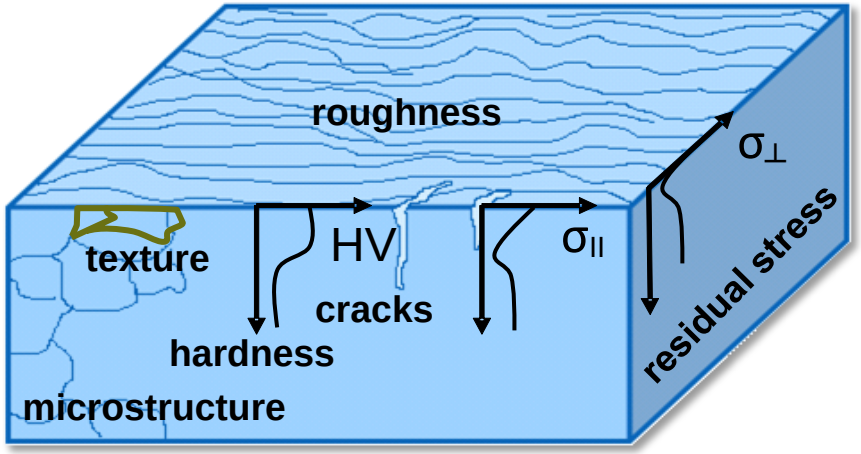


Pictures: GE, ALMA, IWT Bremen, thegreenhead.com

Surface Integrity



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- Famous (thus kind of important)

Subsurface Properties and Surface Integrity

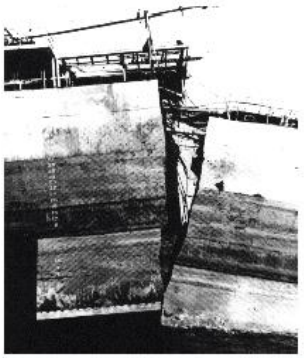
- Below the surface
- Not well understood
- Highly relevant to industry and science

