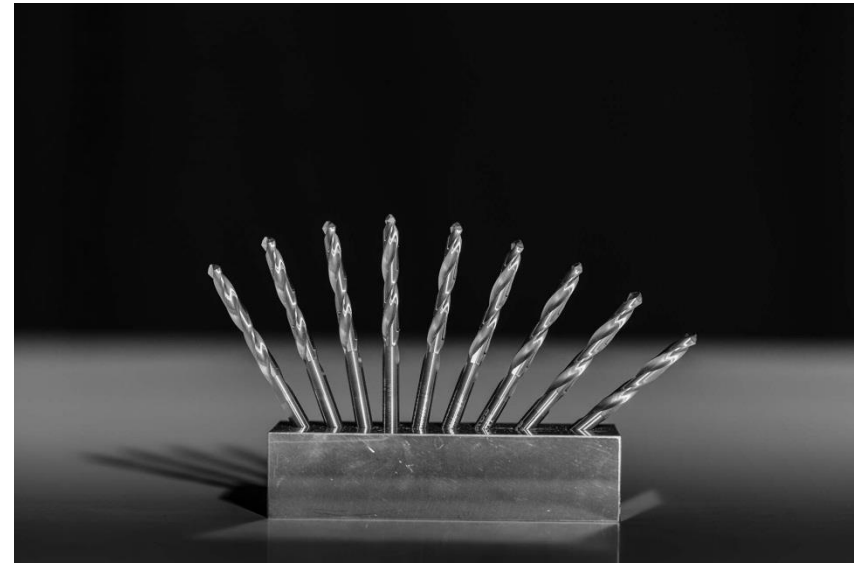

Practical Comparison between the Finite-Element and Mesh-Free Calculation Methods in the Analysis of Machining Simulations

Fraunhofer Institute for Manufacturing Engineering and Automation IPA

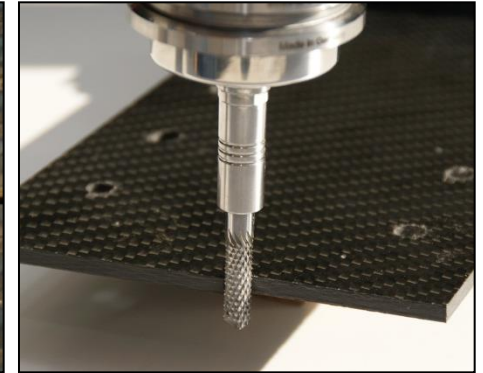
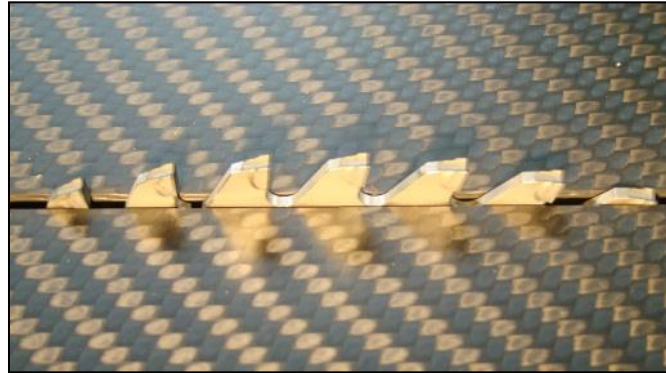
M.Sc. Hector Vazquez Martinez
Department of Lightweight Construction Technologies



Simulation in the Machining Technology

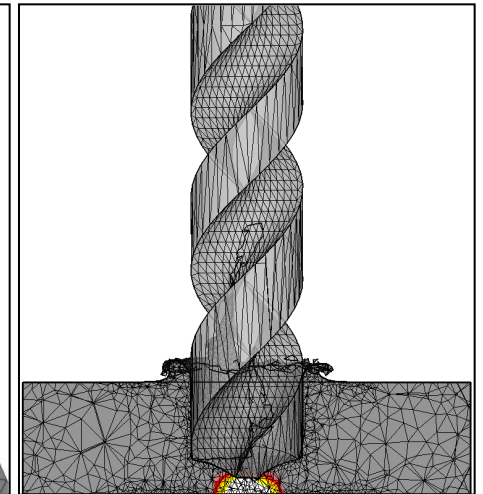
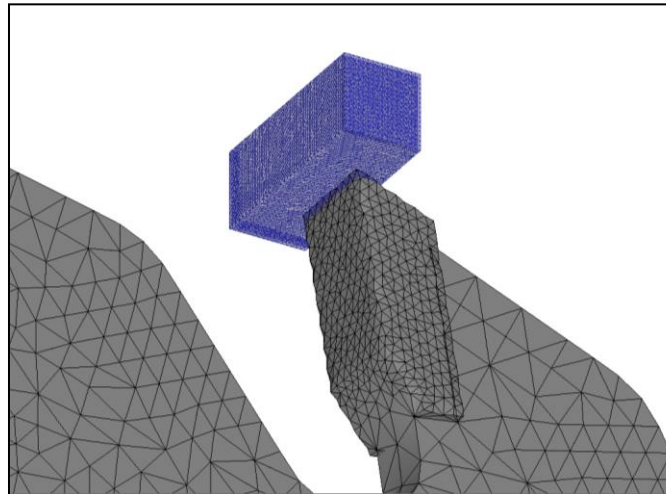
Machining processes

