
Damping in Machine and Cutting Tools

A journey in search

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Machine Tool
Dynamics Laboratory



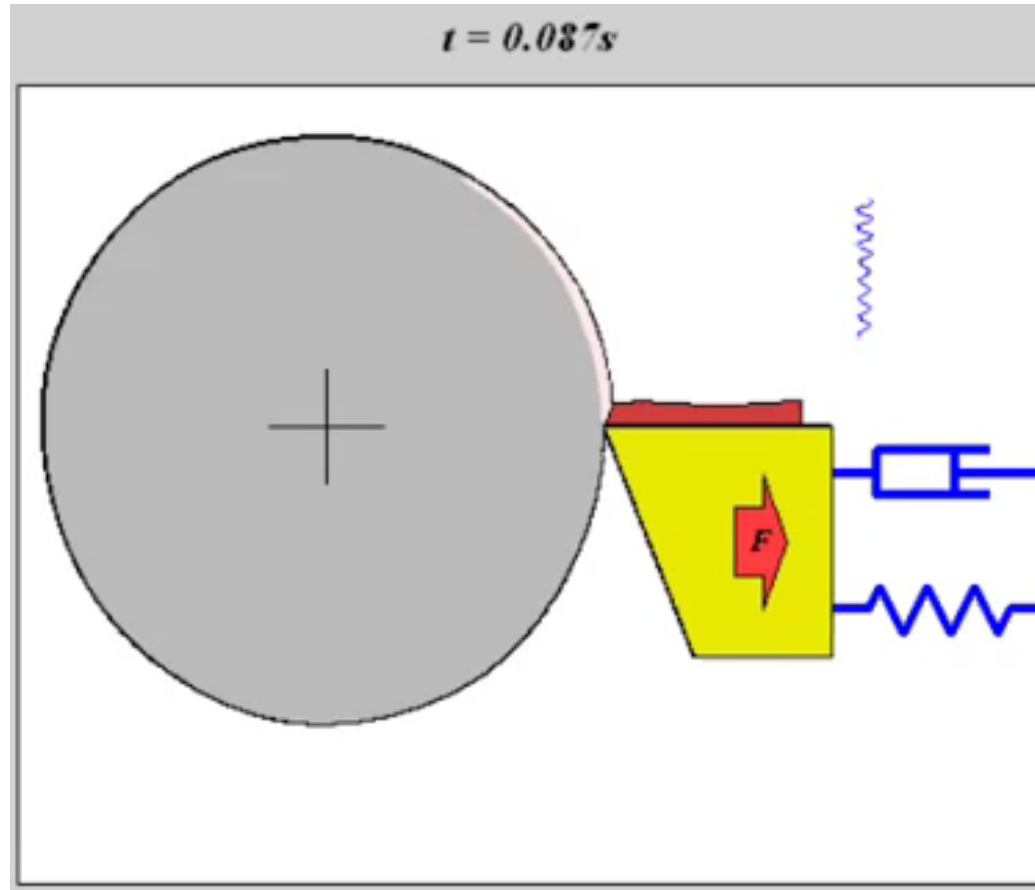
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What is damping?

- Damping is good. Very good.
- Damping is defined as any method of dispersing energy in a vibrating system, and as a result, damping reduces the amplitude of vibration with time



Why do we need damping?



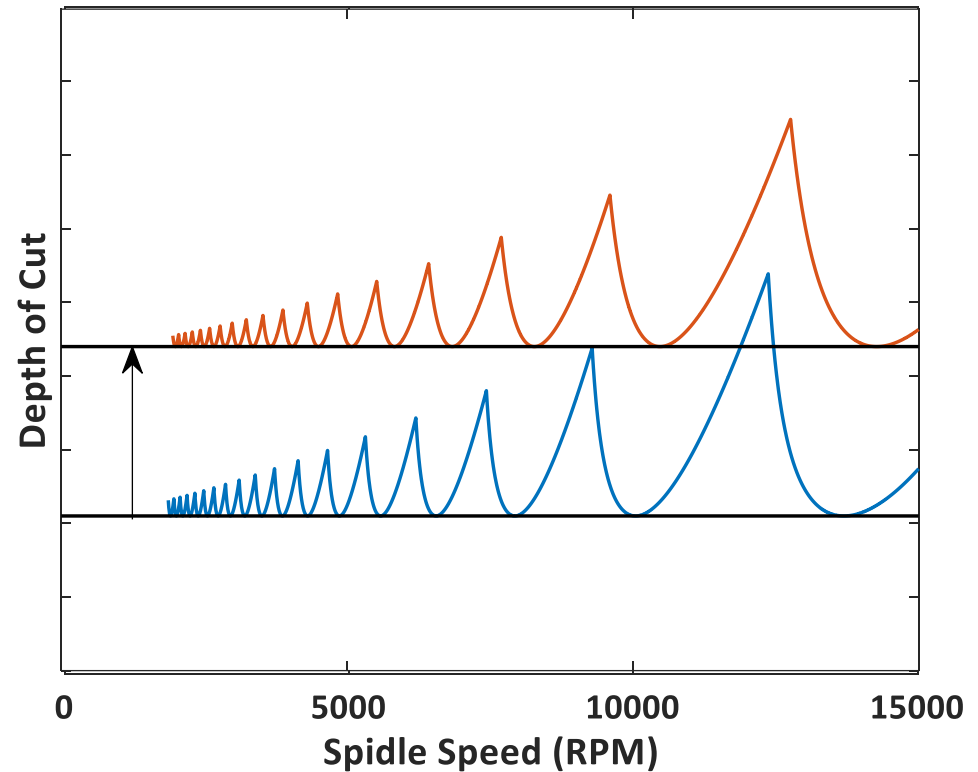
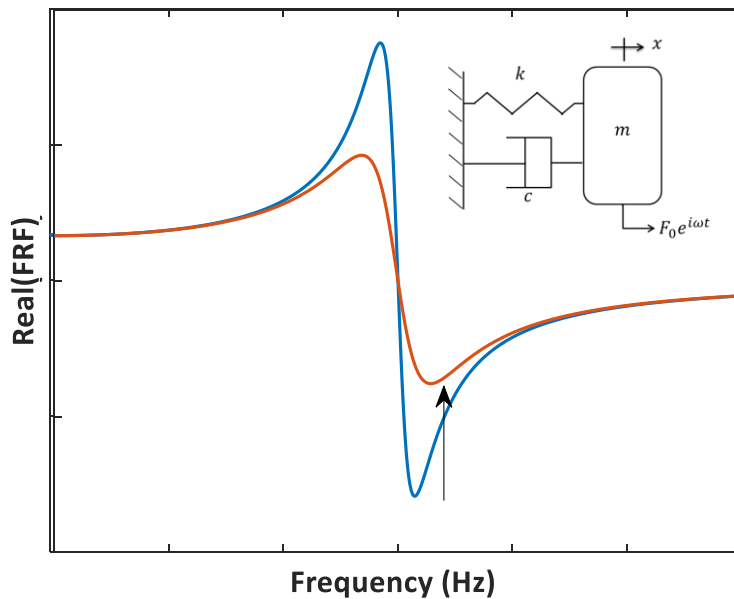
Eynian, 2009



Why do we need damping?

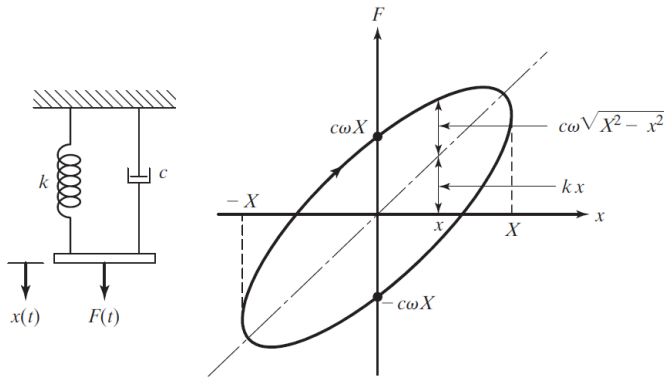
$$a_{lim} = -\frac{1}{2K_t\alpha \operatorname{Real}(H(\omega_c))}$$

$$a_{lim,crit} = \frac{-1}{2K_t\alpha \min(\operatorname{Re}(H(\omega_c)))}$$

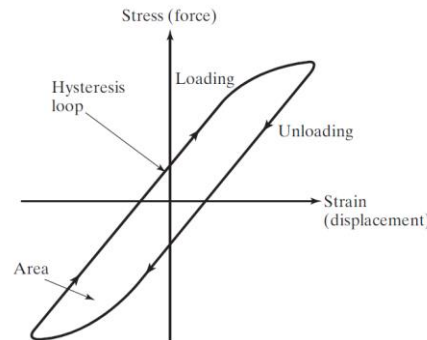


Mechanisms of damping in structures

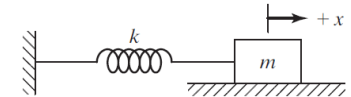
Viscous damping



Hysteretic (structural/material) damping

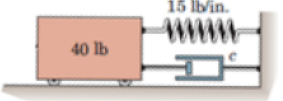
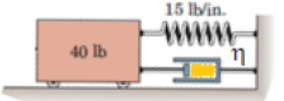
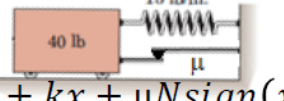








Coulomb (dry-friction) damping



Damping mechanisms in machine tools

RESEARCH ALLIANCE

	Viscous damping  $m\ddot{x} + c\dot{x} + kx = f(t)$	Hysteretic damping  $m\ddot{x} + k(1 + \tan\delta)x = f(t)$	Dry Friction  $m\ddot{x} + kx + \mu N \text{sign}(\dot{x}) = f(t)$
Estructural Parts 		✓	
Bolted Joints 			✓
Guideways 	✓		✓
Rubber 		✓	
Fluids 	✓		
Eddy Currents 	✓		