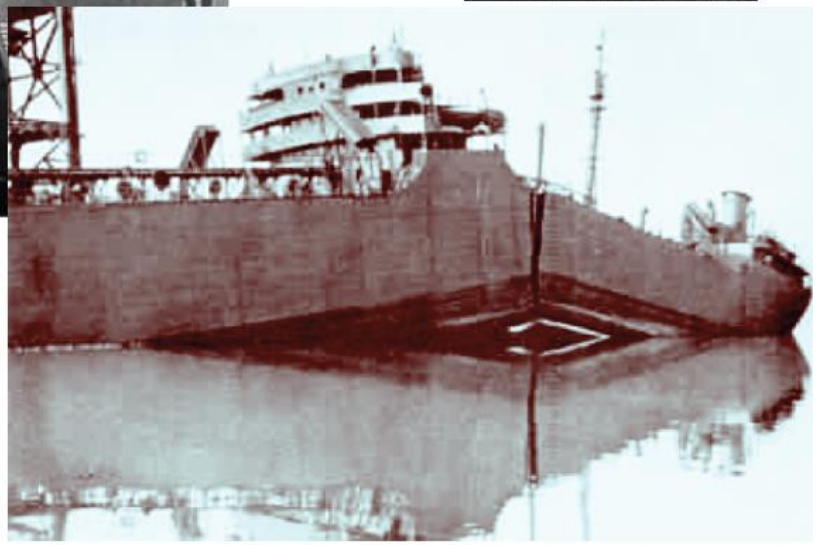
Pictures: thegreenhead.com, IWT Bremen

Surface Integrity

Relevance

Liberty ships

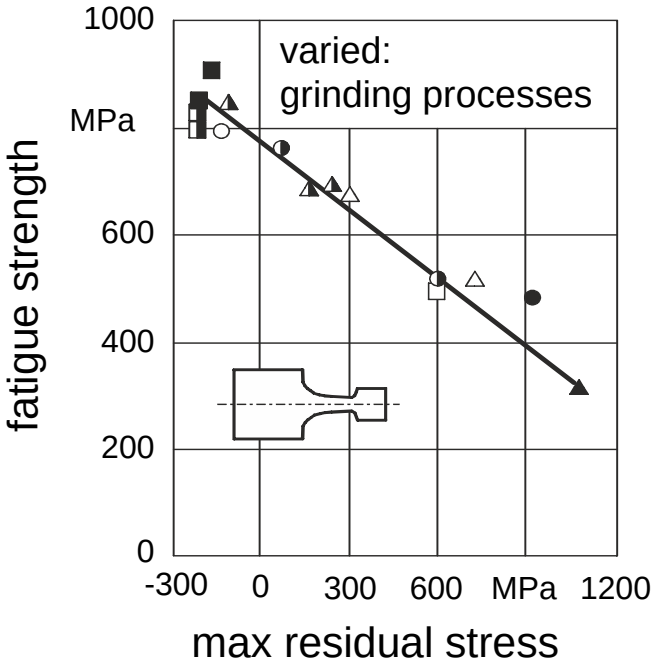




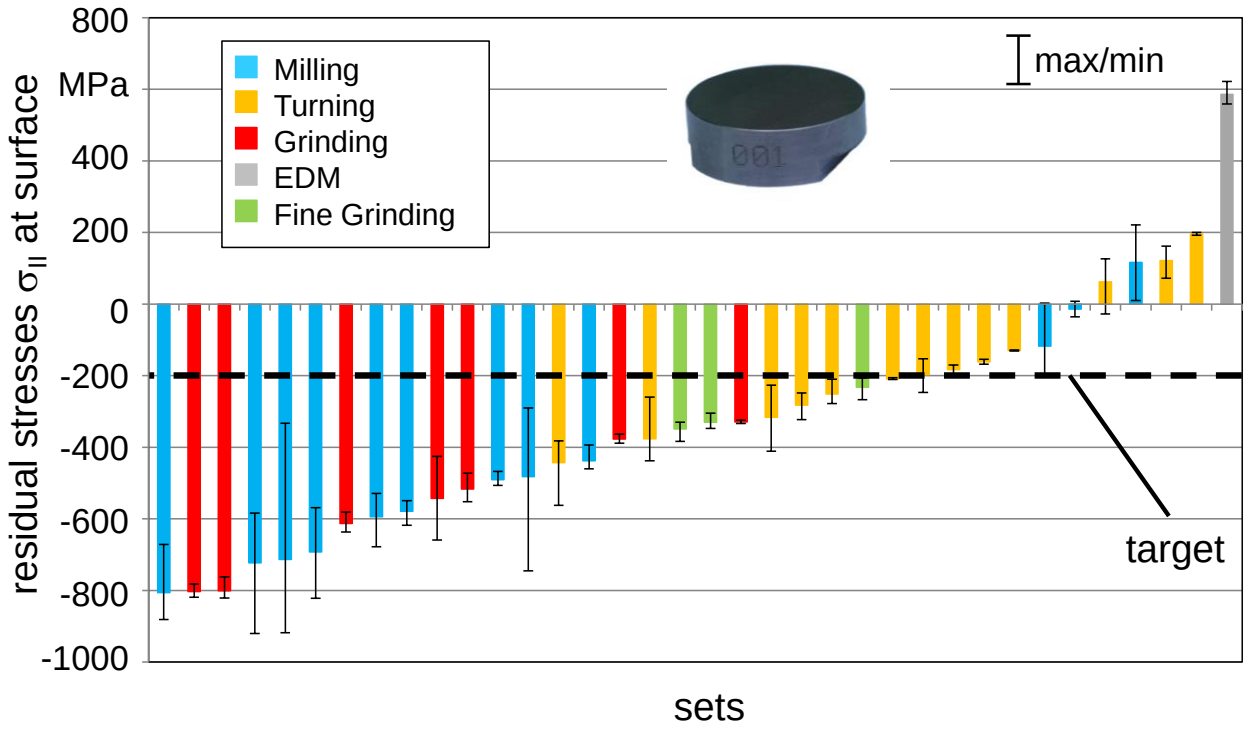
Pictures: ETH Zürich, Wikipedia

Surface Integrity

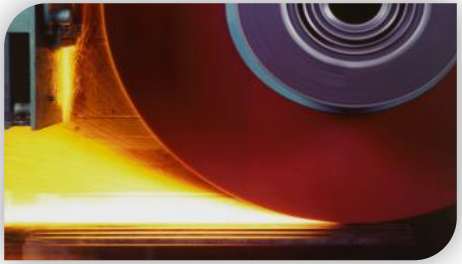
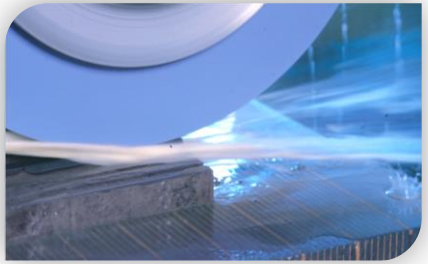
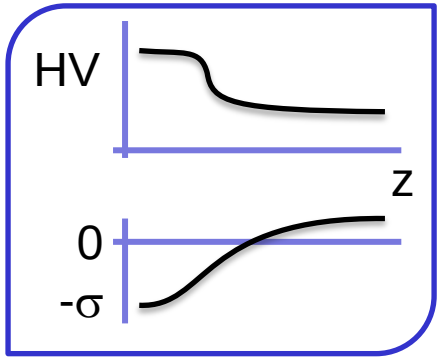
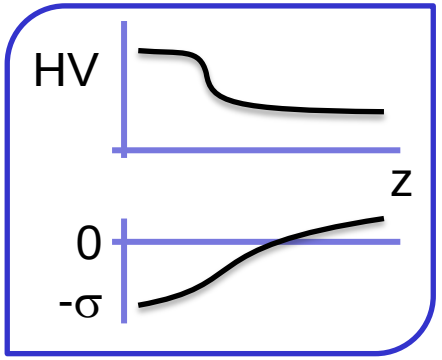
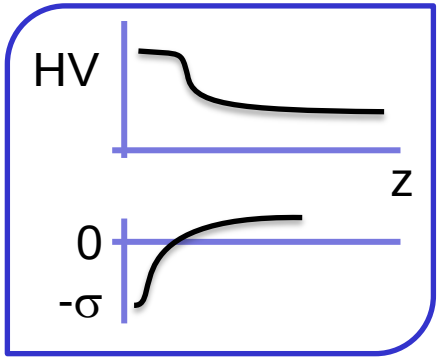
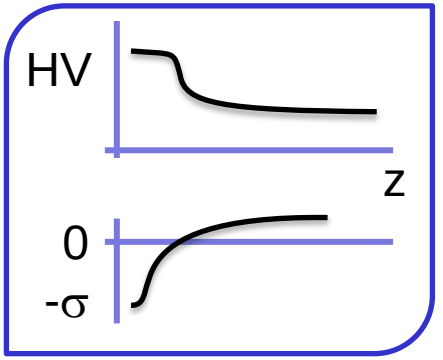
still a frontier of engineering



acc. to Field & Koster,
Annals of the CIRP
27/1, 1971



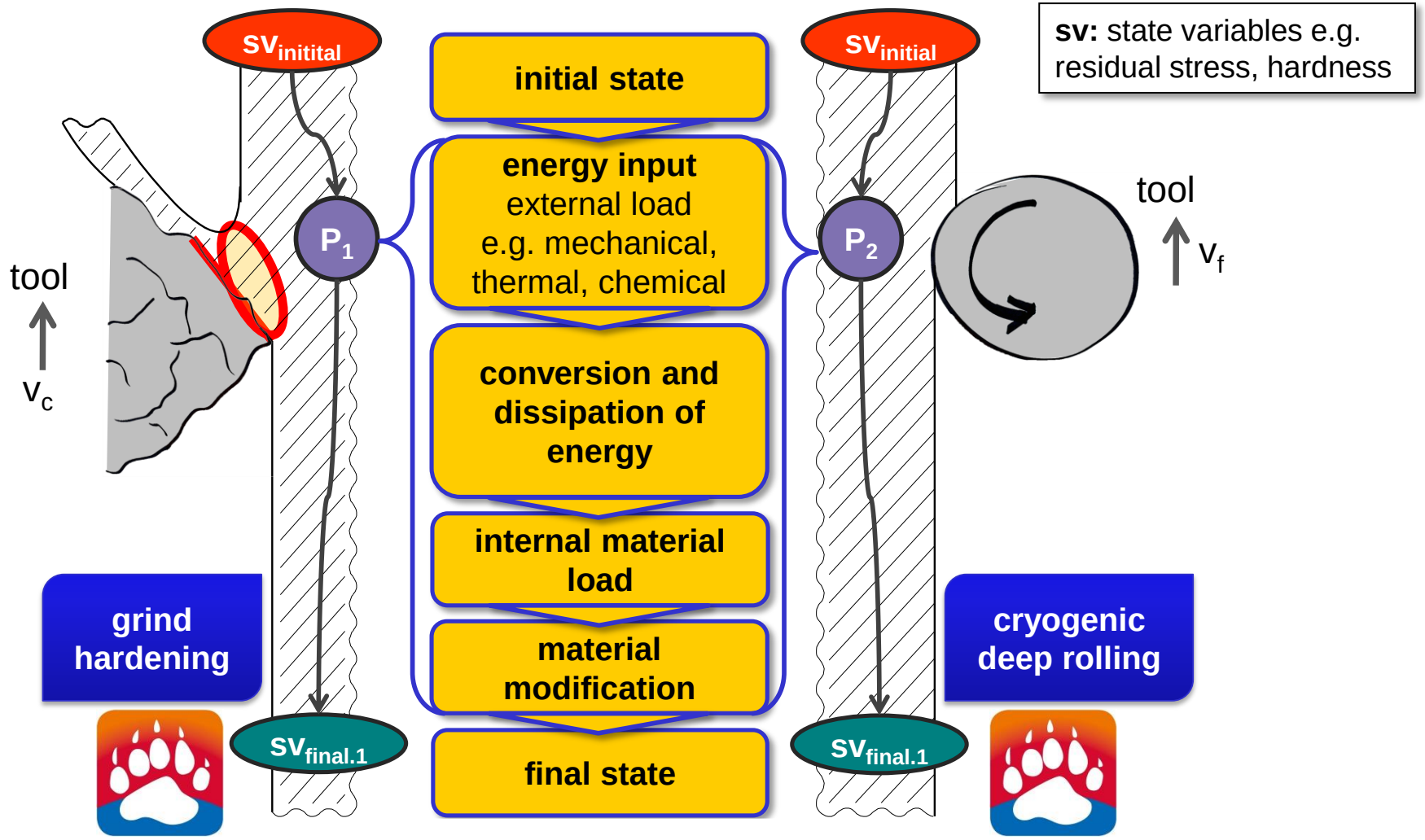
Different processes - identical results

thermal/thermomechanical		mechanical	
			
Induction hardening	Grind hardening	Deep rolling	Grind strengthening
			

➡ Different processes lead to identical surface properties

The new approach of „Process Signatures“

for the prediction of the effects of manufacturing processes

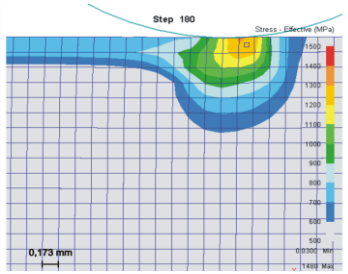


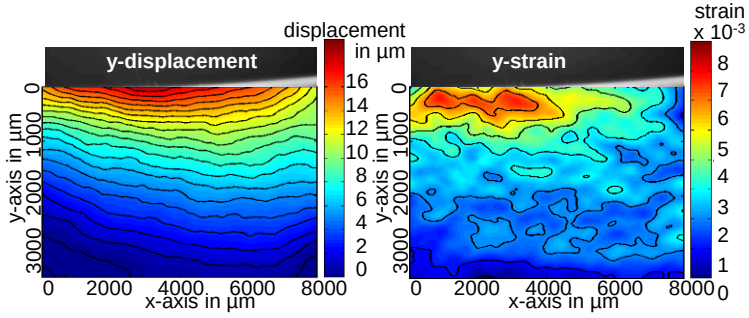
The new approach of „Process Signatures“