- Turning
- Drilling
- Milling
- Sawing



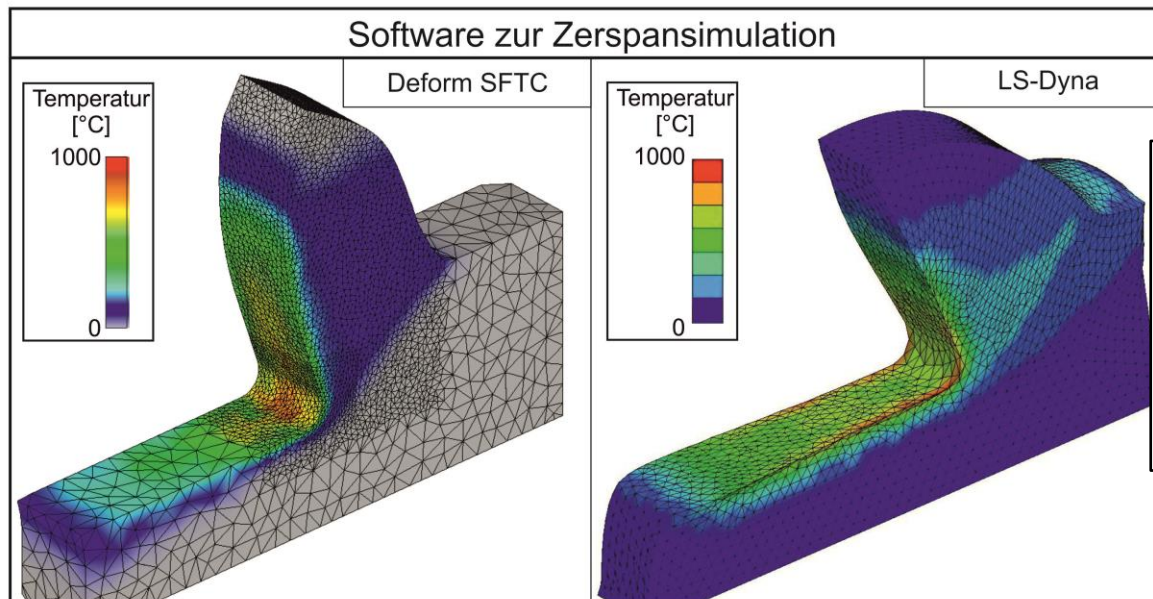
Analyzed variables

- Cutting forces
- Temperature
- Stress
- Strain
- Chip formation



Integration of process simulation in the machining technology

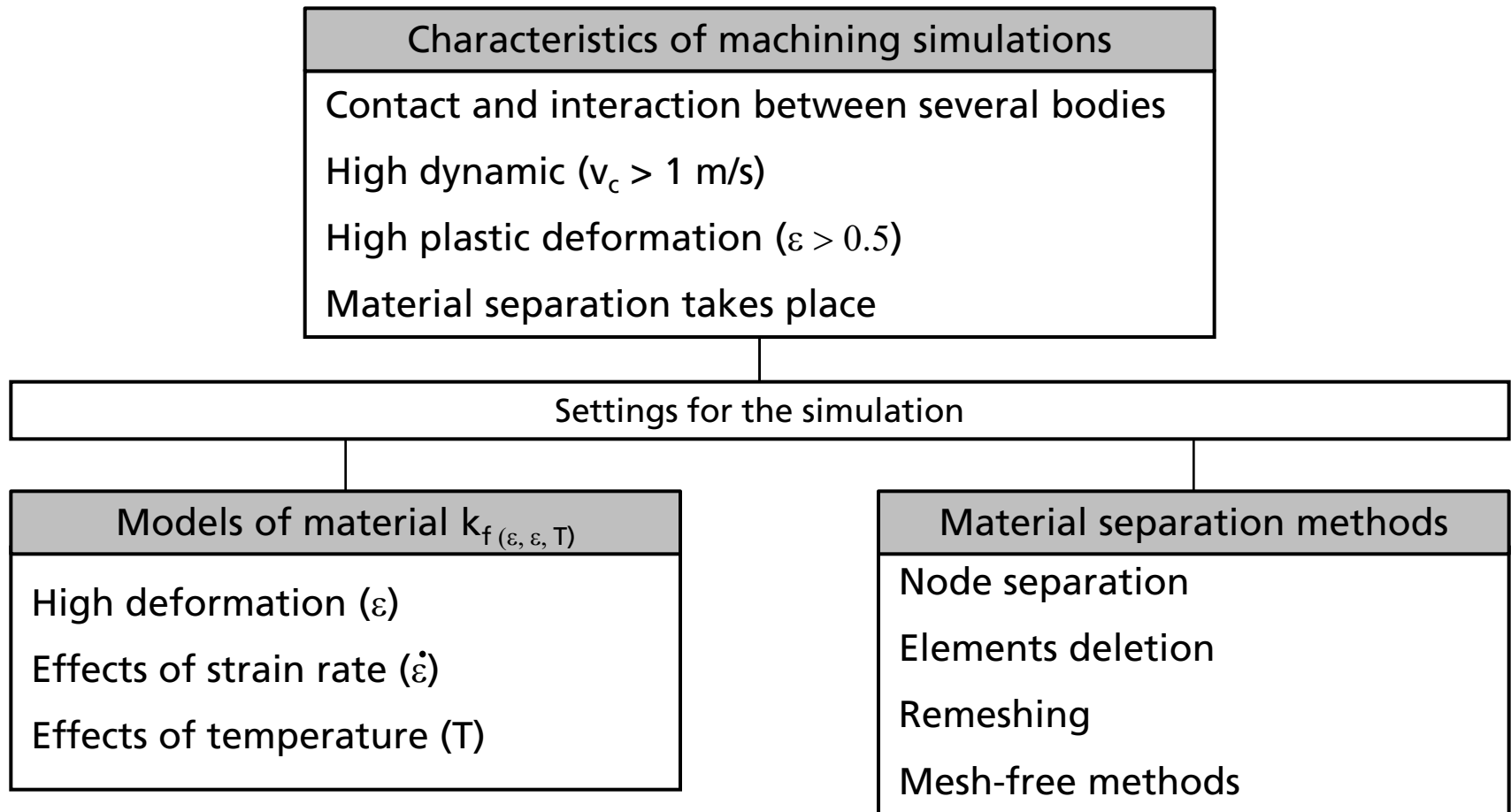
- Determination of the relationships between:
 - cutting and process parameters
 - stress, strain and temperature development inside the process