Munoo, CIRP HPC 2018

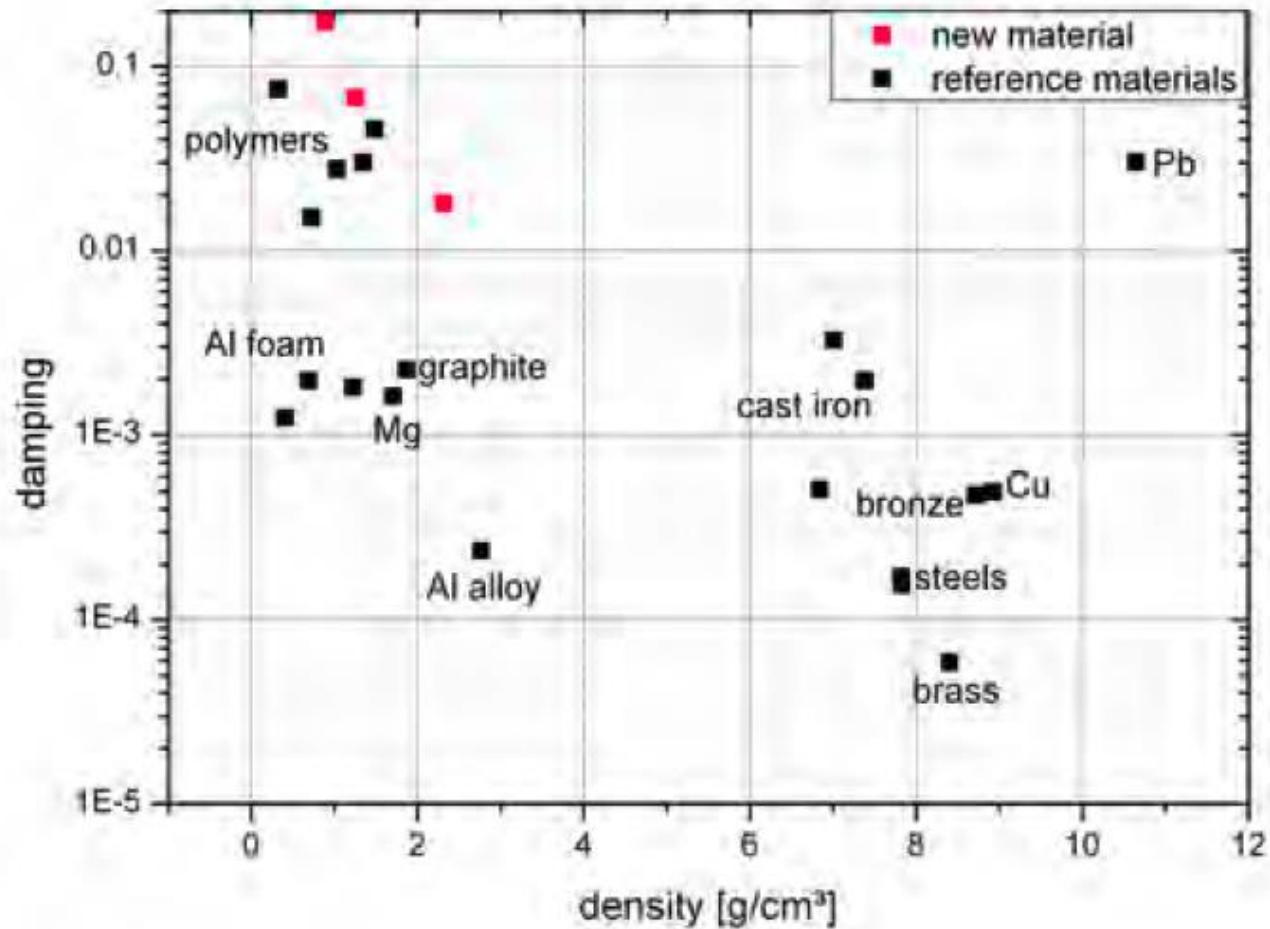


Structure of this talk on damping

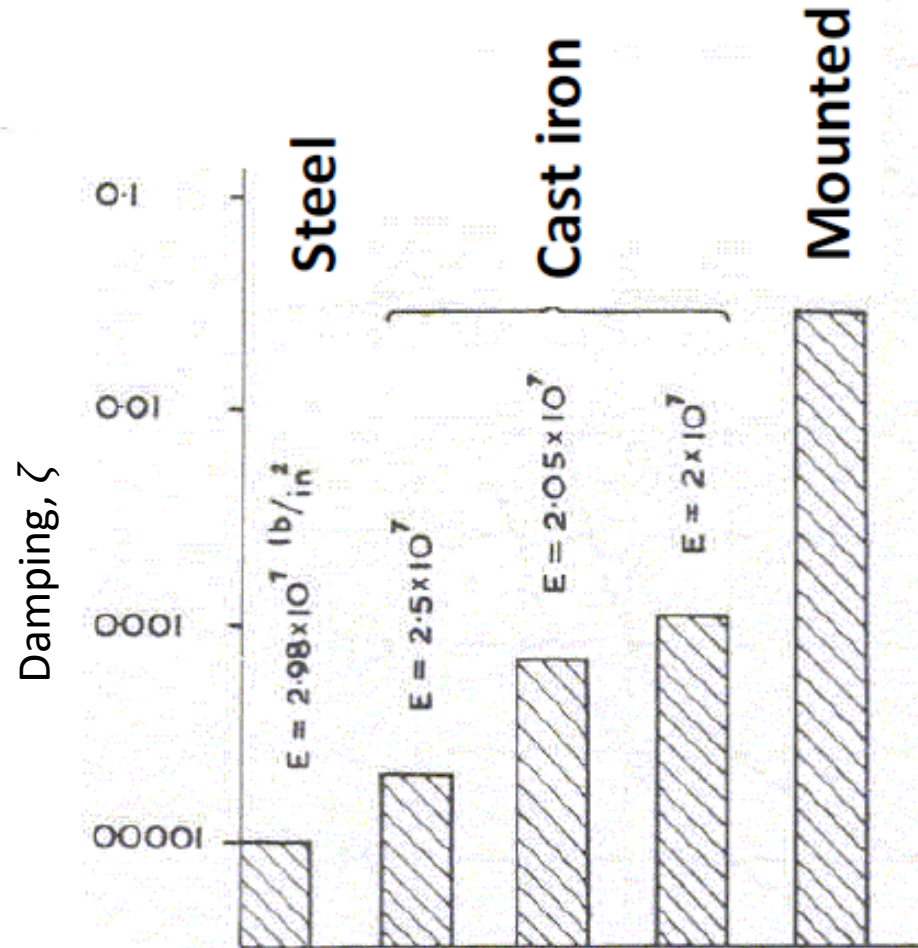
- Damping in materials
- Damping due to joints
- Passive damping
- Active damping



Damping due to materials



Damping in spindles



Koenigsberger and Tlustý, 1970



Damping in machine tools

Over 90% of the damping is at the interfaces. Of the remainder, some is due to materials, and some due to heat loss.

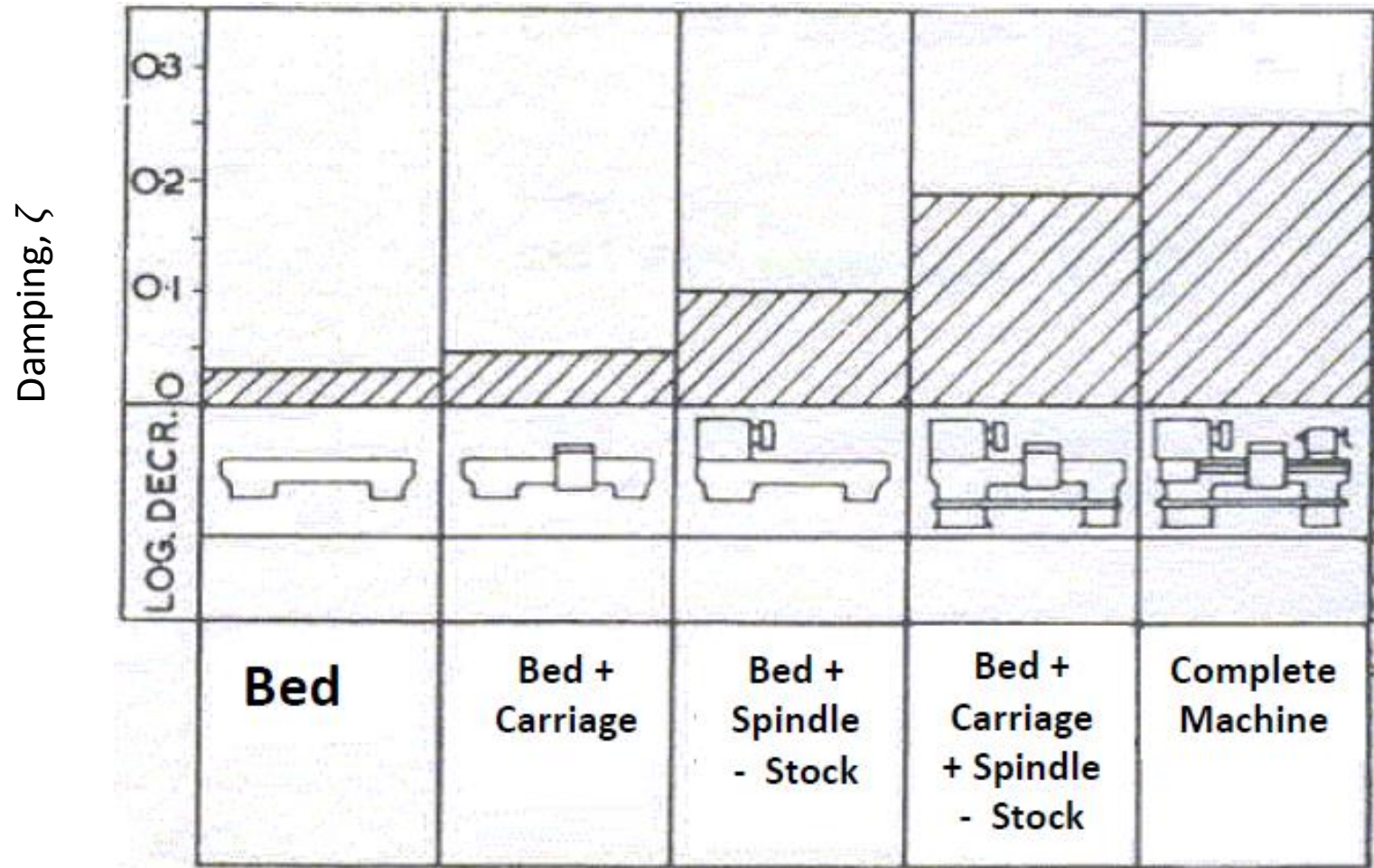


Structure of this talk on damping

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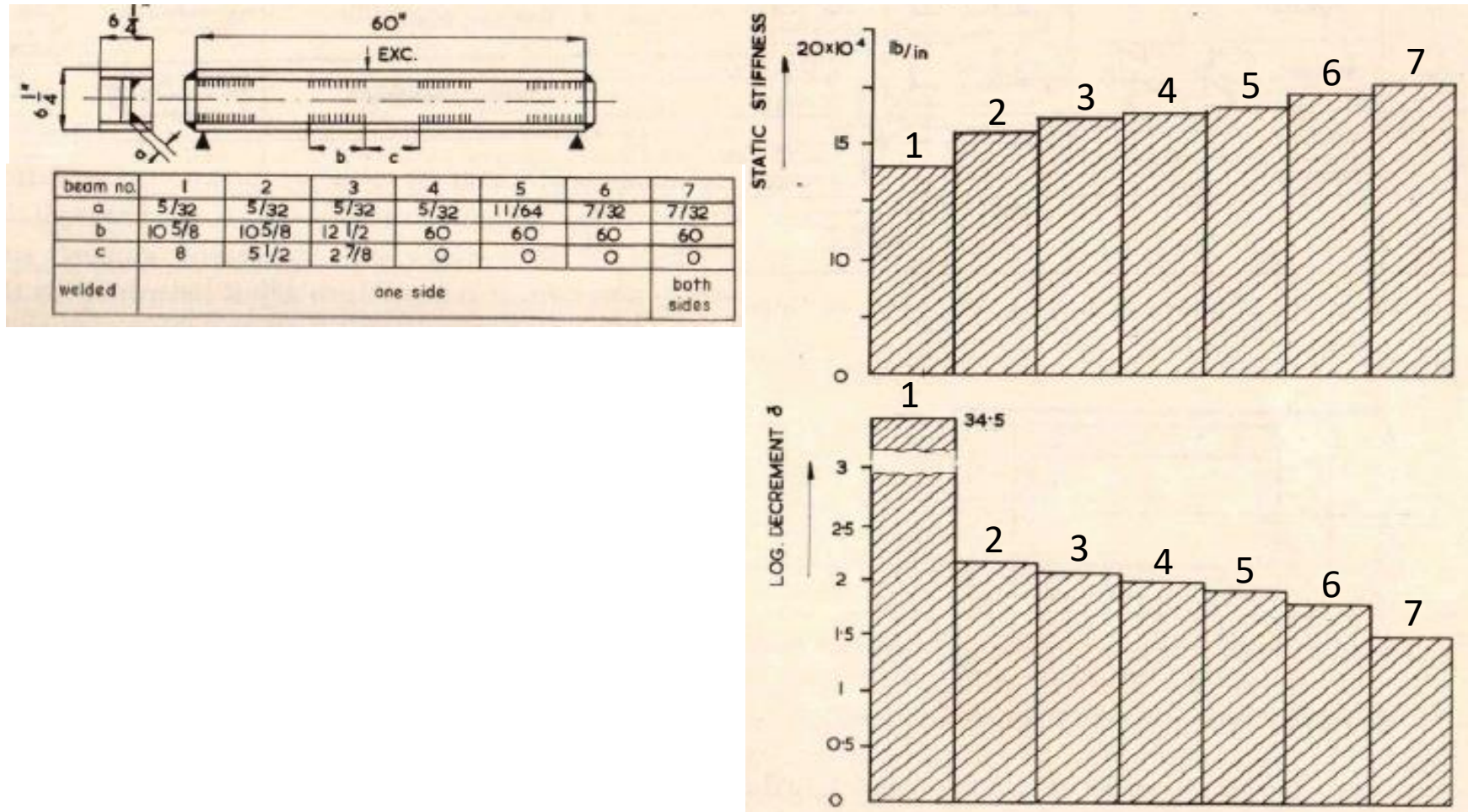
Influence of joints on damping



