PT1 SS 2024

Institute of Photonic Technologies

Lecturers:

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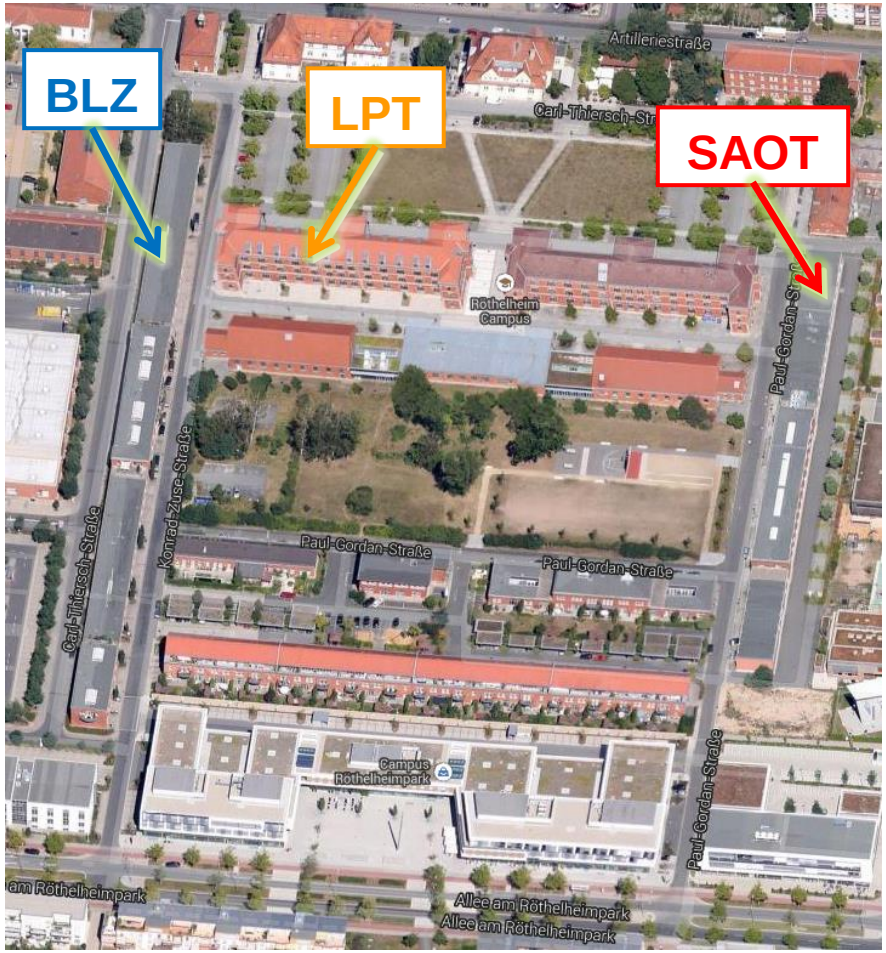
Institute of Photonic Technologies



Quelle: maps.google.de

Research at the LPT:

- Ultrashort Pulse Laser Technologies
- Simulation & Modeling
- Sensing, Control & Real-time Systems
- Photonics in Medical Engineering
- Additive Manufacturing

For more information:
www.lpt.uni-erlangen.de

Lectures at LPT

Lecture	Sem.	SWS	Lecturer
Produktionstechnik 1 / Production Technology 1	WS + SS	2	Prof. Dr.-Ing. Schmidt
Optik und optische Technologien	WS	2	Prof. Dr.-Ing. Schmidt
Lasertechnology	WS	4	Prof. Dr.-Ing. Schmidt/ Dr. Kristian Cvecek/
Laserbasierte Prozesse in Industrie und Medizin	SS	4	Prof. Dr.-Ing. Schmidt
Lasersystemtechnik 1	WS	2	Hon.-Prof. Dr.-Ing. Hoffmann
Lasersystemtechnik 2	SS	2	Hon.-Prof. Dr.-Ing. Hoffmann
Laser in der Mikroproduktionstechnik	SS	1	Prof. Dr.-Ing. Schmidt
Laser in der Medizintechnik	WS	2	Dr.-Ing. Glasmacher
Licht in der Medizintechnik	WS	4	Dr.-Ing. Klämpfl
Lasers in Healthcare Engineering	WS	2	Dr.-Ing. Klämpfl
Laser Tissue Interaction	SS	4	Dr.-Ing. Klämpfl
Photonics in Medical Engineering	WS	4	Dr.-Ing. Klämpfl
Topics of Optical Technologies	WS	2	Silvana Burger, M.Sc.