for the prediction of the effects of manufacturing processes

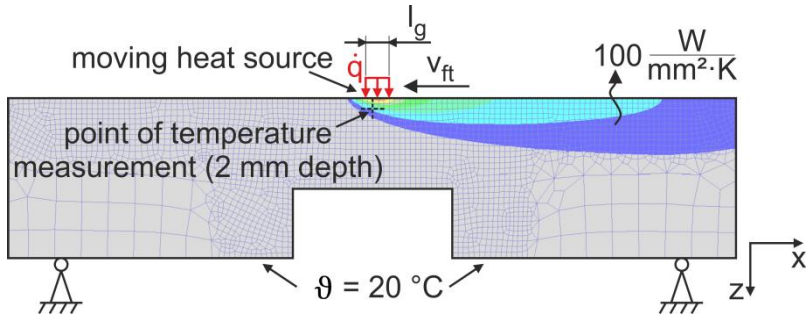
internal material load

strain/stresses





temperatures

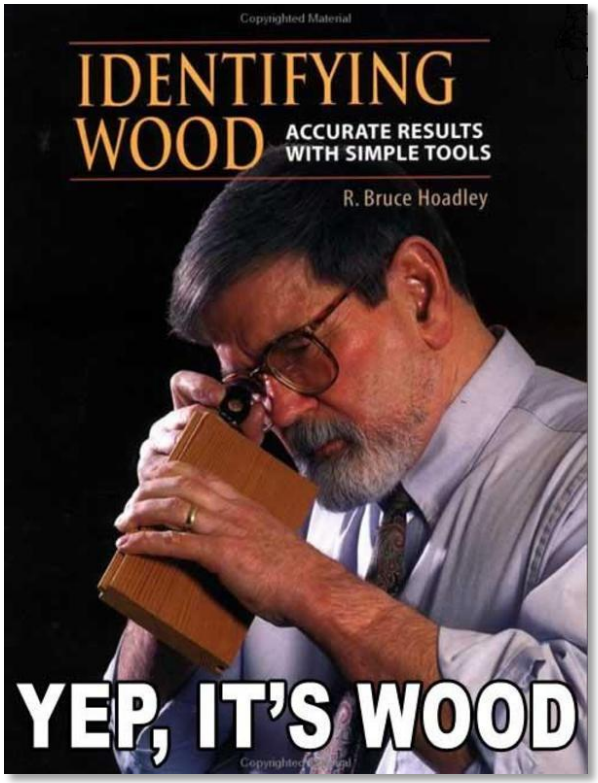


➡ spatial gradients (µm) over time (µs)

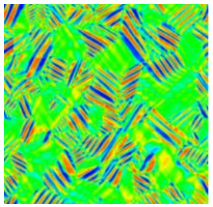
The new approach of „Process Signatures“

for the prediction of the effects of manufacturing processes

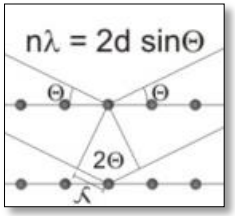
material modification



phase transformation

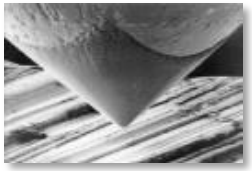


residual stresses

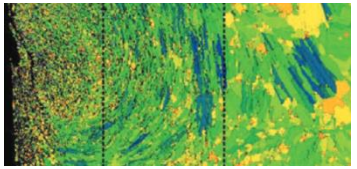


hardness

roughness



grain size

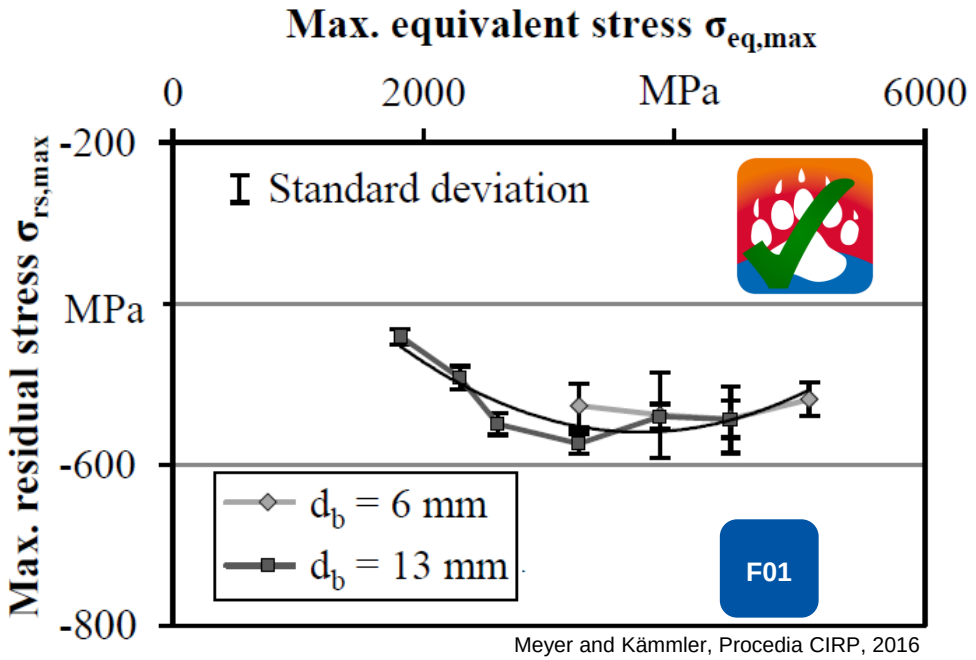


➡ Which are the decisive properties?

The new approach of „Process Signatures“

for the prediction of the effects of manufacturing processes

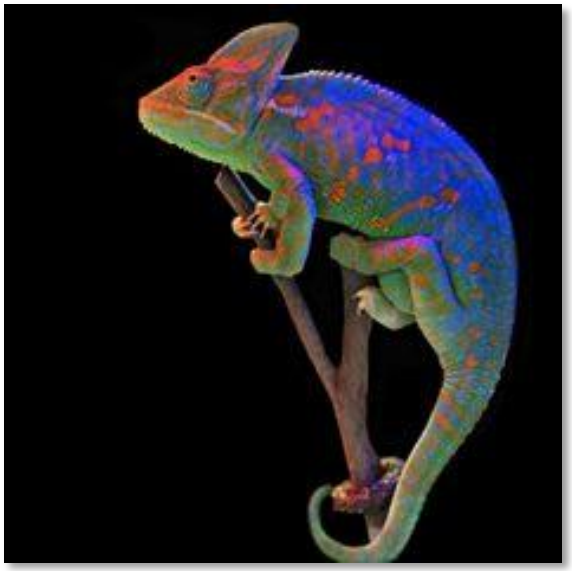
internal material load → **material modification**



Meyer and Kämmler, Procedia CIRP, 2016

Outline

Recent frontiers of machining



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Pictures: thegreenhead.com, nationalgeographic.com

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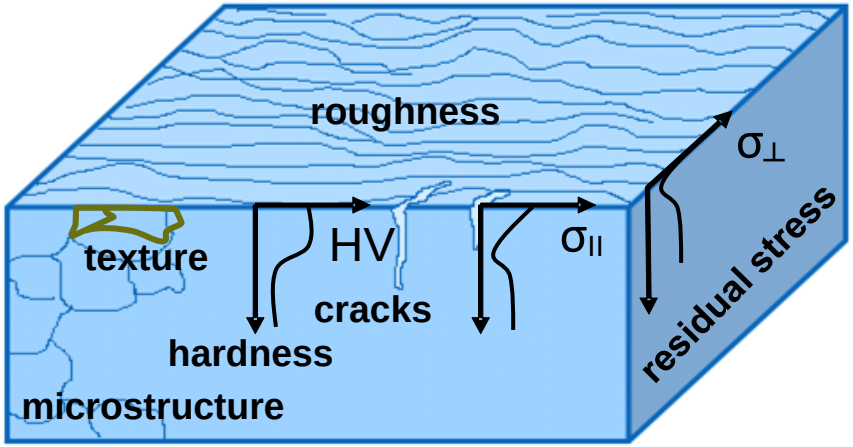

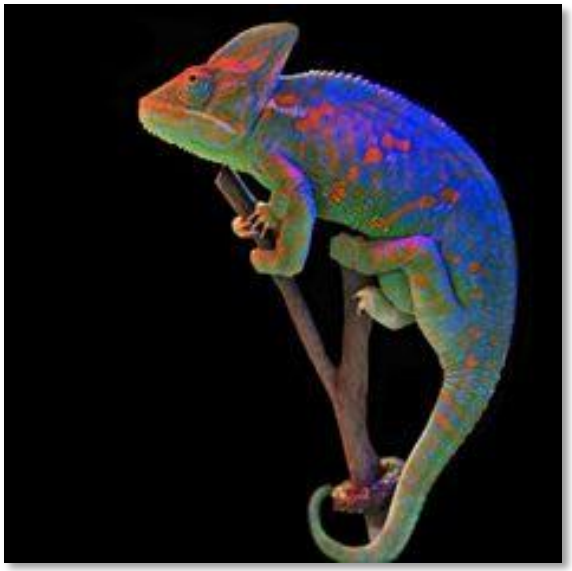

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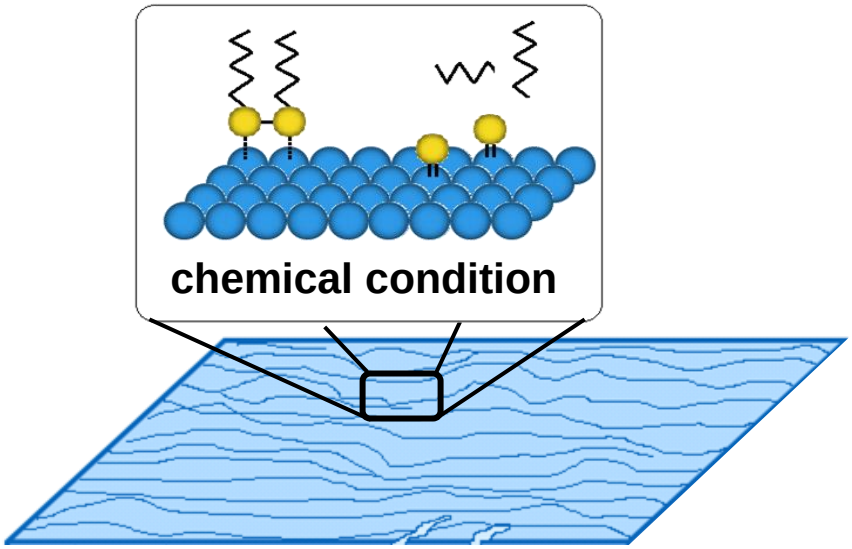