Koenigsberger and Tlustý, 1970



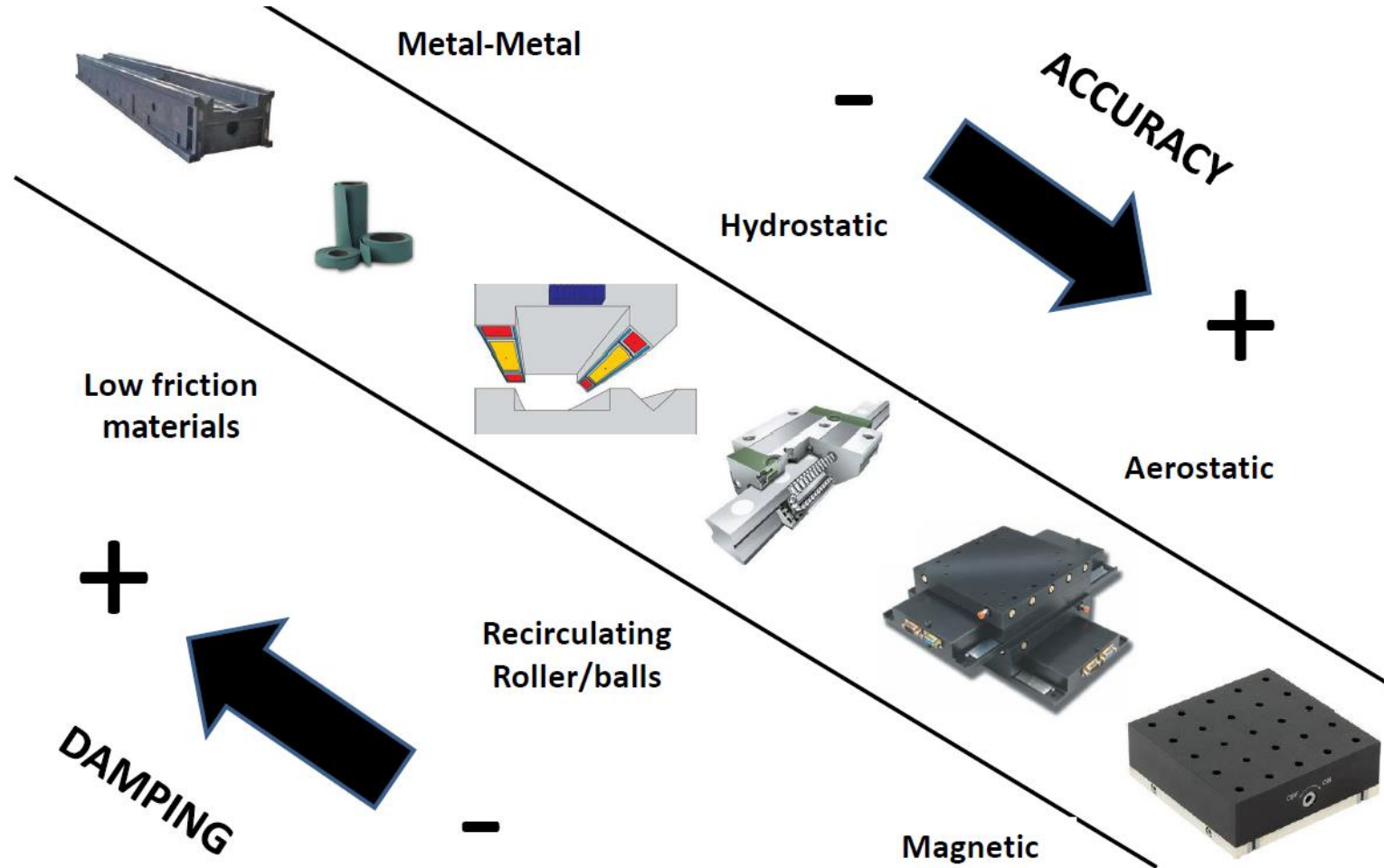
Influence of weld length on damping



Koenigsberger and Tlustý, 1970



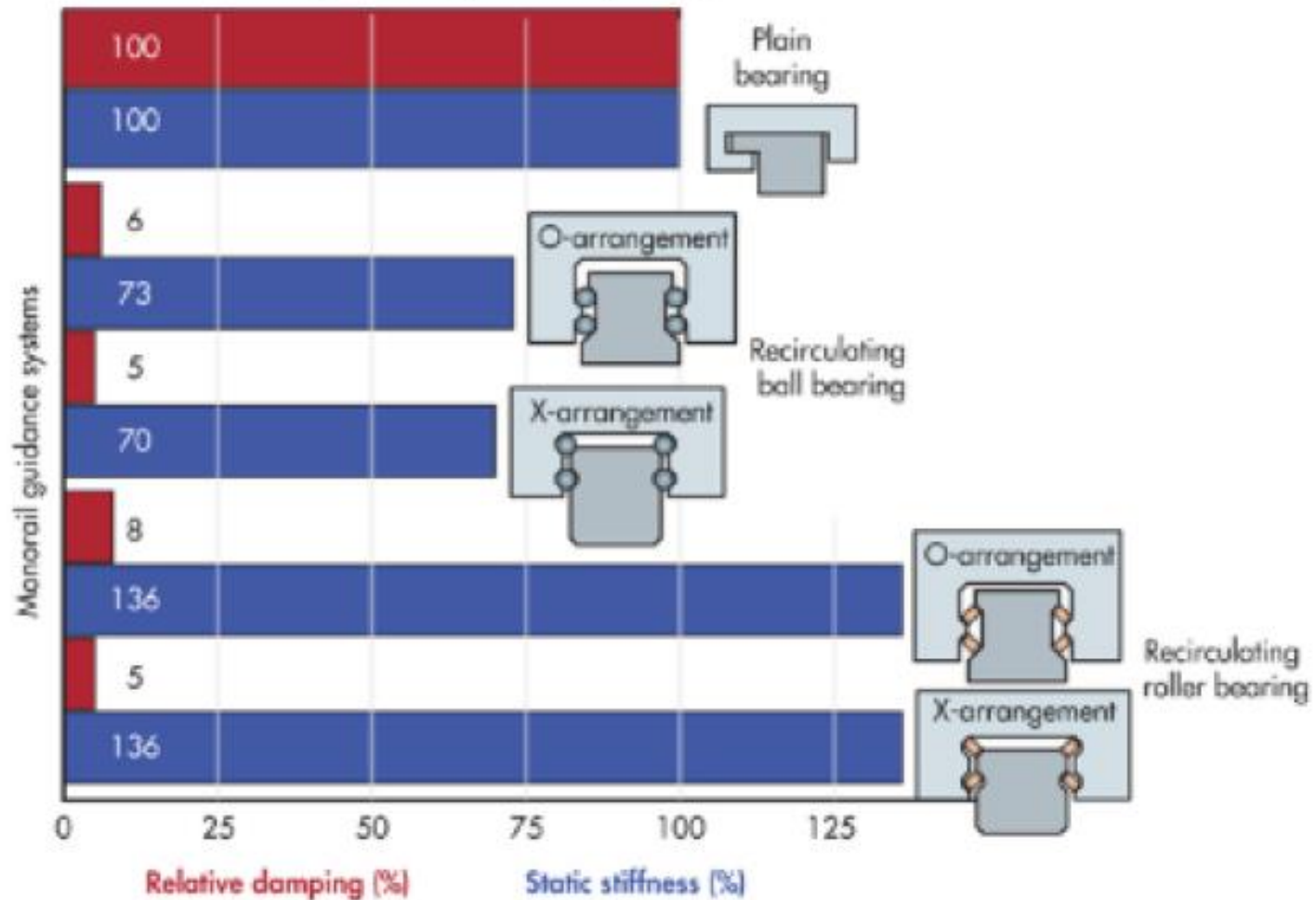
Accuracy vs. damping



Munoo, CIRP HPC 2018



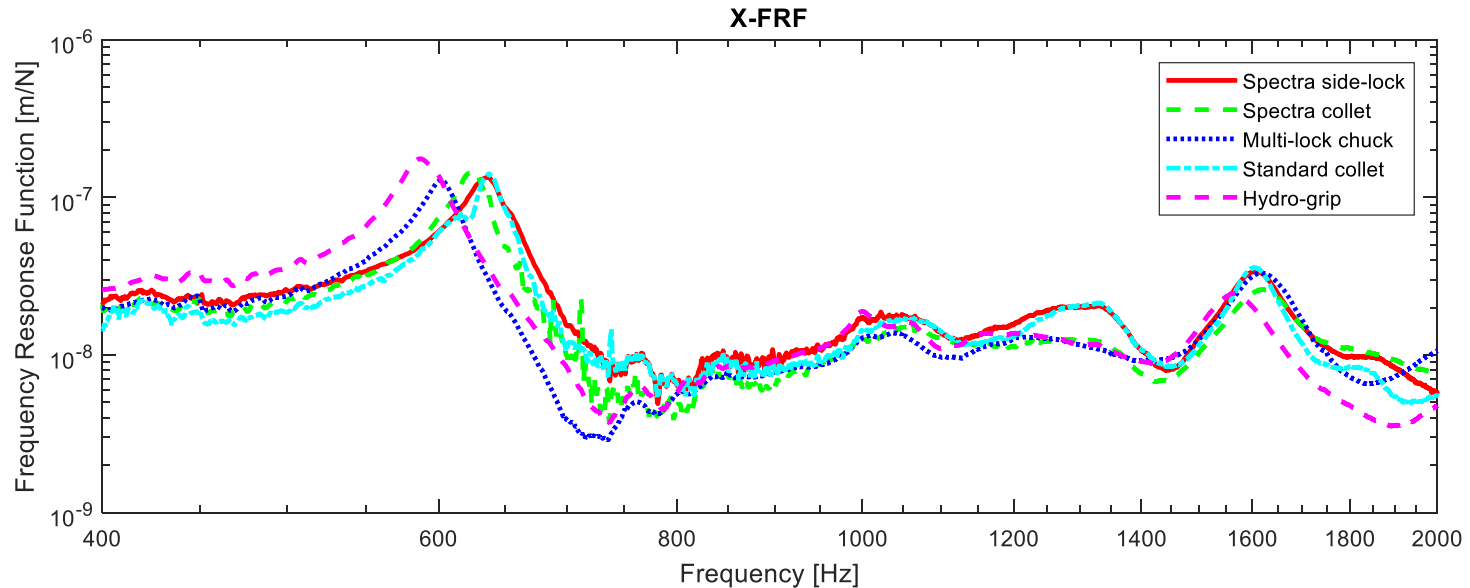
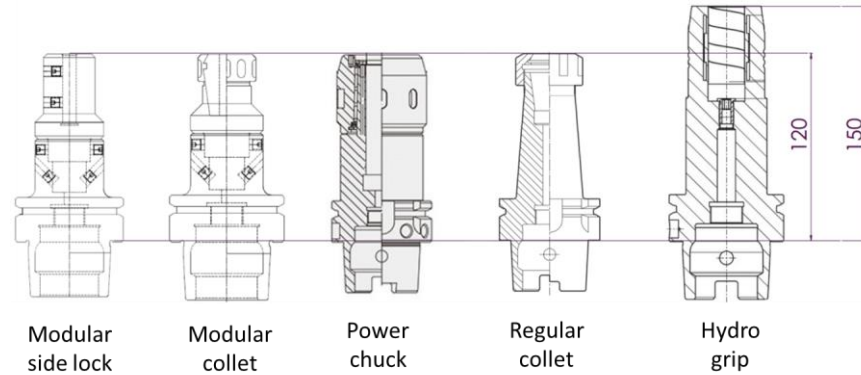
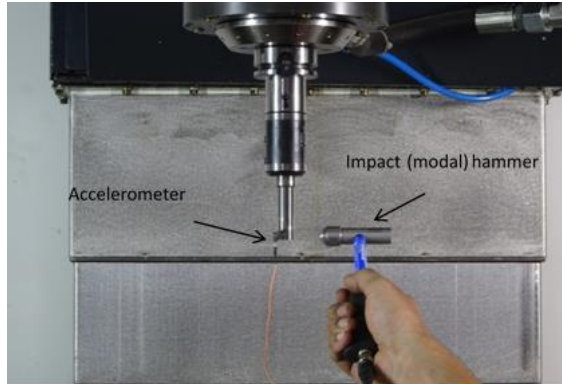
Damping in linear guideways



Munoa, CIRP HPC 2018



Damping in tool and tool holder joints

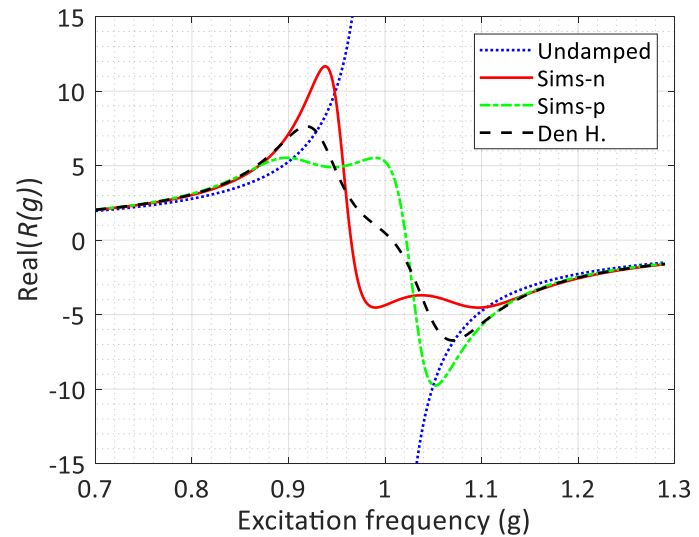