Schedule Lectures

Day	Lecture unit
24.06.2024 (Prof. Schmidt)	LU05 – Water Jet + Plasma Beam
01.07.2024 (Dr. Cvecek)	LU06 – Electron Beam
08.07.2024 (Dr. Cvecek)	LU07 – Laser based Joining + Cutting
15.07.2024 (Prof. Schmidt)	LU08 – Additive Manufacturing

Lectures are available via StudOn

Schedule Lectures

Day	Lecture unit
26.06.2024	EX05 – Water Jet + Plasma Beam
03.07.2024	EX06 – Electron Beam
10.07.2024	EX07 – Laser based Joining + Cutting
17.07.2024	EX08 – Additive Manufacturing

Exercises on-site from 08:15 am to 09:45 am at lecture room H14
Additionally exercises are available via StudOn

Literature

[1] Hügel, Helmut ; Graf, Thomas: *Laser in der Fertigung* : *Strahlquellen, Systeme, Fertigungsverfahren*. 2., neu bearbeitete Auflage. Wiesbaden : Vieweg+Teubner, 2009

[2] Ion, John C.: *Laser processing of engineering materials* : *Principles, procedure and industrial application*. Amsterdam, s.l. : Boston, 2005

[3] Poprawe, Reinhart: *Lasertechnik für die Fertigung* : *Grundlagen, Perspektiven und Beispiele für den innovativen Ingenieur ; mit 26 Tabellen*. Berlin : Springer, 2005 (VDI-Buch)

[4] Schultz, H.: *Electron beam welding*. Cambridge : Woodhead Publishing Ltd, 1994

[5] Schultz, Helmut: *Elektronenstrahlschweißen* : *Grundlagen, Maschinen und Anwendungen*. 3., vollständig überarbeitete und erweiterte Auflage. Düsseldorf : DVS Media, 2017 (Fachbuchreihe Schweißtechnik Band 93)

[6] Steen, William M. ; Mazumder, Jyotirmoy: *Laser material processing*. 4th Edition. London : Springer-Verlag London, 2010

[7] Wang, Jun: *Abrasive waterjet machining of engineering materials*. Zürich : Trans Tech Publ, 2003 (Materials science foundations 19)

Lecture Unit 05

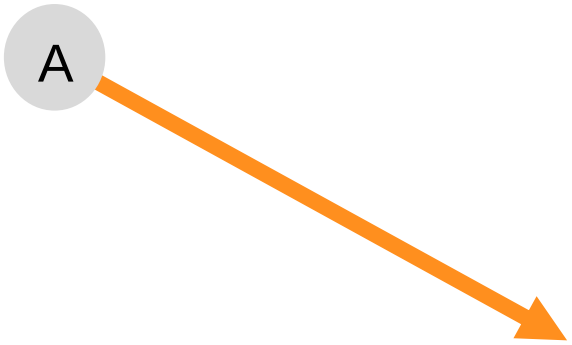
Beam Processing Tools
Water Jet & Plasma Jet/Arc

Beam Processing Technologies within DIN 8580

Primary Shaping	Forming	Cutting	Joining	Coating	Change of mat. prop
PBF-EB/M	Laser Bending	Water Jet Cutting	Electron Beam Welding	DED-LB/M	Hardening
PBF-LB/M		Laser Beam Cutting	Laser Beam Welding		VPP
DED-LB/M		Laser Beam Drilling	Plasma-beam-welding		
		Electron Beam Drilling			

Beam definition:

- Straight line, limited on one side, propagating to infinity on the other side
- Starting from a point A moving into a defined direction



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In reality: finite beam diameter, beam divergence, absorption and beam drift

Beam Processing Tools: Introduction

Examples for beam processing tools

Water Jet

© Koppe

Electron Beam

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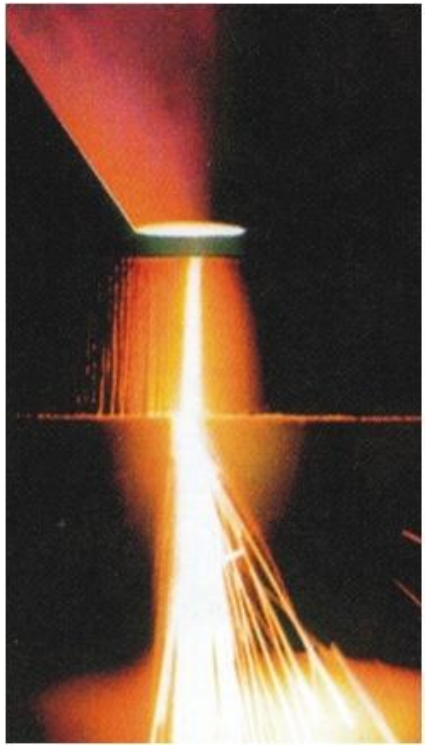
Laser Beam