Approximation and close analysis of the high thermo-mechanical loading conditions inside the process

- Tool development through virtual experimentation

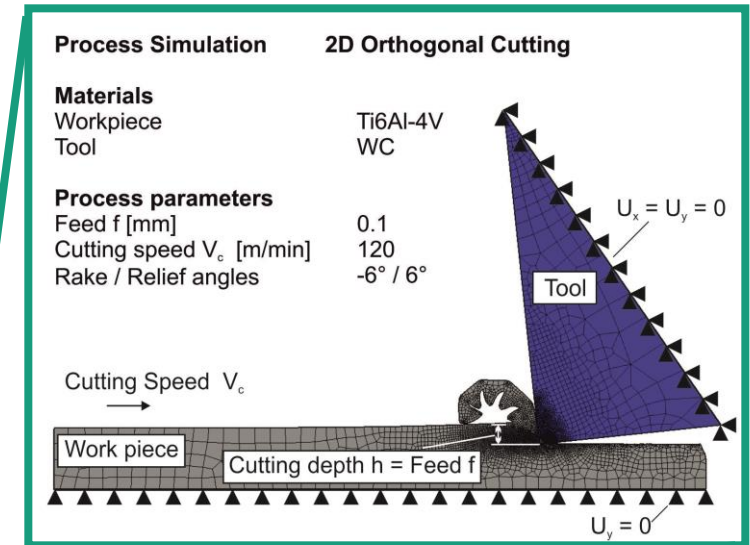
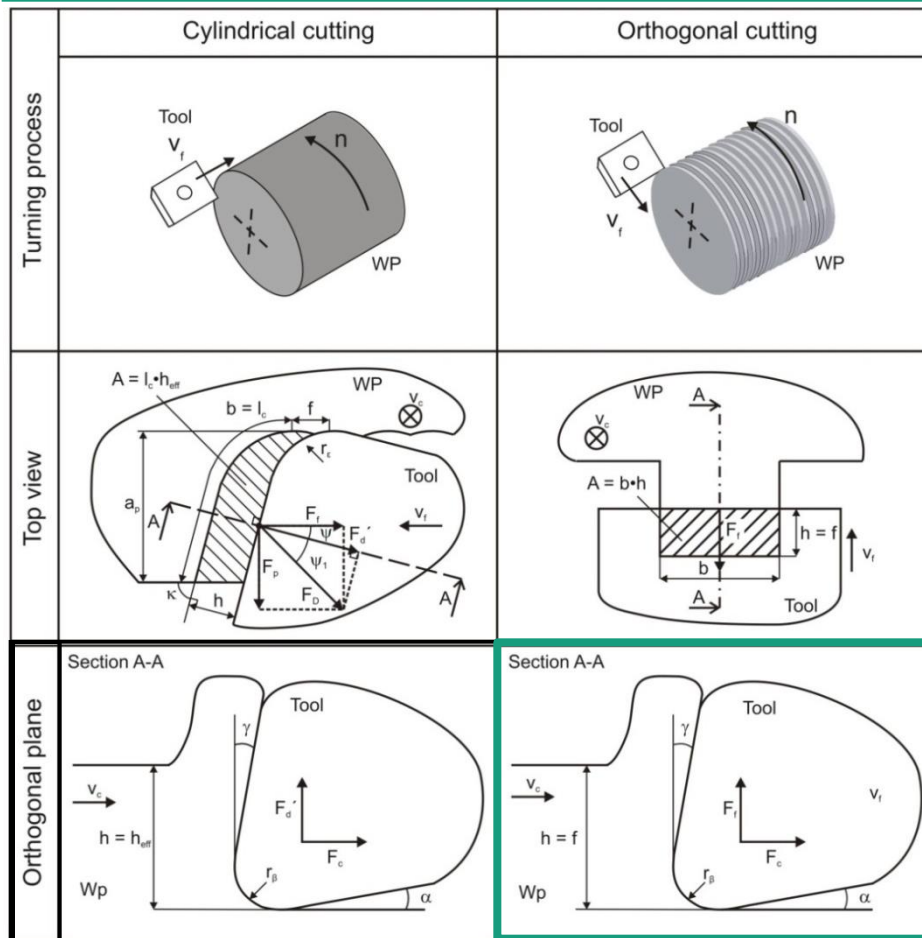
Main requirements in the simulation of machining processes