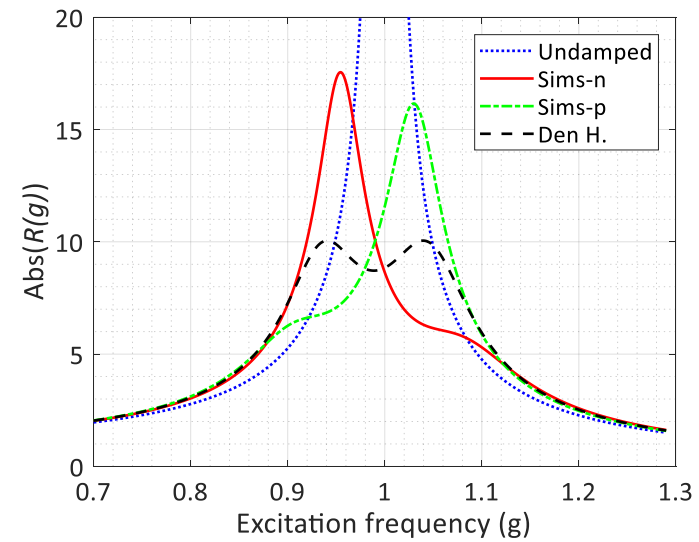
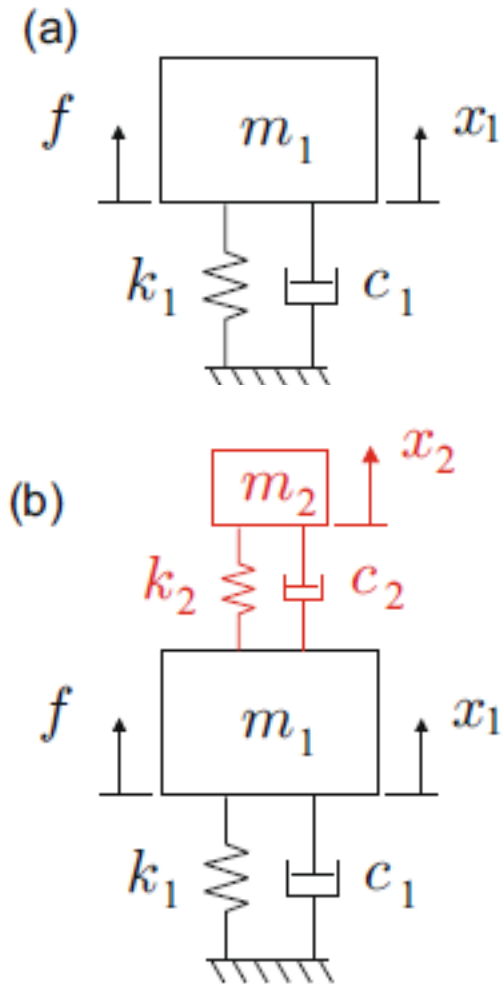


Structure of this talk on damping

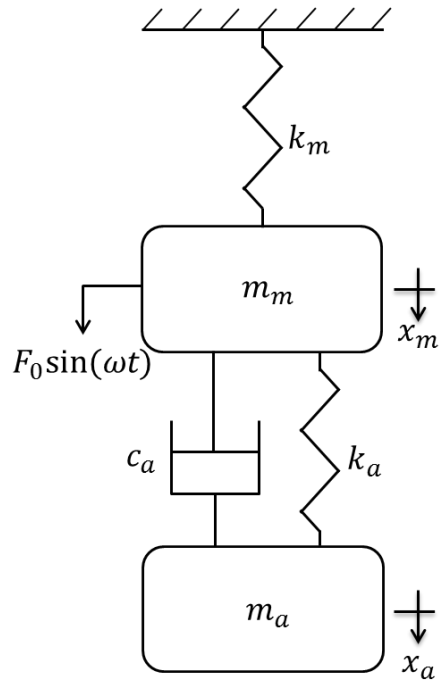
- Damping in materials
- Damping due to joints
- **Passive damping**
- Active damping



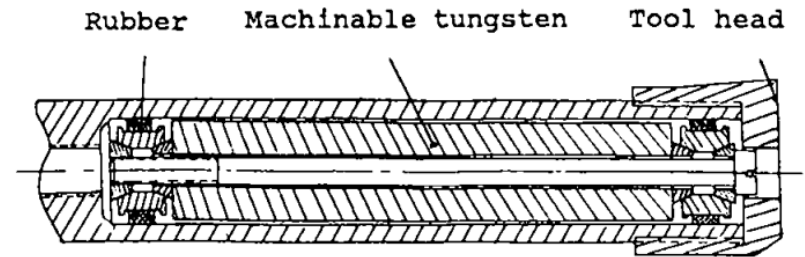
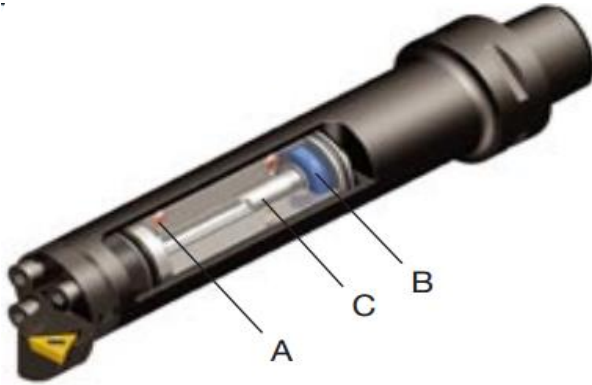
Passive damping



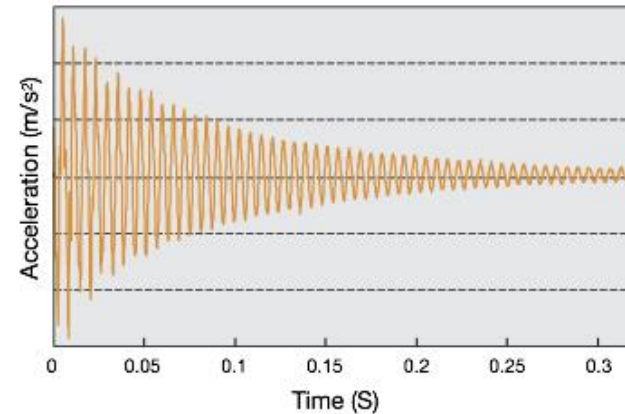
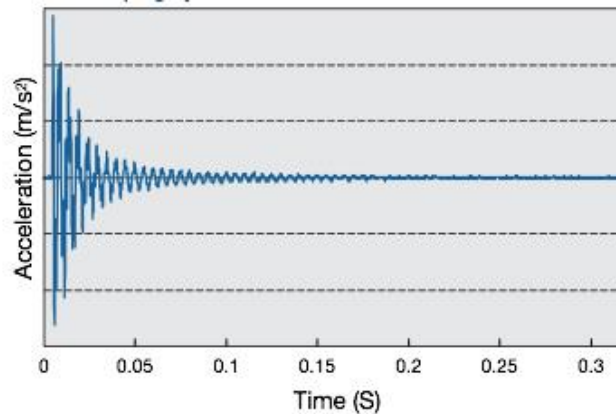
Vibration absorber in boring bars