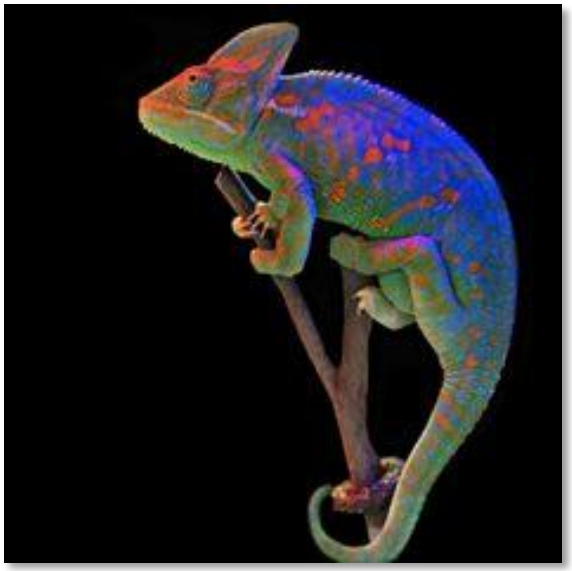

Surface Chemistry

- Changes with temperature
- Complex mechanism
- Interacts with its environment in machining

A Chameleon

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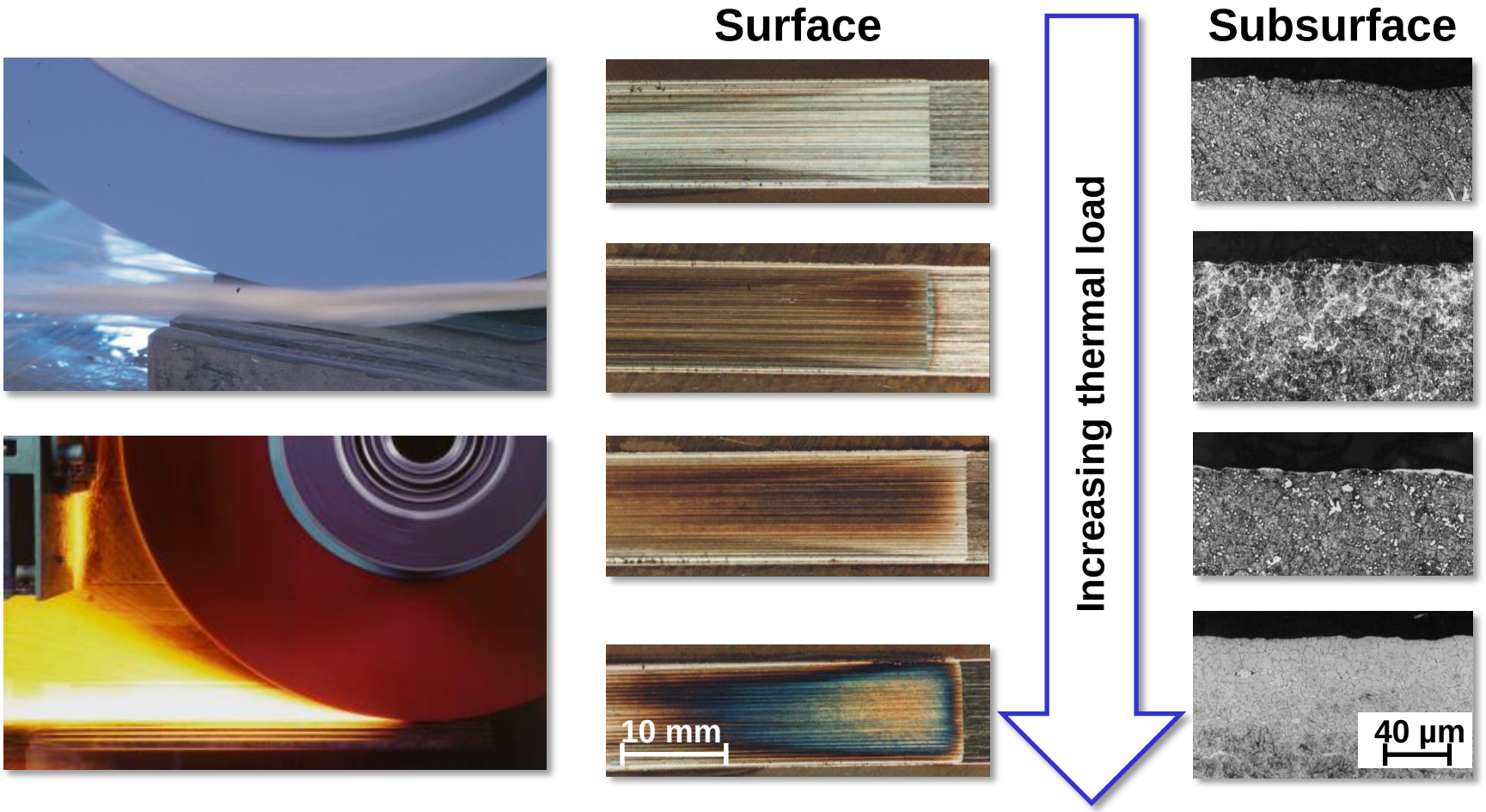
- Interacts with its environment using „code“

Pictures: nationalgeographic.com

Thermal load in manufacturing proceses

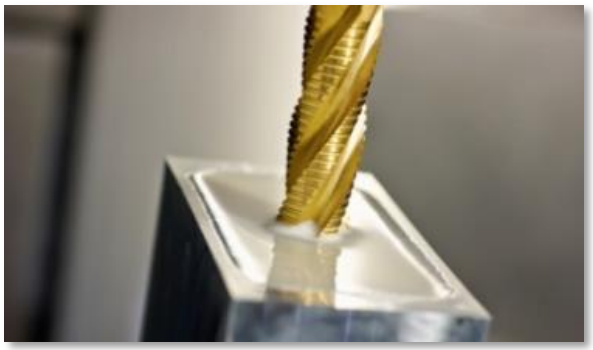
Require application of metalworking fluids



Pictures: IWT Bremen

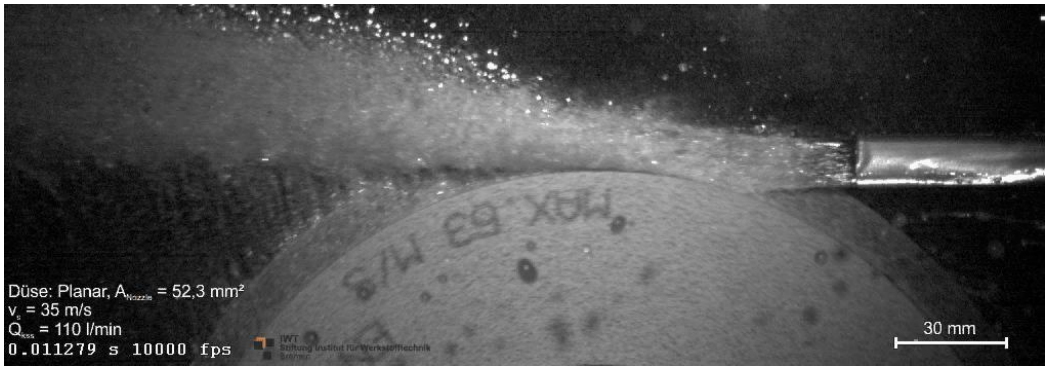
Metalworking Fluids in manufacturing processes