Plasma Jet

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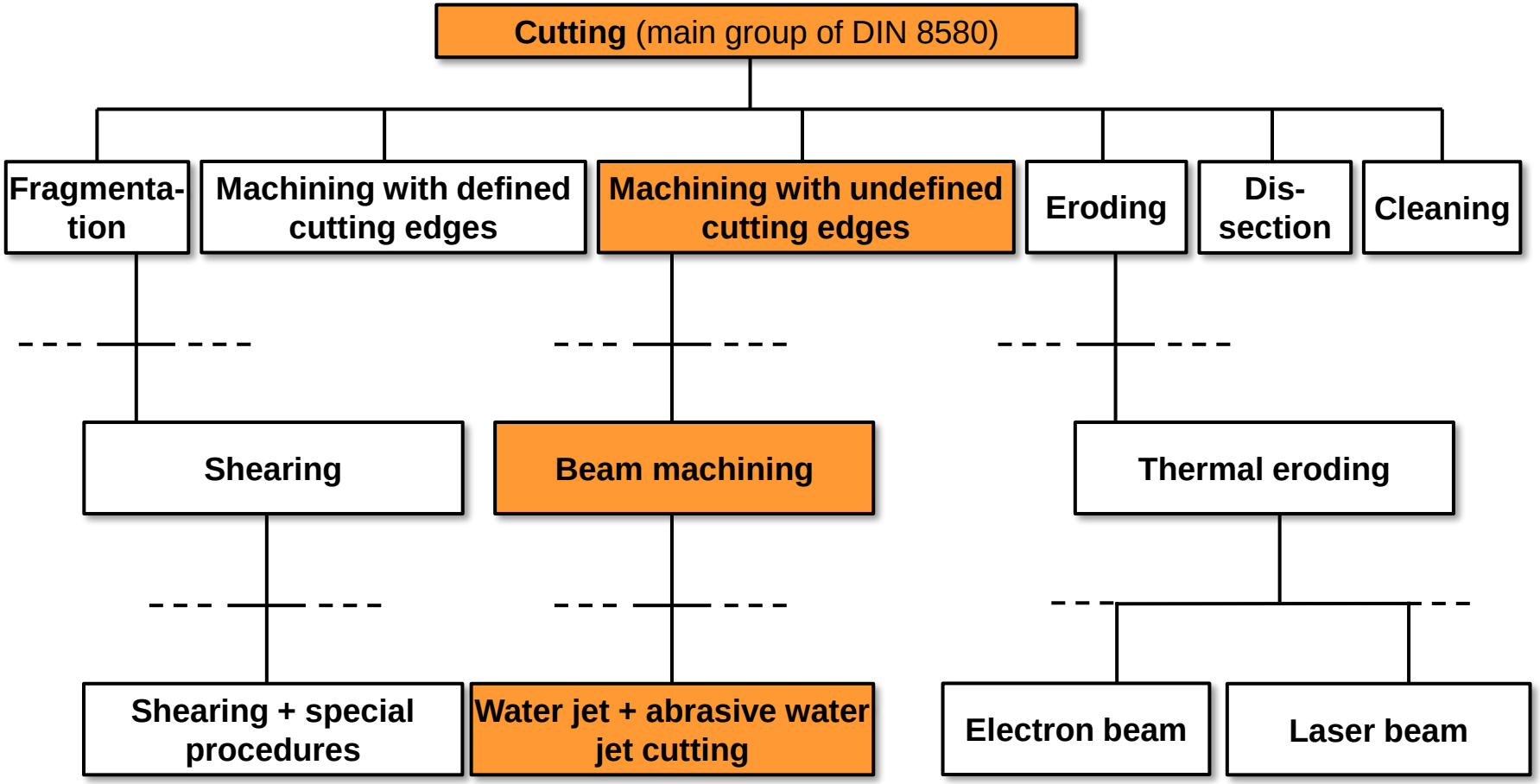
Water Jet