Tuned boring bars – passive damping



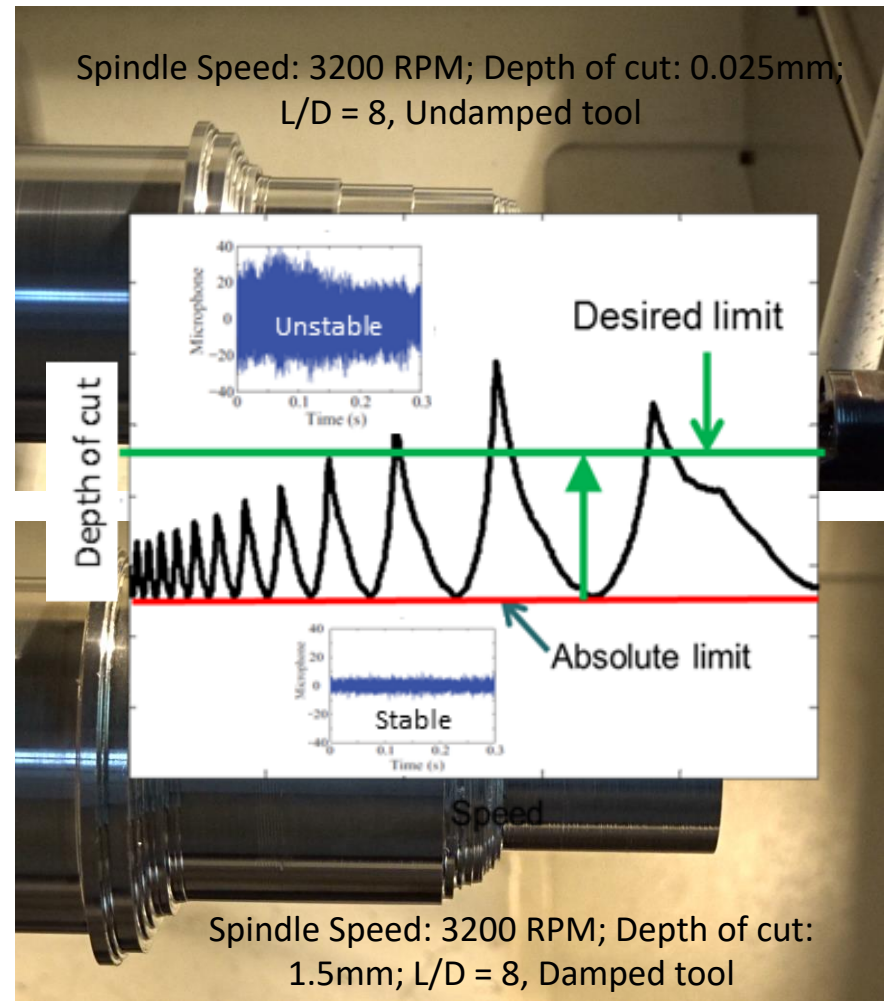
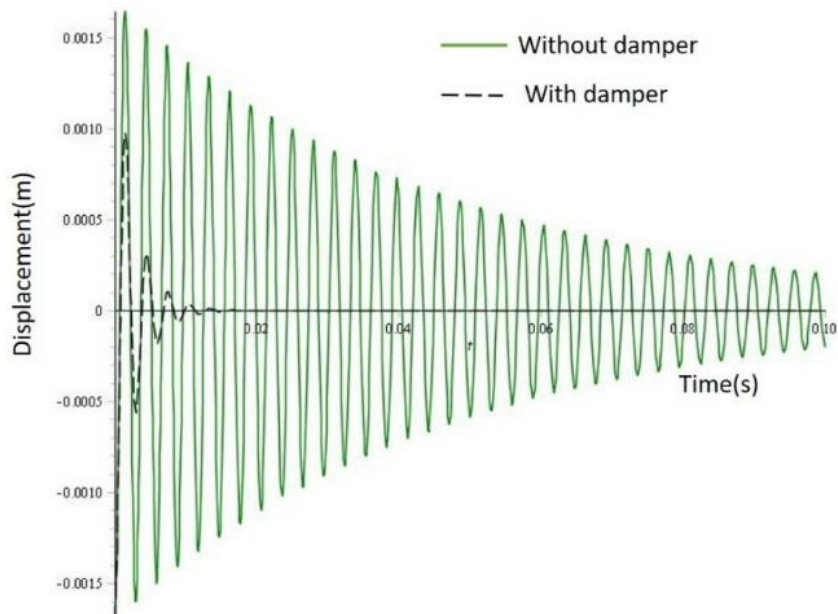
The main parts of the damped boring bar are:
a) heavy turning body, b) rubber brushes c) special oily liquid



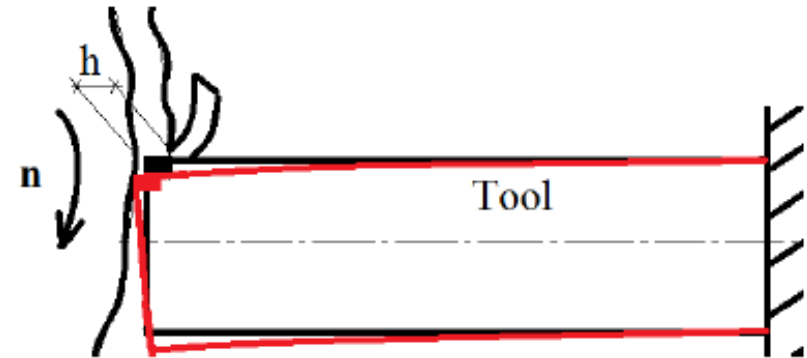
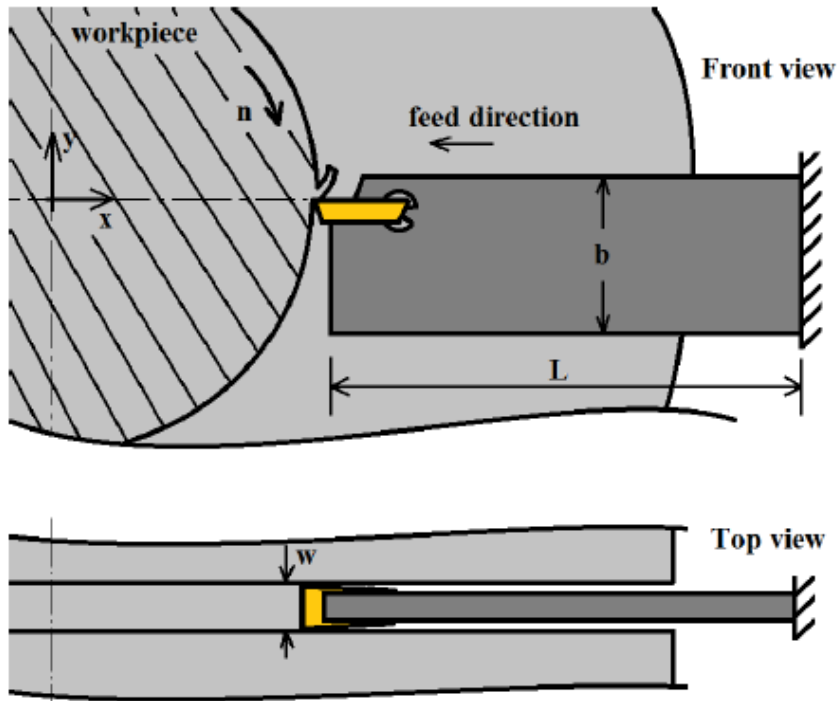
Source: Sandvik



Vibration absorber in boring bars

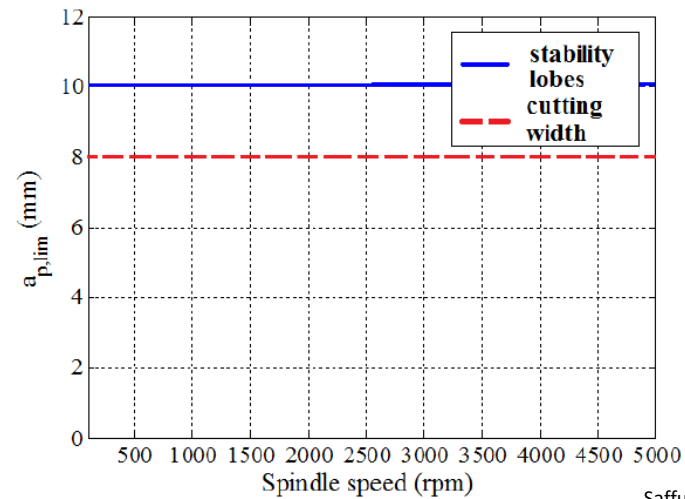
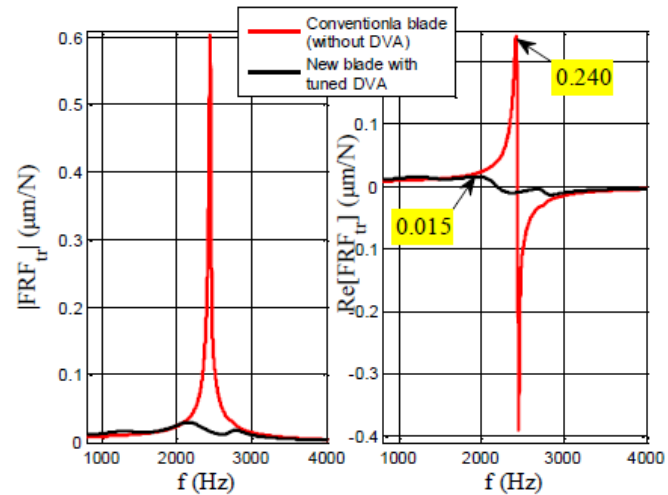
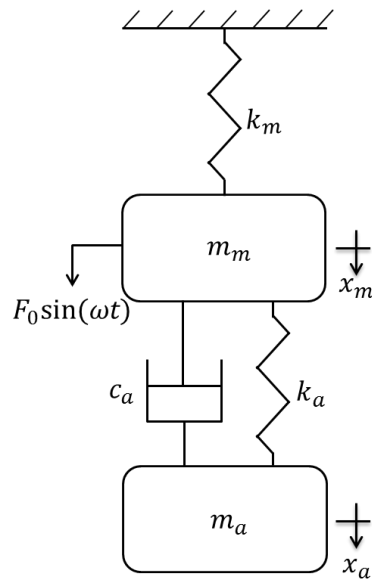
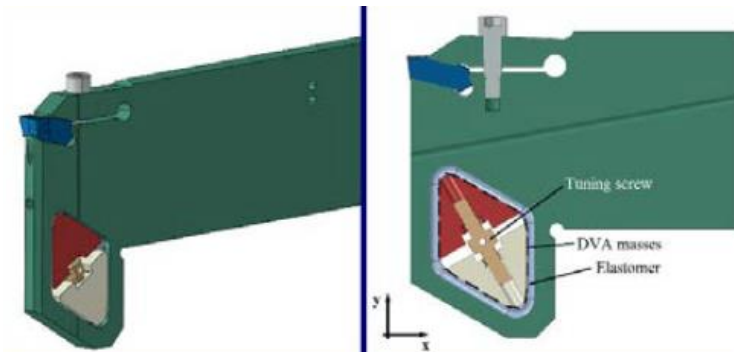