Tasks and supply



Main Tasks

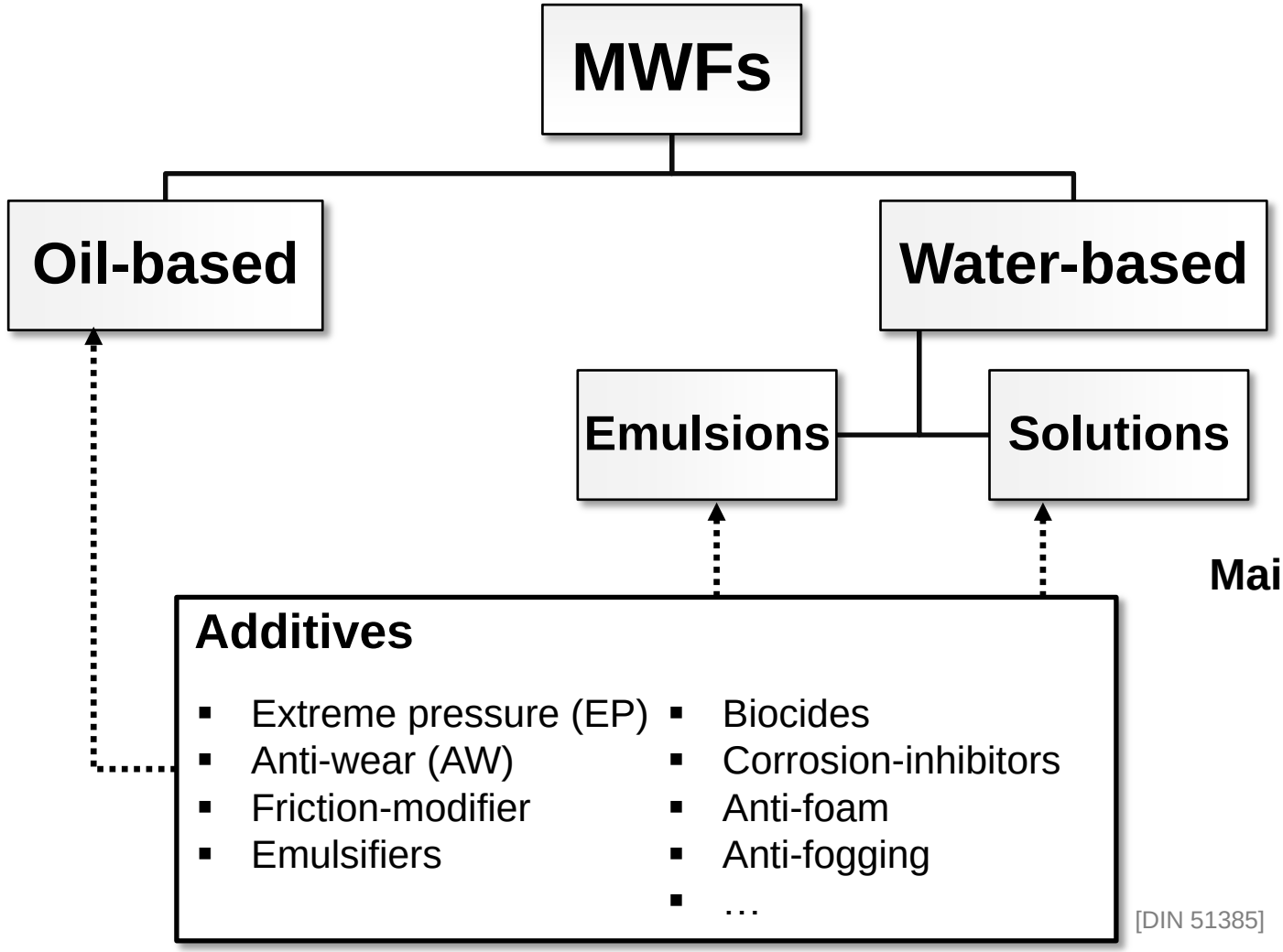
- Lubrication
- Cooling
- Chip removal



Pictures: IWT Bremen, metalfluids.com, mwfmag.com

Metalworking Fluids in manufacturing processes

Composition



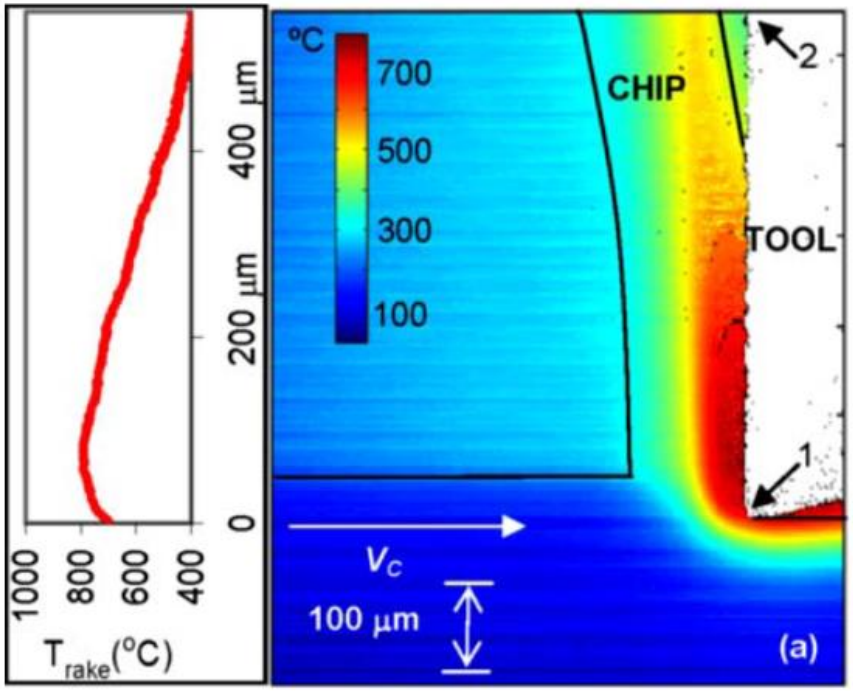
Main Questions

- Where?
- Why?
- How?

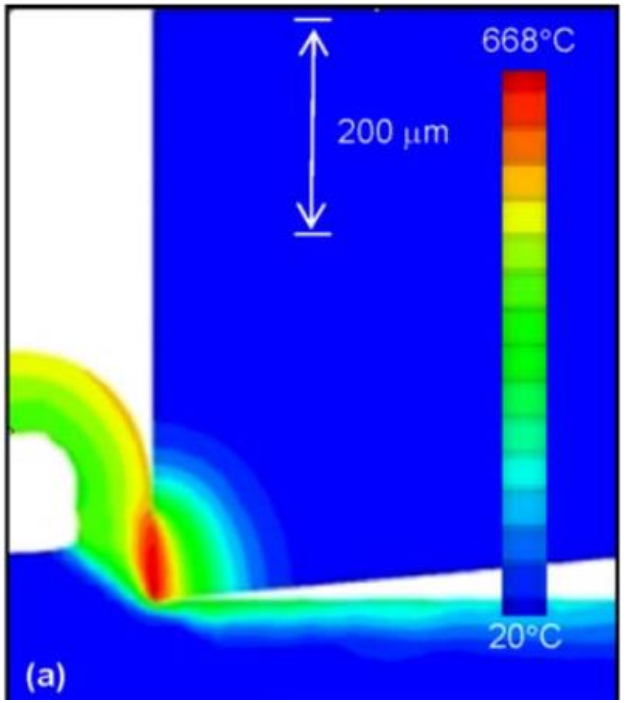
[DIN 51385]

Metalworking Fluids in manufacturing processes

Target site: Contact zone between tool and workpiece

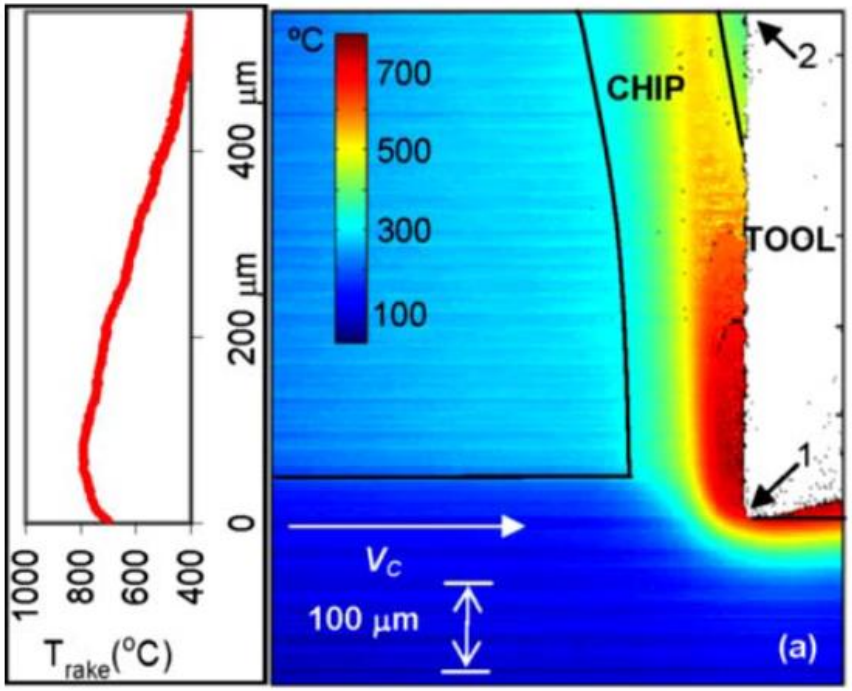


[Davies et al., 2005]