Classification of Water Jet Cutting according to DIN 8580



Water Jet: Basics

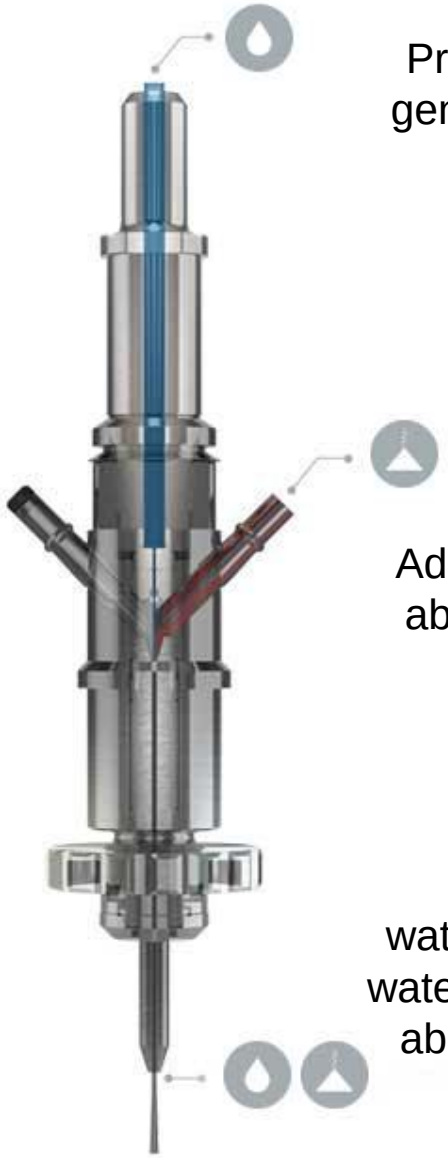
Basics:

- Generation of a water jet with high pressure (up to 6,500 bar) using high pressure pump
- Transformation of pressure into velocity using gemstone nozzles
- Addition of abrasive substances for improved cutting performance

→ differentiation between water jet and abrasive water jet

- Generation of high sound pressures depending on the exit velocity of the water

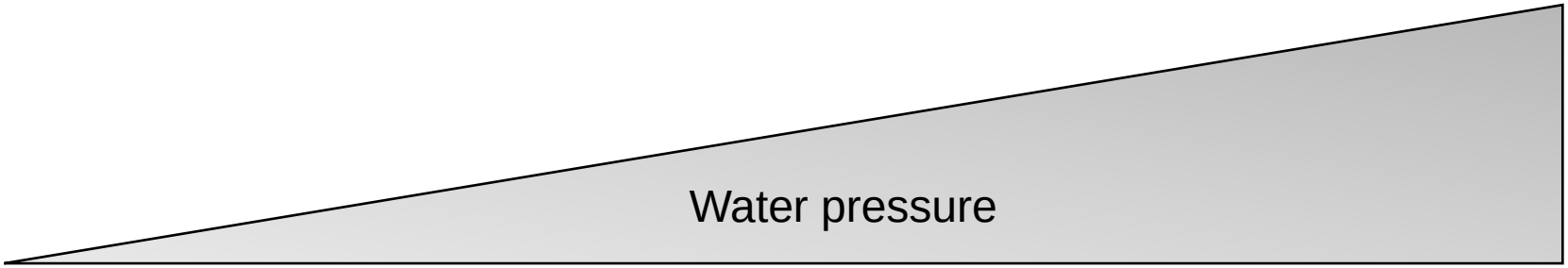
→ Noise reduction by processing underwater