Grooving



$$w_{cr} \cong \frac{+1}{2K_{ct}Re[G_{xy}]}$$

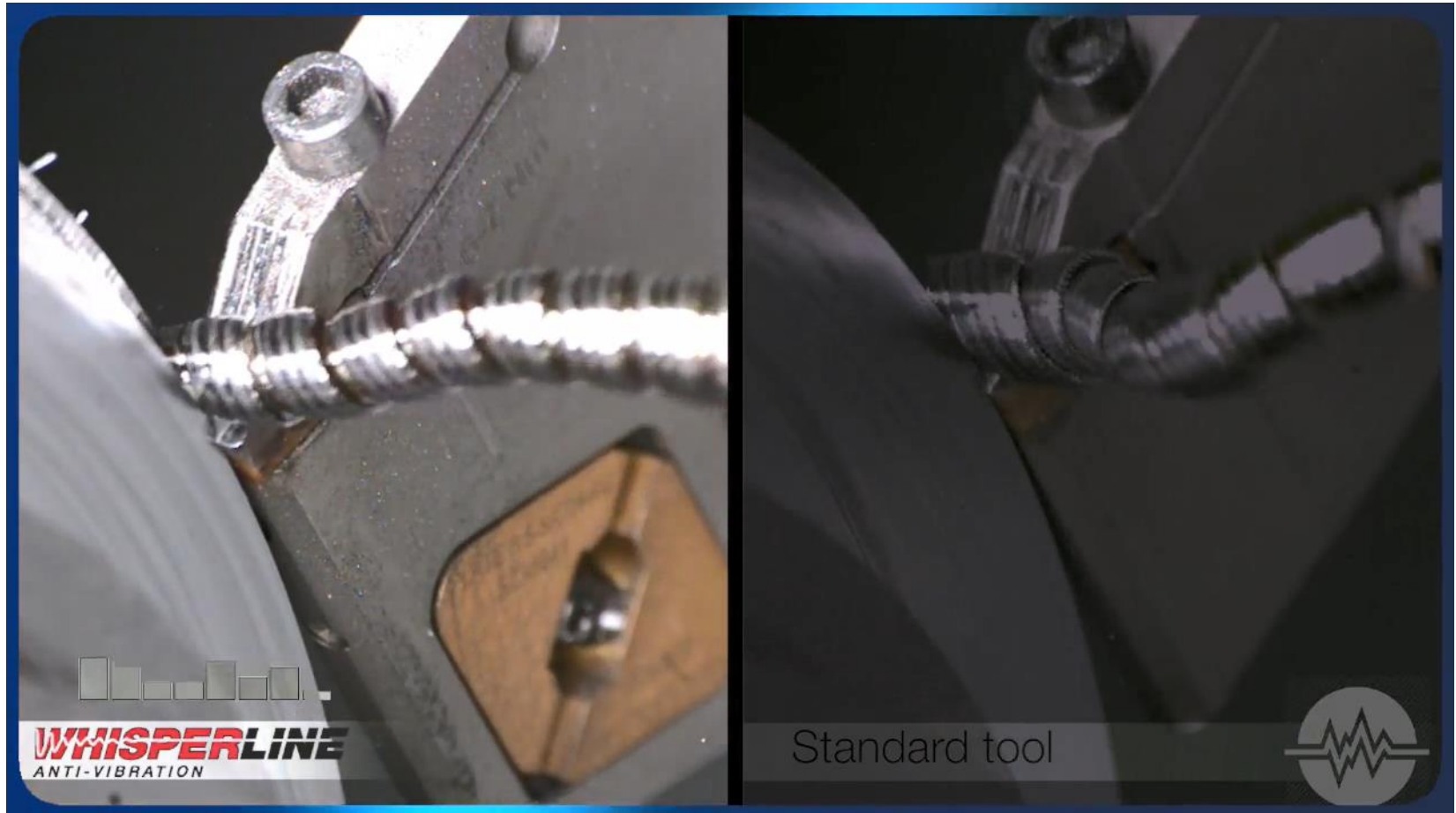
Vibration absorber for grooving



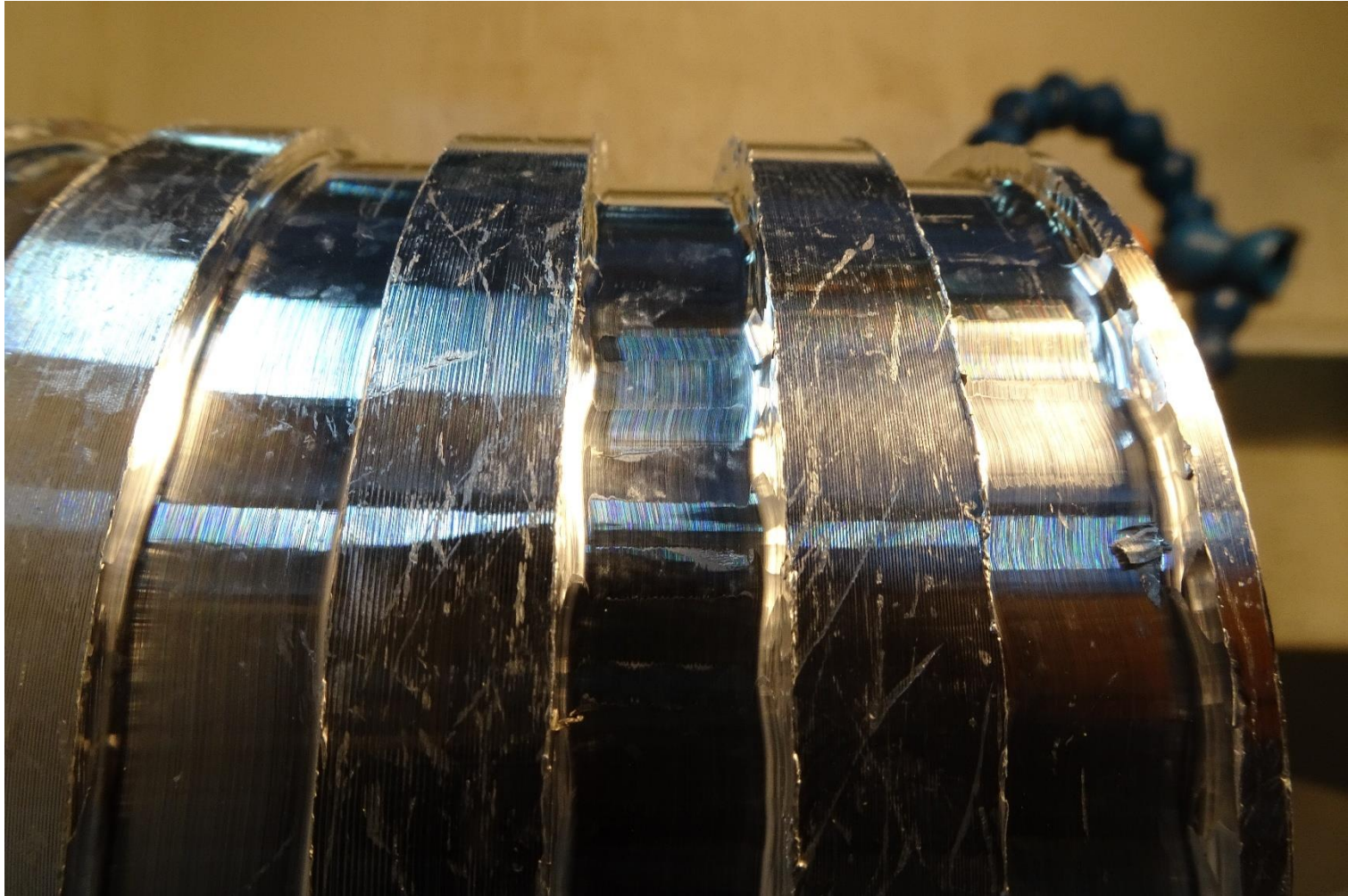
Saffury, CIRP CMMO 2017



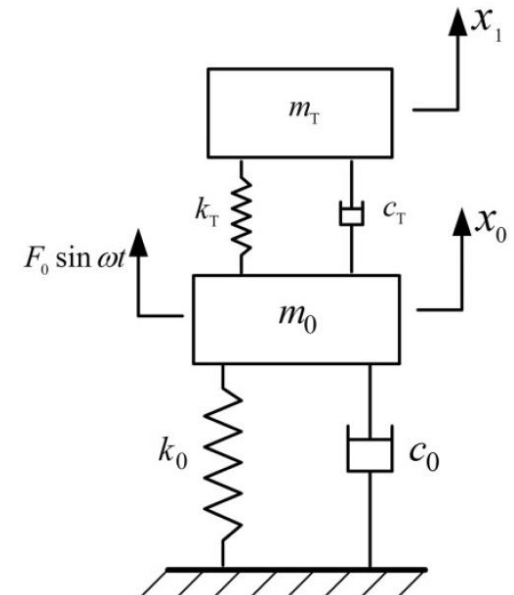
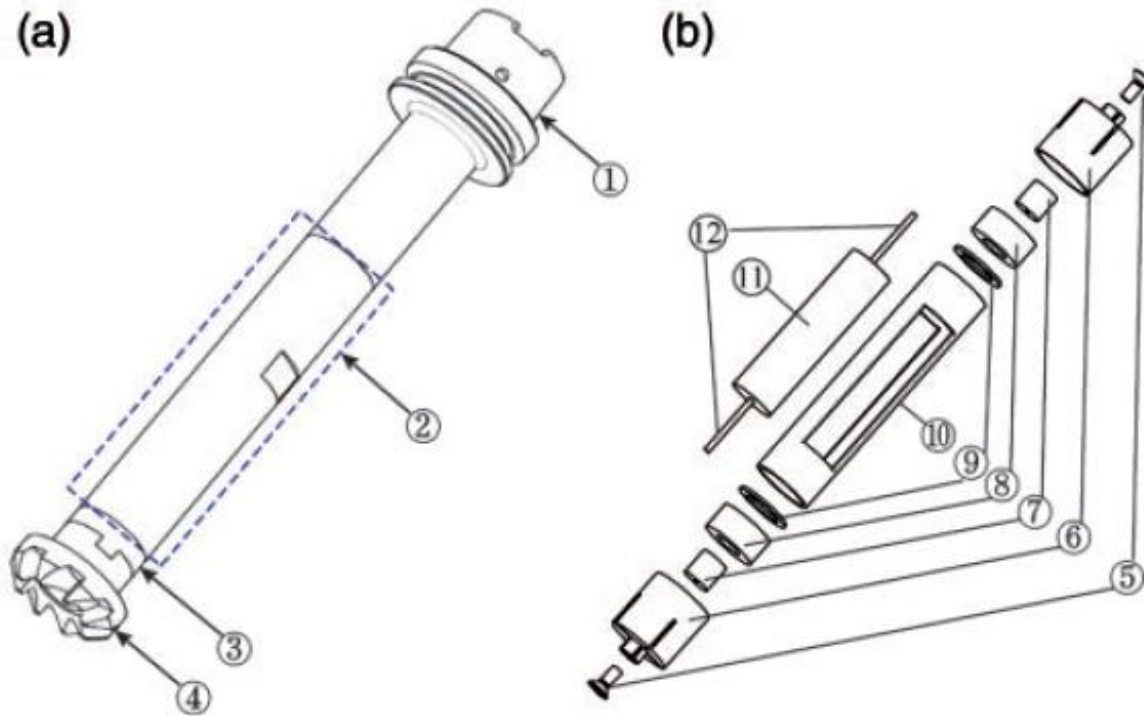
Grooving: avoiding chatter with a damped tool



Damping snaking chatter in grooving?