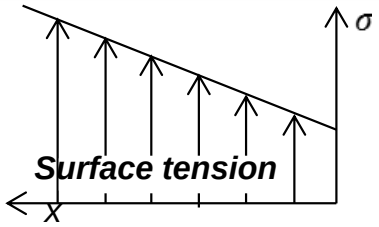
Metalworking Fluids in manufacturing processes

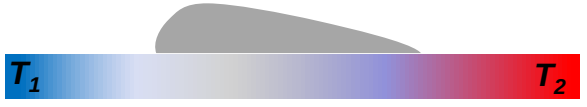
Target site: Contact zone between tool and workpiece



[Davies et al., 2005]

Marangoni effect

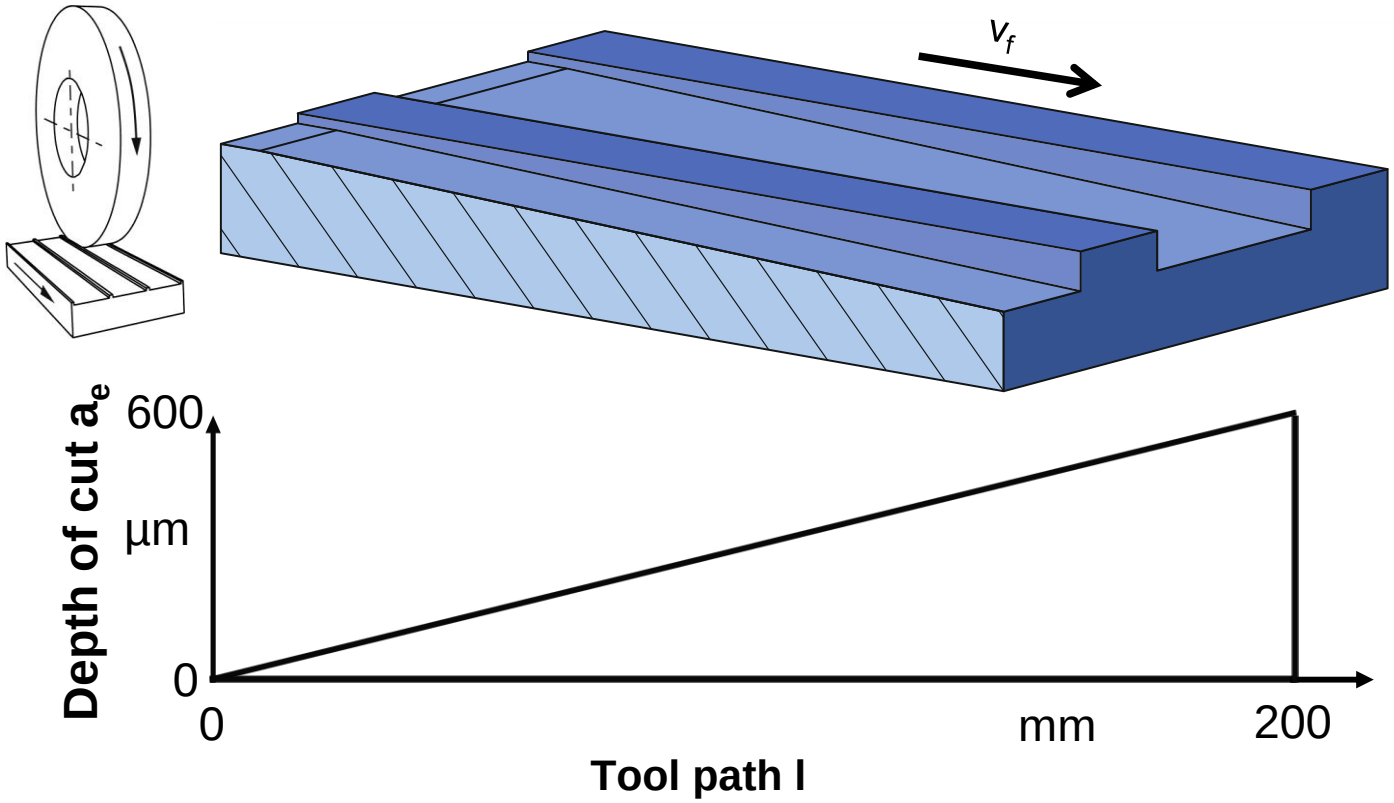




➡ Target site depends on the type of process

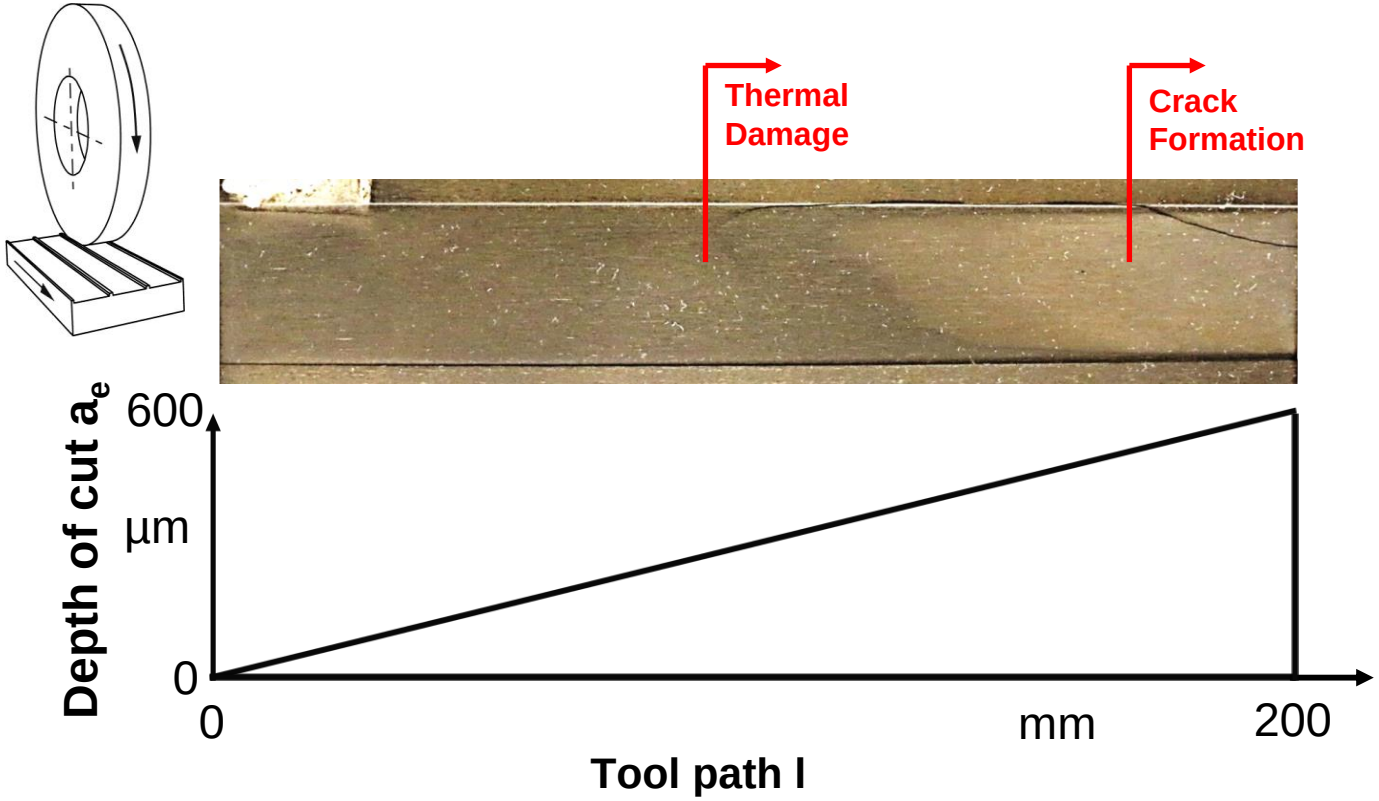
Metalworking Fluids in manufacturing processes