Alternative numerical methods in LS-Dyna

Mesh dependent	Mesh free		
FEM Finite element method • Discretization into a grid of finite elements • Element based connectivity • Requires additional separation or fracture formulations	SPH Smoothed particle hydrodynamics • Discretization through SPH-particles • Absence of an interconnected grid • A smoothing function defines an influence length and interaction strength between particles • Allows the modeling of solid and fluids	EFG Element free Galerkin • Mesh free principle • Weak formulation of the method has a higher order • Mesh supports contact and boundary conditions • The user interface in LS-Dyna for EFG is not fully implemented	DEM ...

Schematic representation of a turning process simulation



Representation of turning processes into 2D-FE-simulations

Design of a turning process simulation

Mechanical 3D-Simulation

■ Calculation methods: FEM / SPH / EFG

■ Software: LS-Dyna, version 7.1.1

■ Process : Orthogonal turning

■ Cutting distance: 0.85 [mm]

■ Termination time: 0.17 [ms]

■ Cutting tool

■ Material: Tungsten carbide (WC)

■ Element type: rigid shell elements

■ Number of elements: 16,500

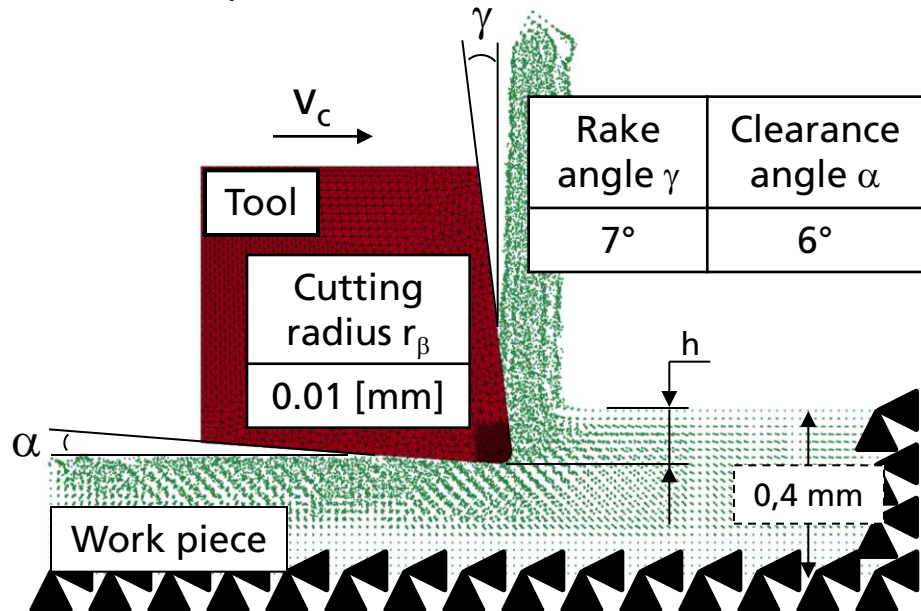
■ Smallest element size: 3 μm

■ Work piece

■ Material: Al7075

■ Material model: Plastic kinematic (MAT_003)

■ Process parameters



Cutting speed v_c	Cutting width b	Cutting depth h
300 [m/min]	0.25 [mm]	0.1 [mm]

Design of a turning process simulation

Simulation parameters

■ Parameters of the **FEM** simulations

- Element types: tetrahedral volume elements
- Number of elements//nodes: 30,000//50,000
- Smallest element size: 9 [μm]
- Separation: Adaptive remeshing

■ Parameters of the **SPH** simulations

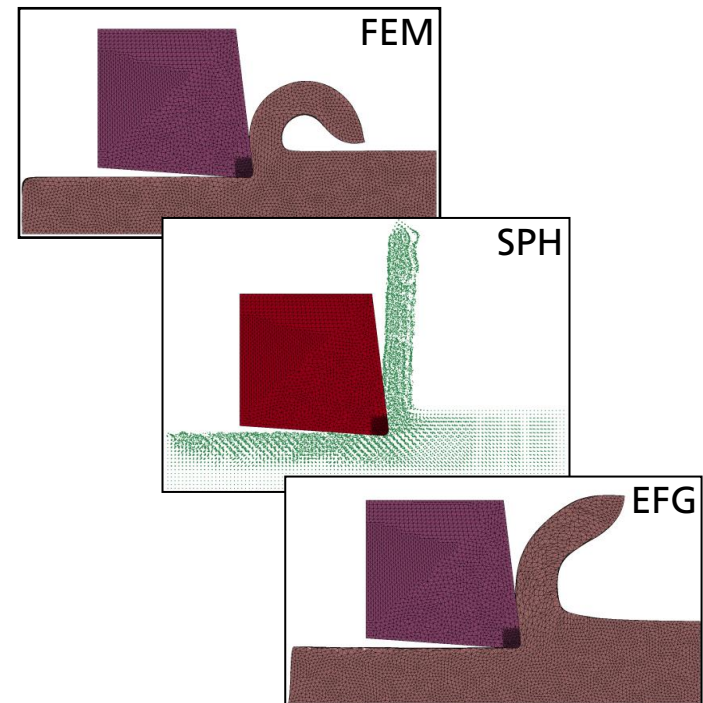
- Element types: SPH
- Number of particles: 40,000
- Separation: -none-