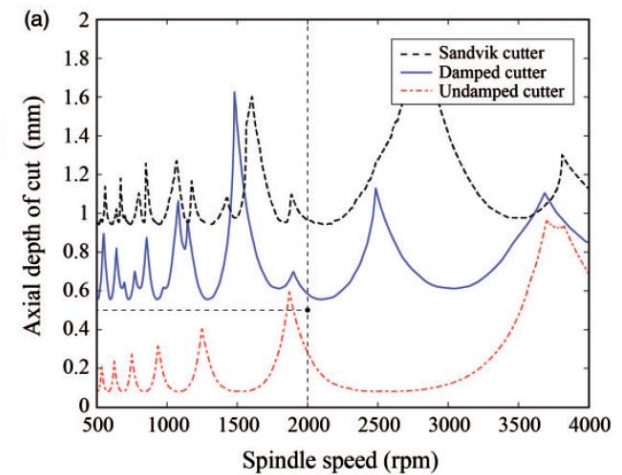
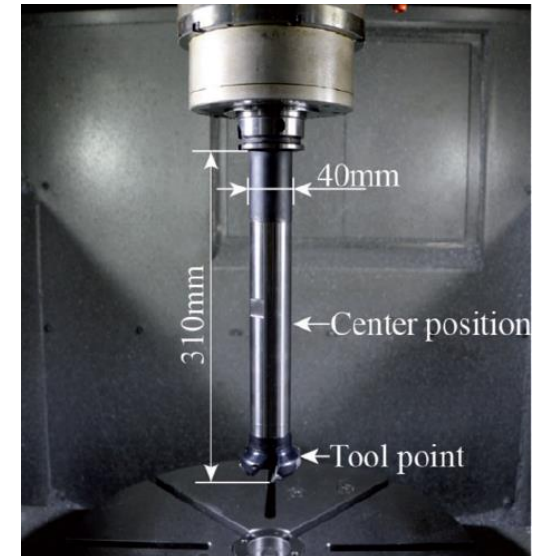
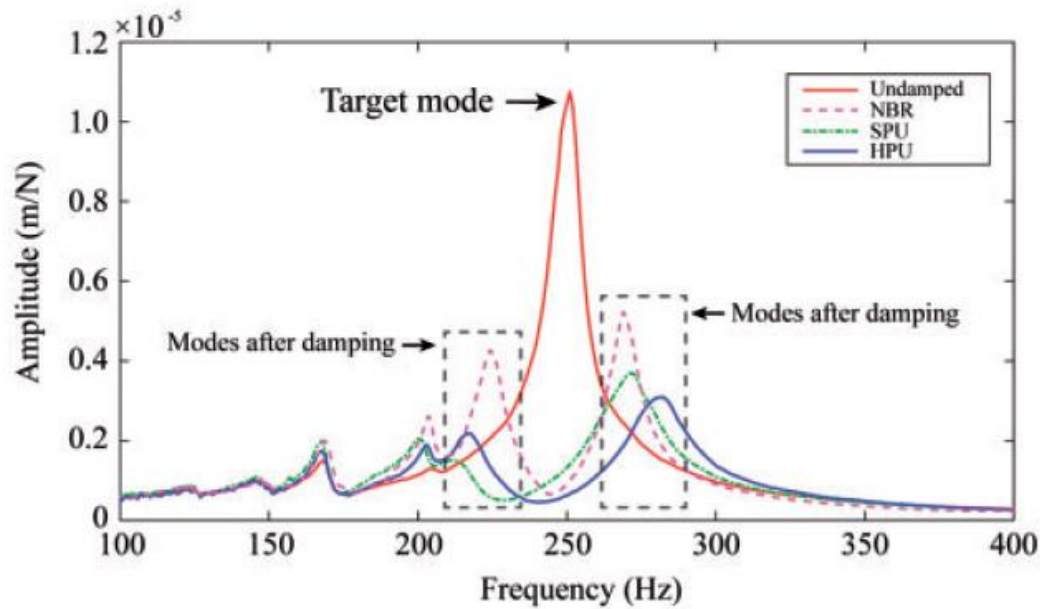
Damped milling holder



Yang et al. JVC, 2018



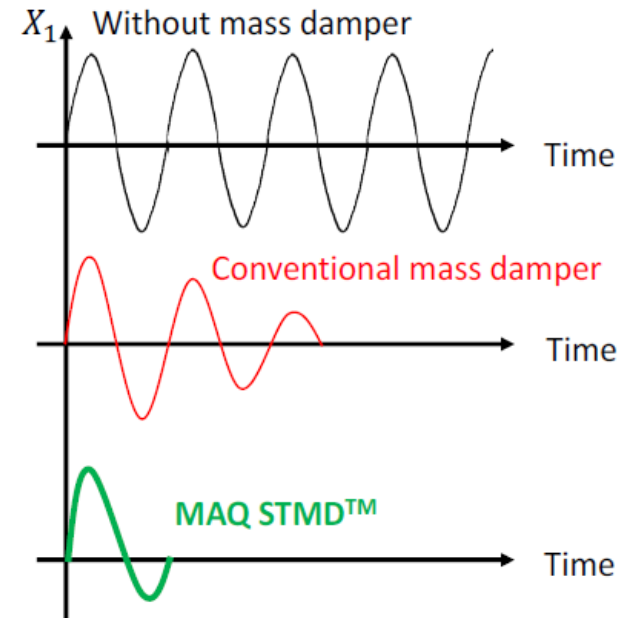
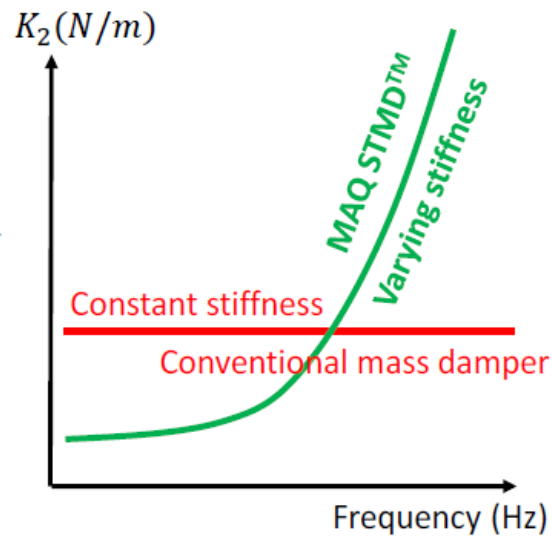
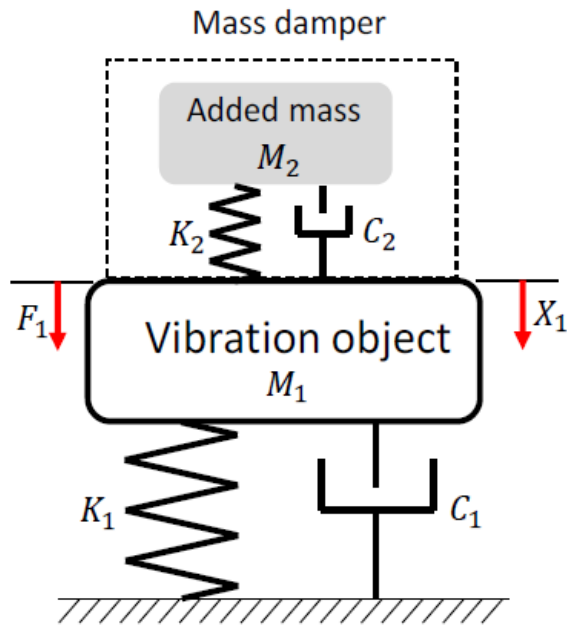
Damped milling holder