Efficiency and relevance



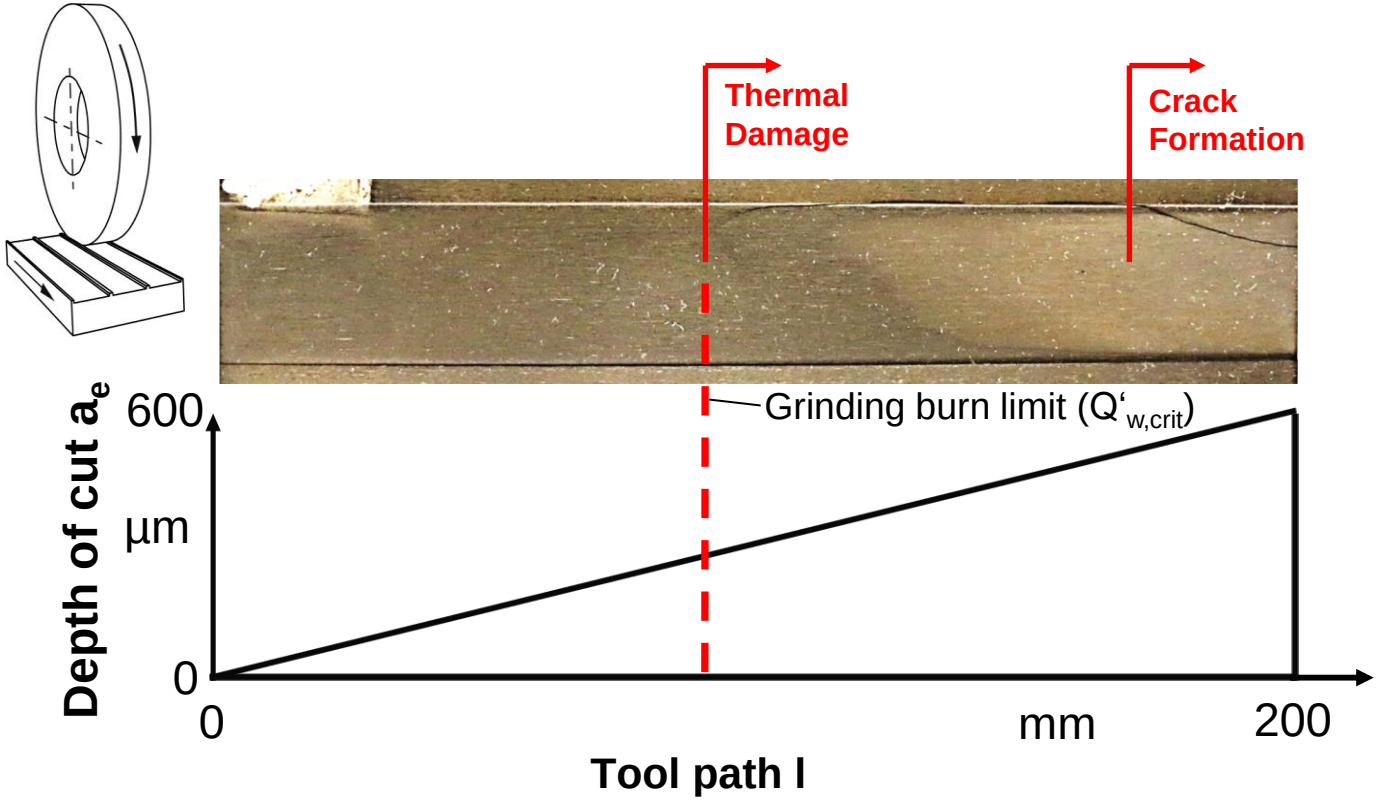
Metalworking Fluids in manufacturing processes

Efficiency and relevance



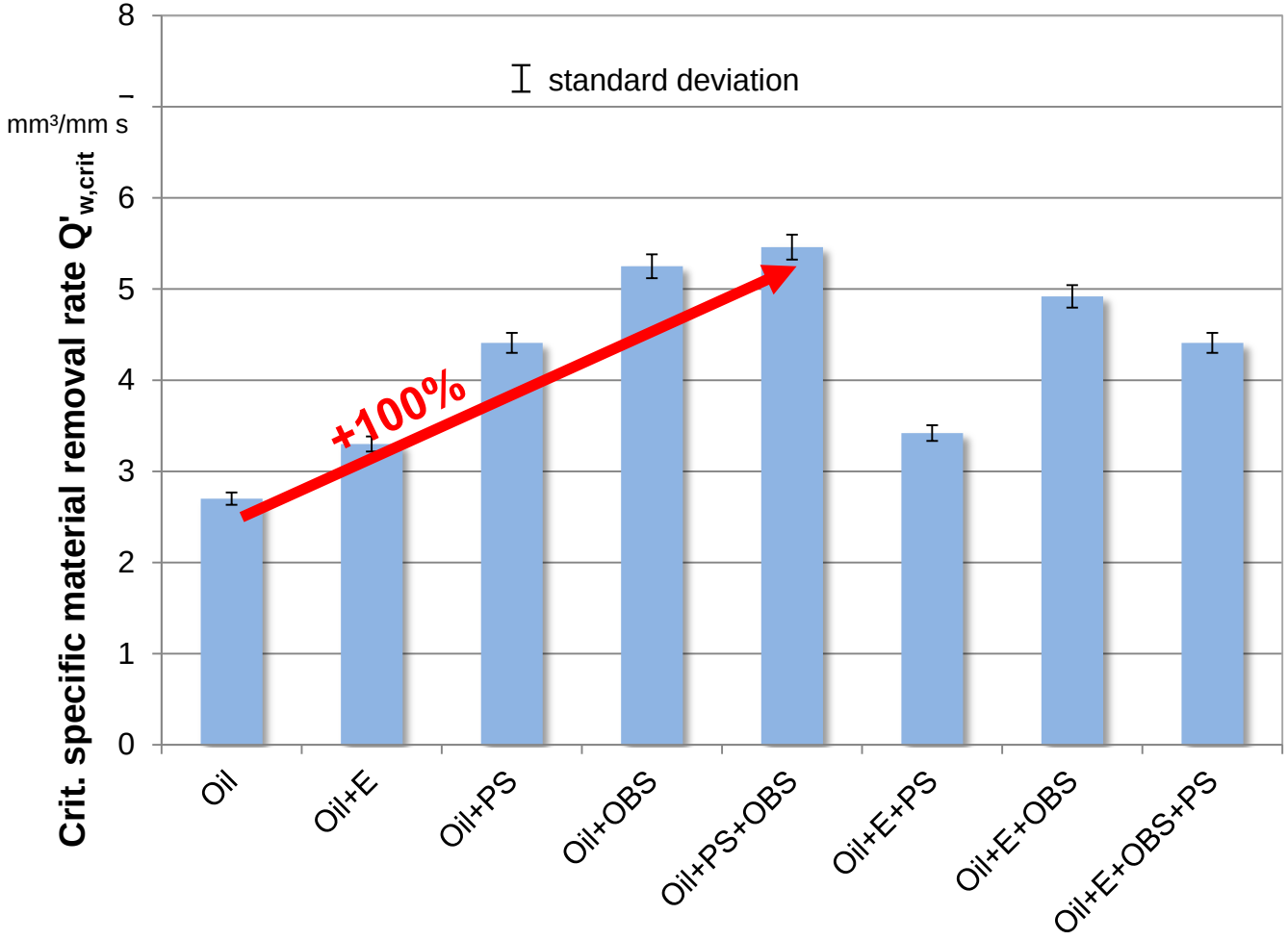
Metalworking Fluids in manufacturing processes