■ Parameters of the **EFG** simulations

- Number of elements//nodes: 30,000//50,000
- Smallest element size: 9 [μm]
- Separation: Adaptive remeshing

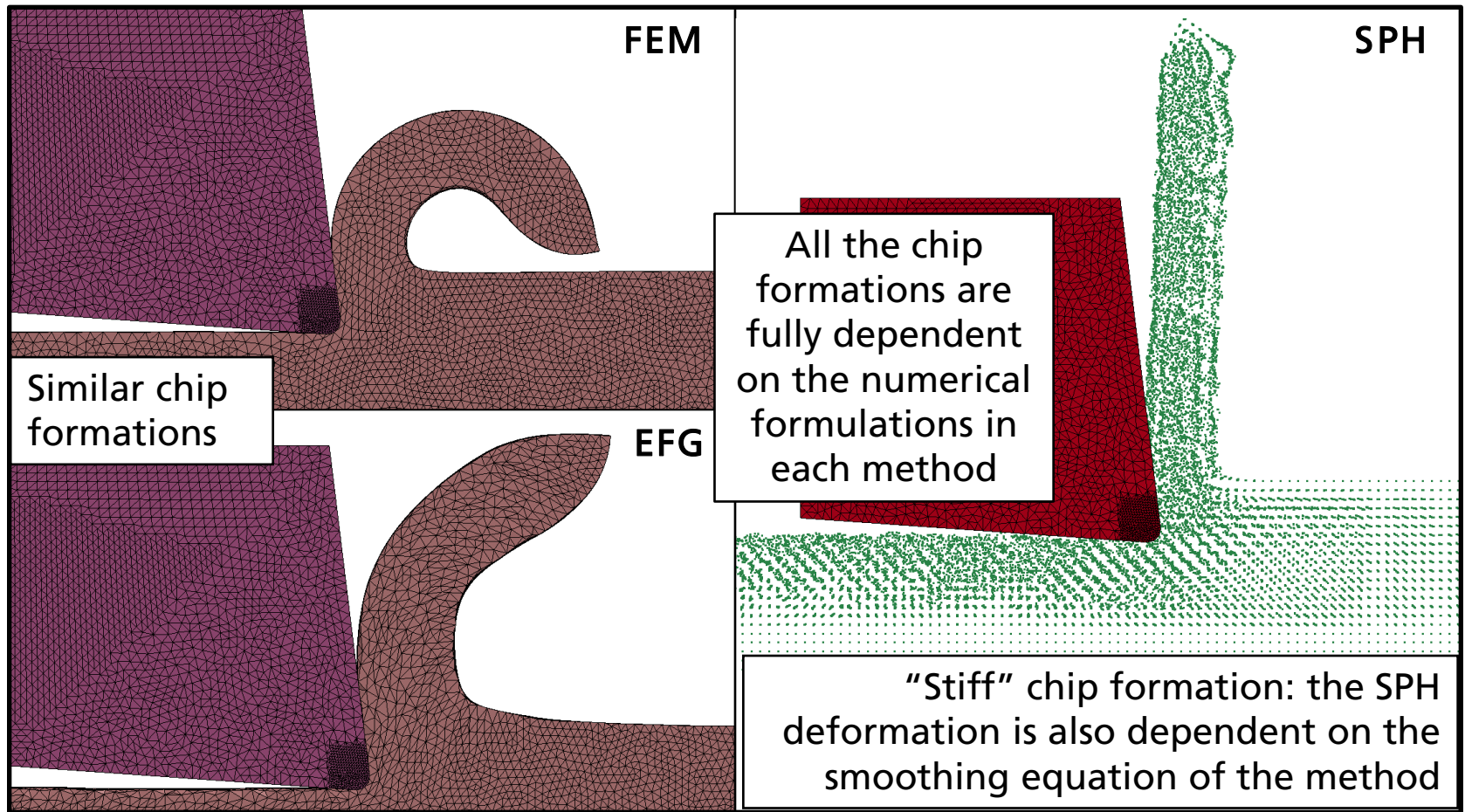
■ Interface properties

- Contact: nodes to surface
- Sliding friction coefficient: $\mu = 0.1$



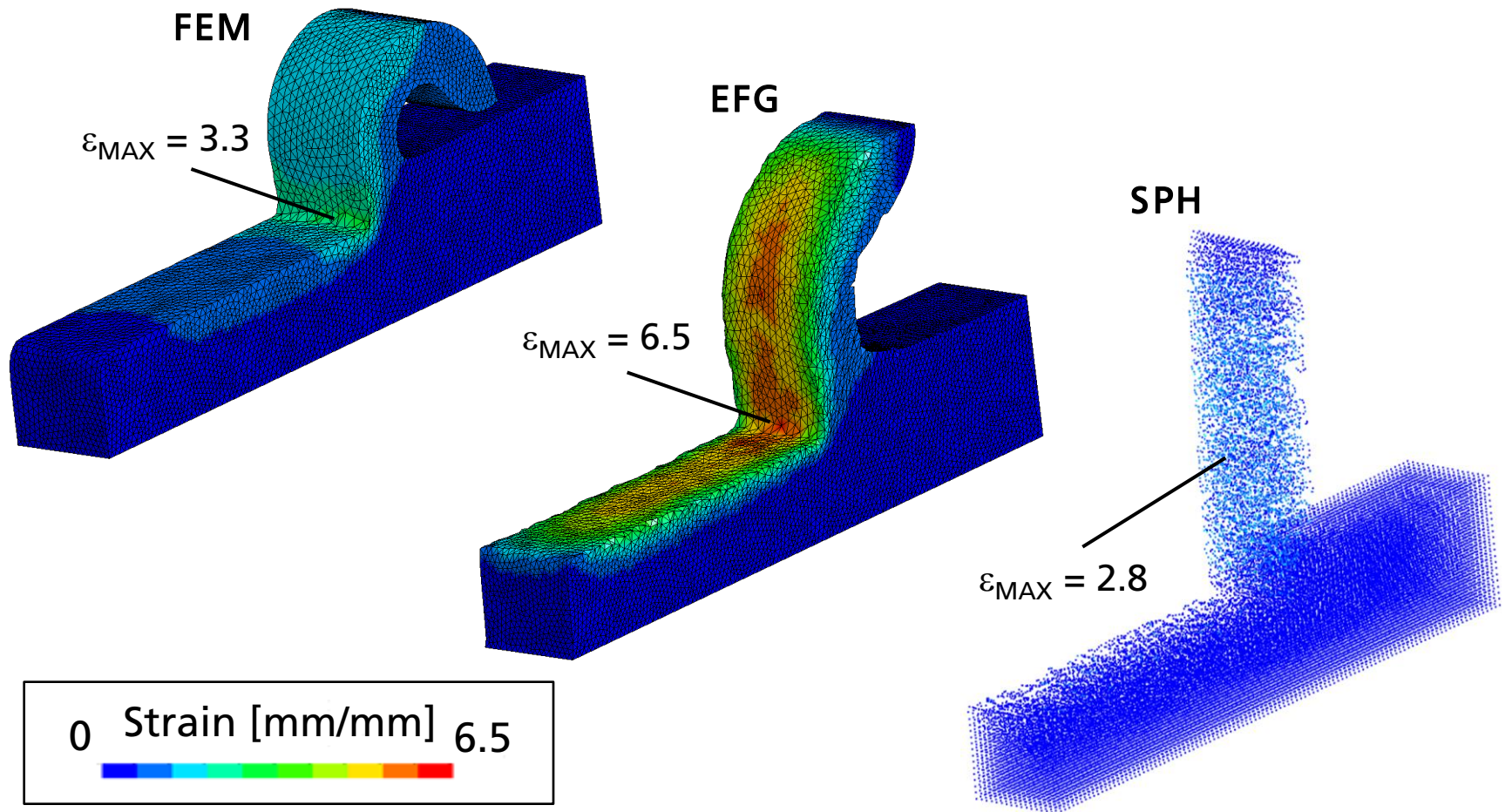
Comparison between FEM, EFG and SPH