Yang et al. JVC, 2018



Self-tuning mass dampers

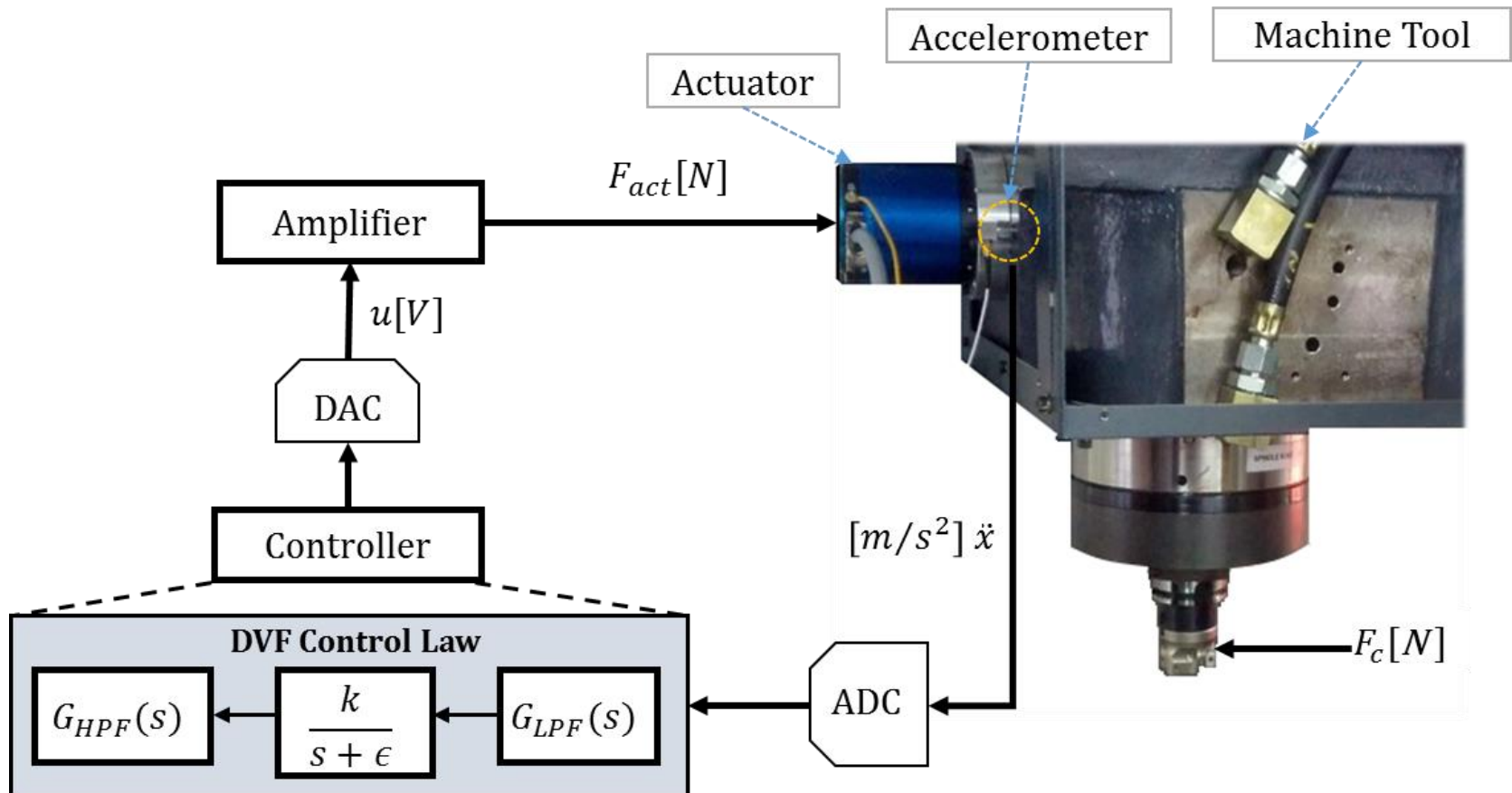


Structure of this talk on damping

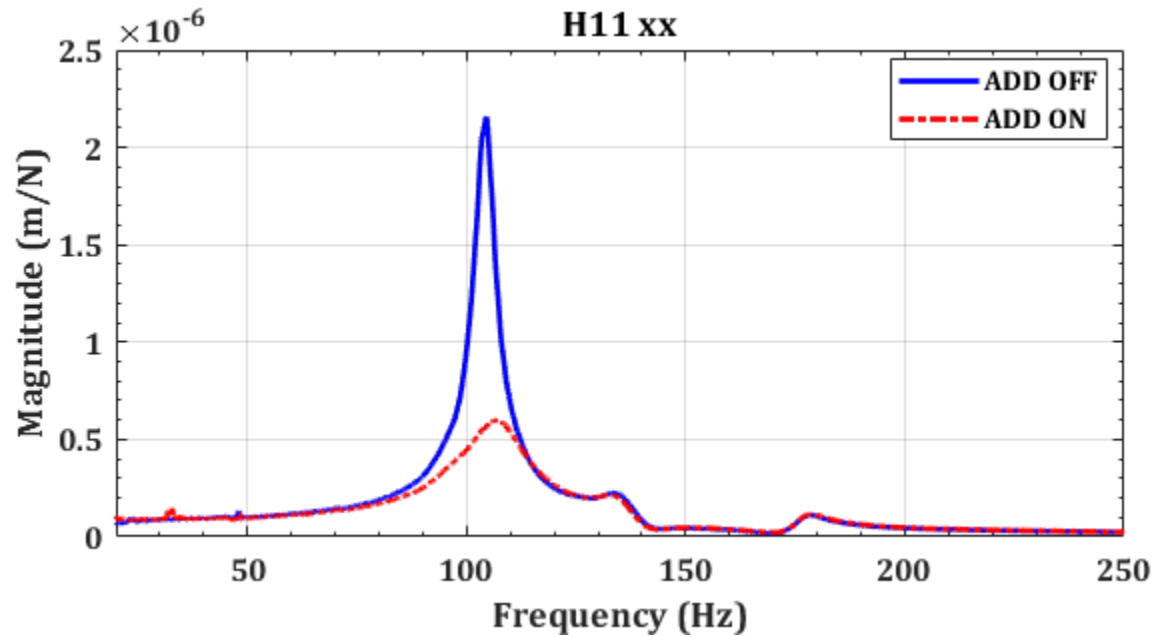
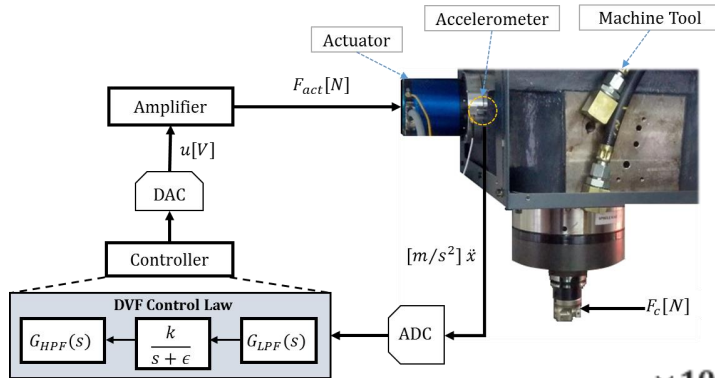
- Damping in materials
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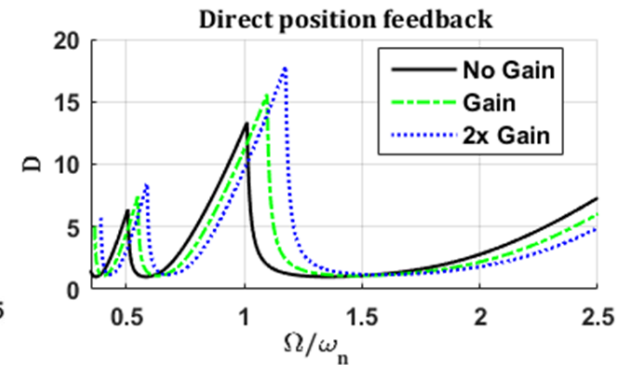
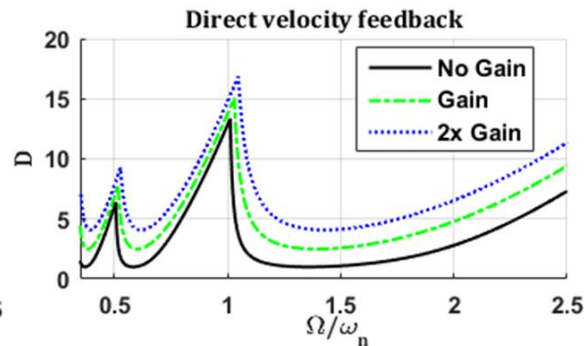
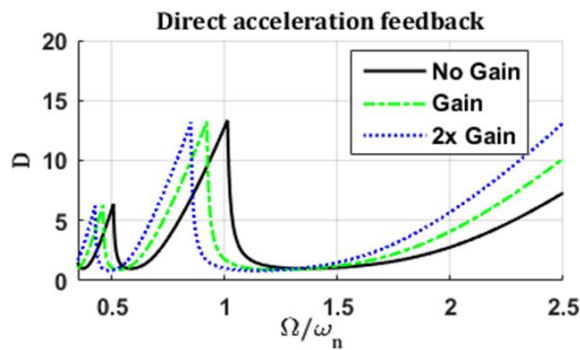
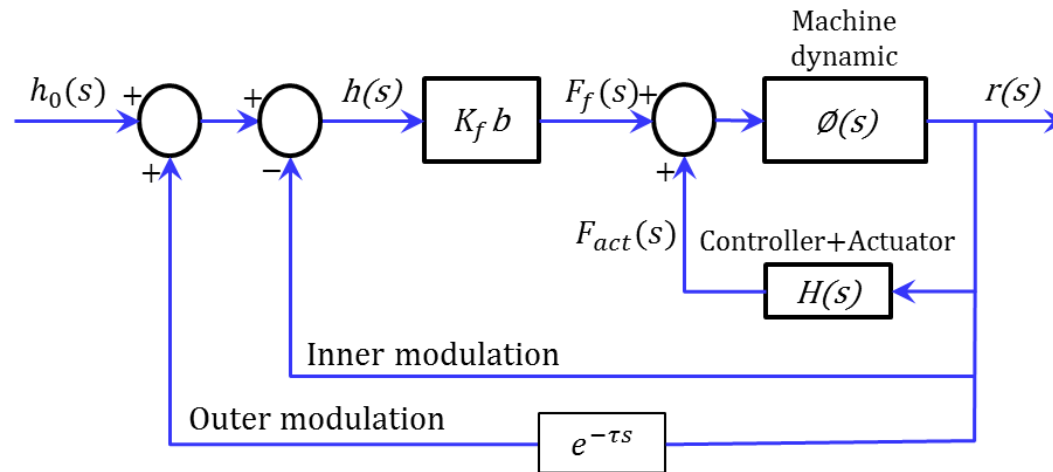
Active damping



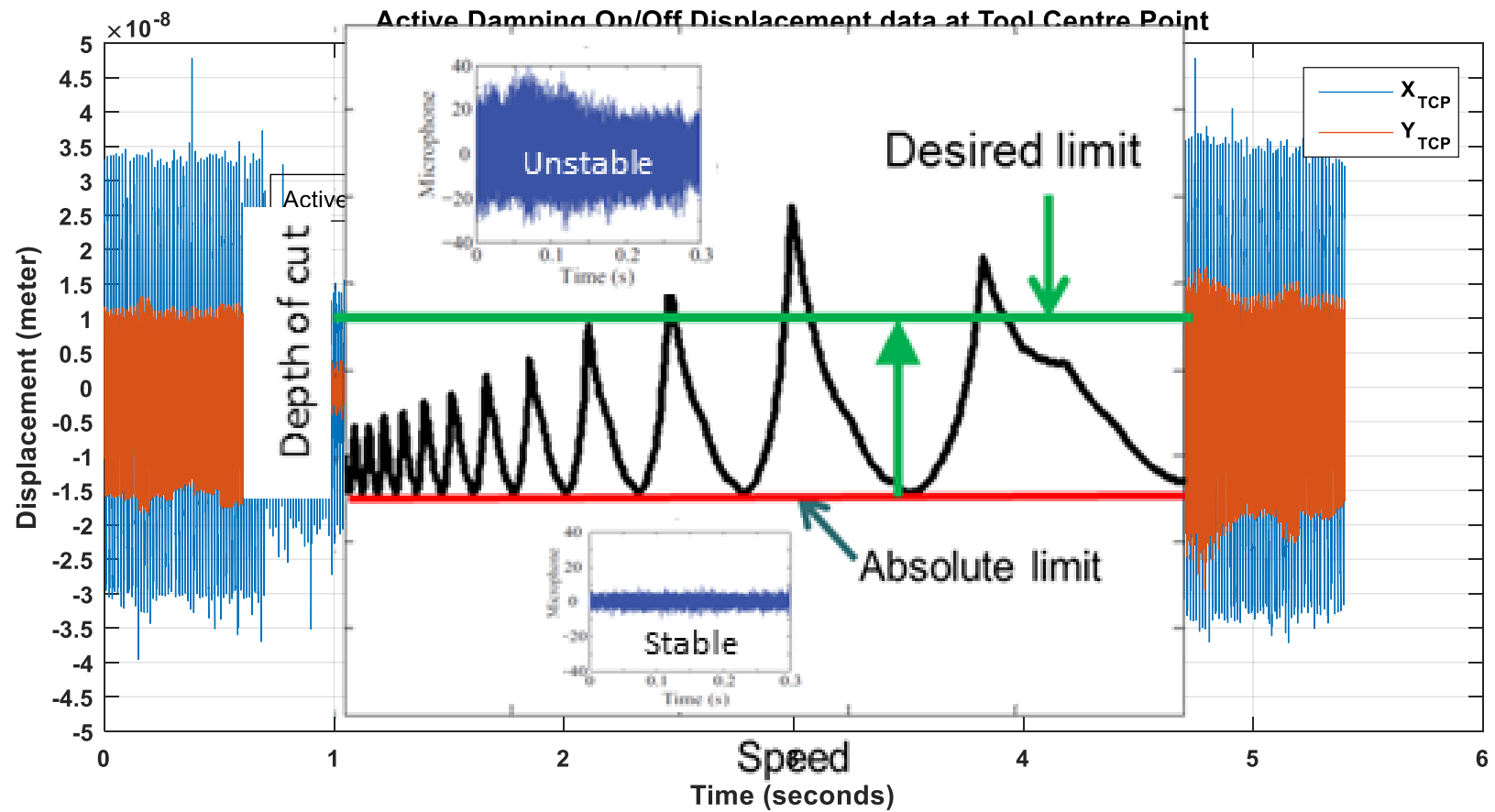
Active damping



Active damping: influence of kind of feedback



Active damping



Active damping

IK4  IDEKO
Research Alliance

Rough milling process



Active damping

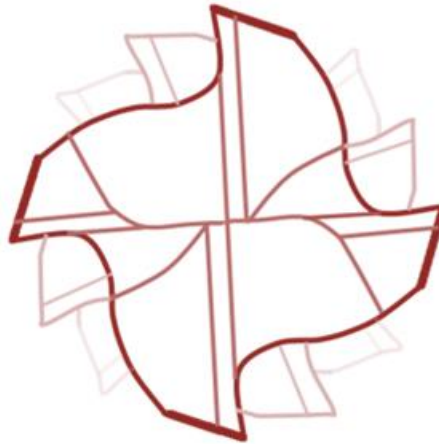


In summary...

- Damping is good. Very good.
- Material level advances can only do so much for you.
- Should you cast or weld?
- The real damping is at the interfaces.
- When/where possible consider passive and/or active damping solutions.
- The journey in search continues ...



Thank you



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