Efficiency and relevance



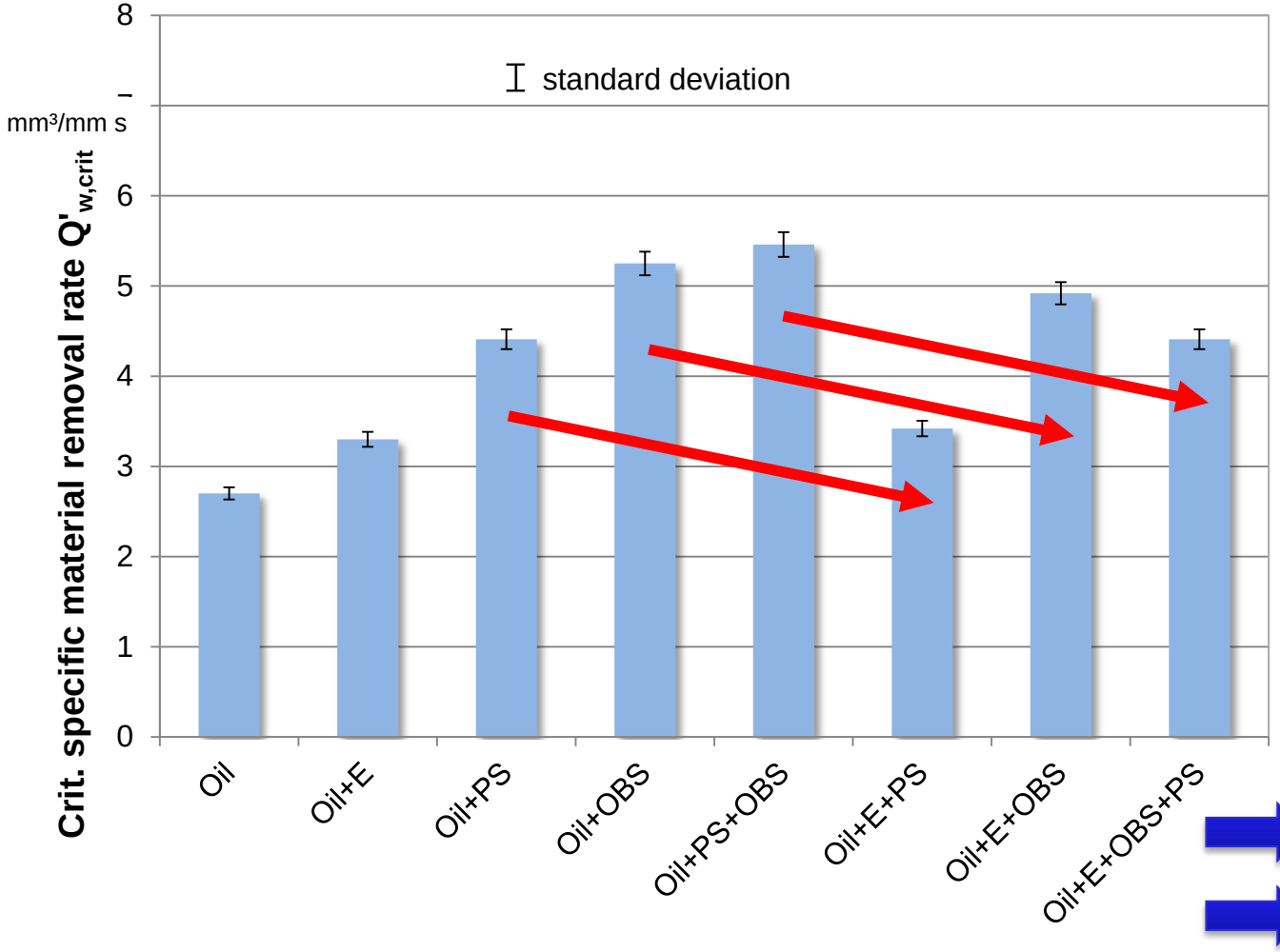
Metalworking Fluids in manufacturing processes

Efficiency and relevance



Metalworking Fluids in manufacturing processes

Efficiency and relevance

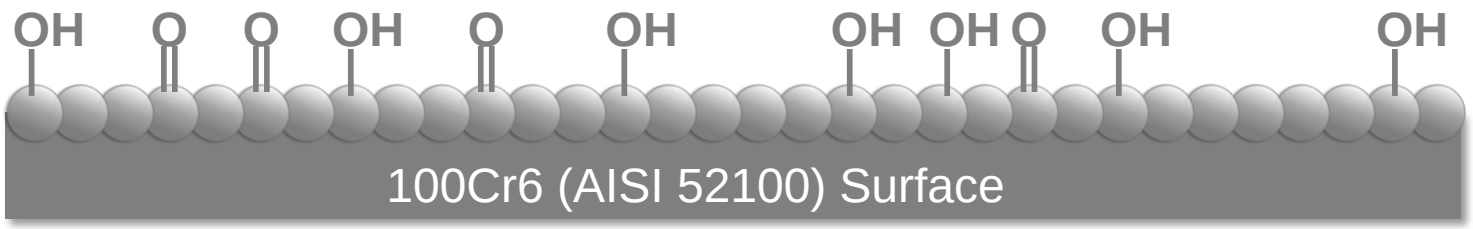


Considerable effect

Antagonism?

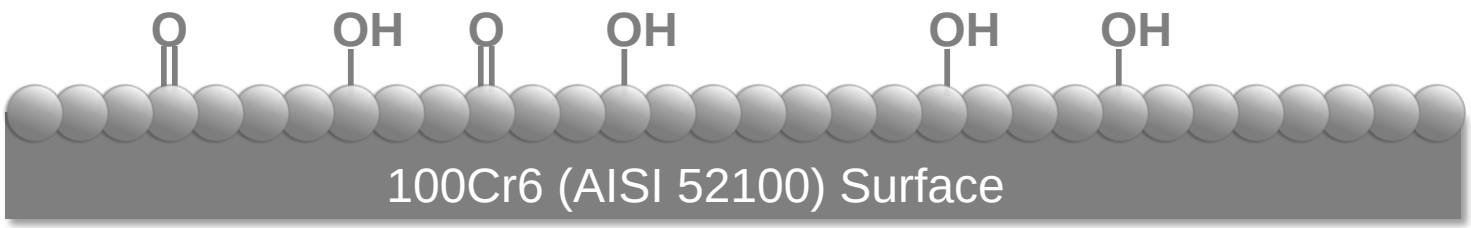
Metalworking Fluids in manufacturing processes

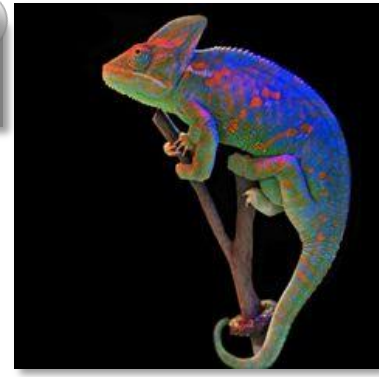
interactions with metal surfaces



Metalworking Fluids in manufacturing processes

interactions with metal surfaces





Metalworking Fluids in manufacturing processes

interactions with metal surfaces

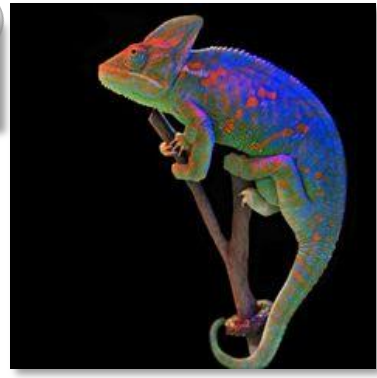
Polysulfide 40 (PS)

Overbased sodium sulfonate (OBS)

van der Waals forces, hydrogen bonds

ionic interactions

100Cr6 (AISI 52100) Surface



Metalworking Fluids in manufacturing processes

interactions with metal surfaces

Polysulfide 40 (PS)

Overbased sodium sulfonate (OBS)

Ester (E)

van der Waals forces, hydrogen bonds

ionic interactions

100Cr6 (AISI 52100) Surface

Type and strength of inteaction depending on various factors

Frontiers of Engineering

a multi-disciplinary challenge!

Surface Integrity

- Identification of working mechanisms
- Multifactorial effects during the process
- Interdisciplinary challenge
  - Manufacturing Technologies
  - Materials Science
  - Computer Science
  - Physics
- First steps taken based on new understanding

Surface Chemistry

- Confirmation of working mechanisms
- Multifactorial effects during process
- Interdisciplinary challenge
  - Manufacturing Technologies
  - Materials Science
  - Chemistry
  - Microbiology
- First steps taken based on new understanding

➡ We are on our way to paradigm-shift by knowledge-based manufacturing

Pictures: thegreenhead.com, nationalgeographic.com

Thank you for your kind attention!

This work is funded by the European Research Council and the German Research Foundation.
The financial support is gratefully acknowledged.

Contact:

Dr.-Ing. Dipl.-Biol. Daniel Meyer

Stiftung Institut für Werkstofftechnik (IWT)

Badgasteiner Str. 3

28359 Bremen, Germany

Tel.: +49 (0) 421 218 51149

Fax: +49 (0) 421 218 51102

Email: dmeyer@iwt.uni-bremen.de