Chip formation



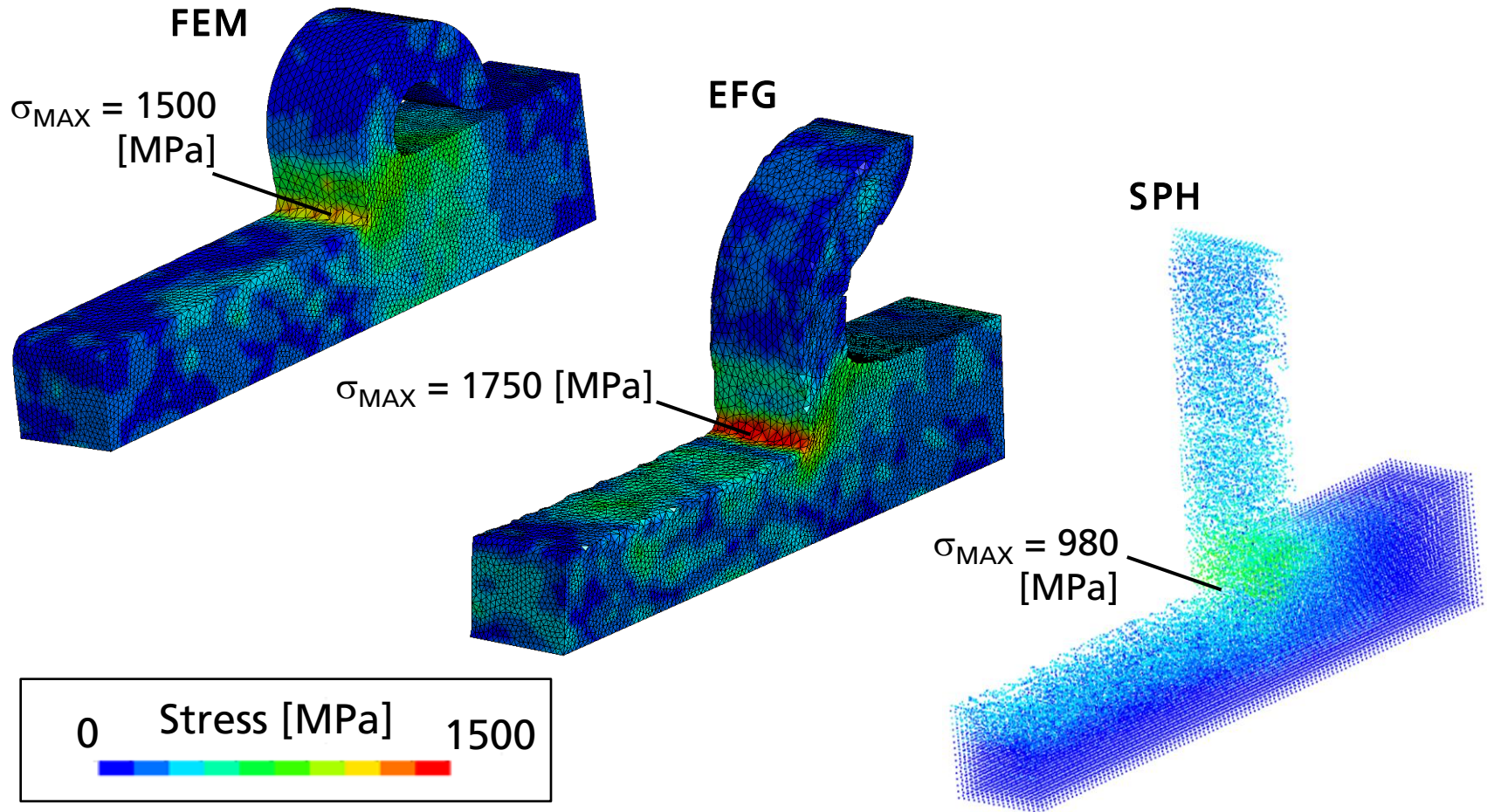
Comparison between FEM, EFG and SPH

Strain



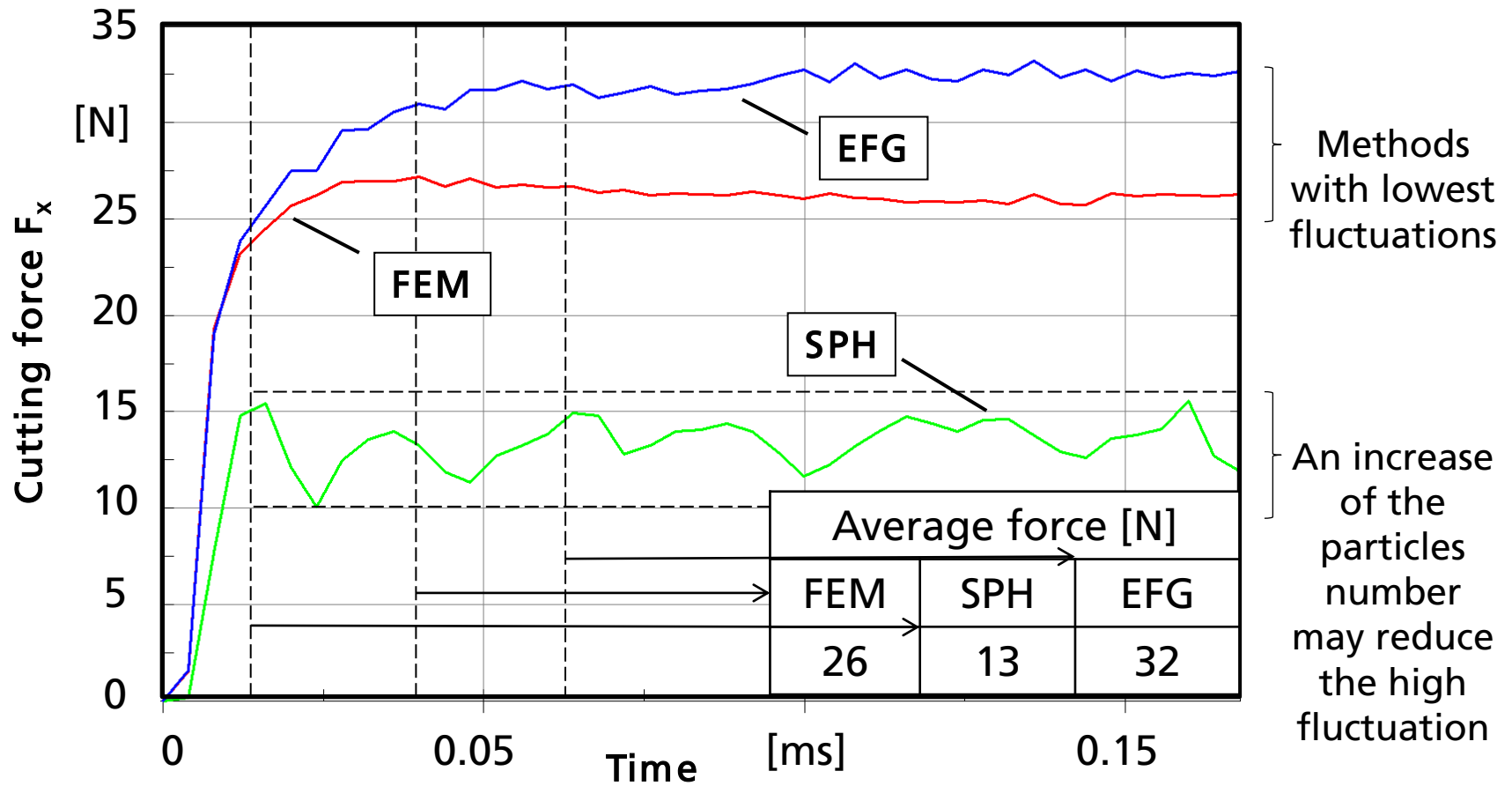
Comparison between FEM, EFG and SPH

Stress



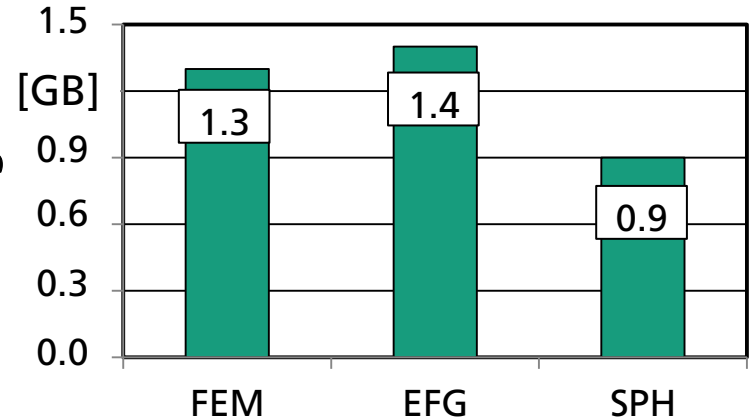
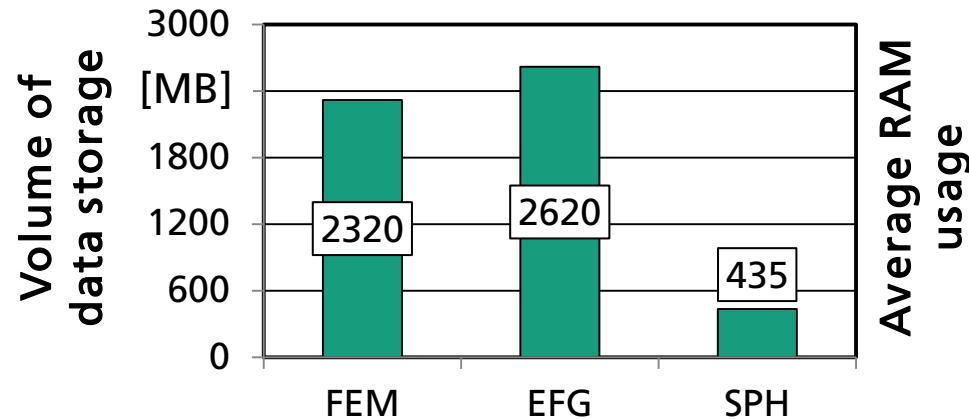
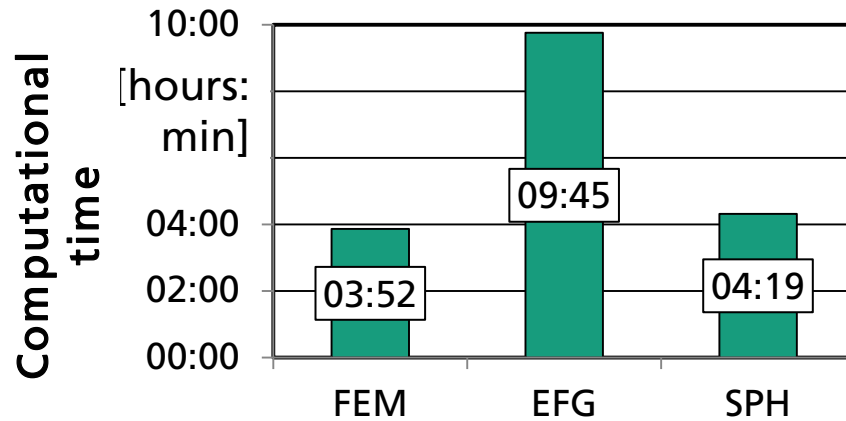
Comparison between FEM, EFG and SPH

Cutting force F_x



Comparison between FEM, EFG and SPH

Calculation time und memory usage



Comparison between FEM, EFG and SPH

Conclusions

	Good properties	Numerical error reports take place at the beginning		No need of separation criterion	Formulation equations of higher order
	Manageable environment	Stability # error reports	Manageability # configuration steps and cards	Theoretical precision	Field of application
	Rough environment				
Highest time and memory costs	FEM				General applications
	EFG				Analyses of deformation (chip formation)
	Lowest calculated values	SPH			
		Setup over the k-file		Dependency on the smoothing function	

Thank you for your attention!

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