flowwaterjet.de

Water Jet: Interaction with Matter

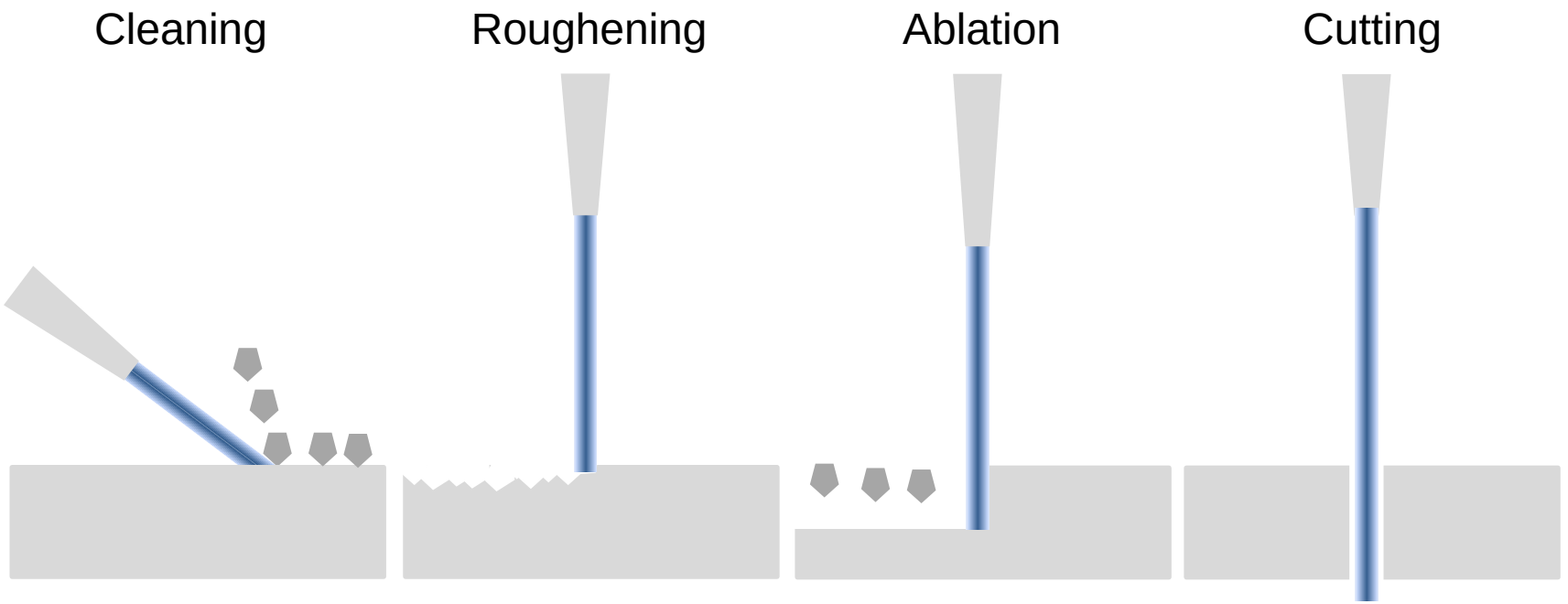
Water jet as a processing tool

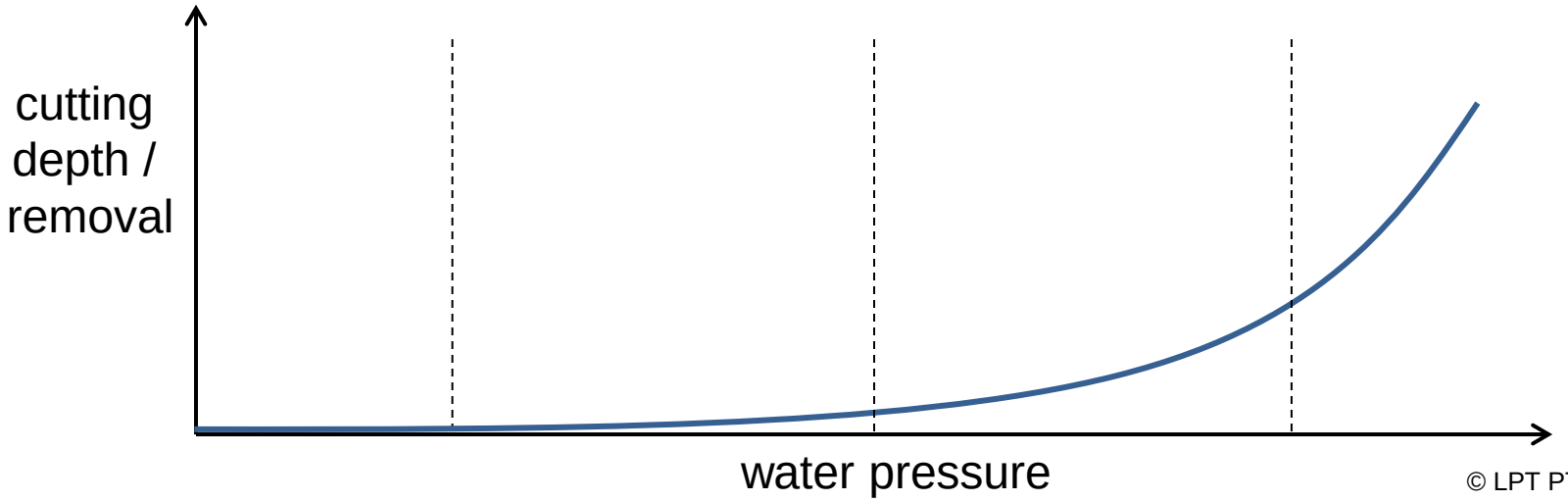


cleaning (100-500 bar) cutting (1500-6000 bar)

- High pressure → high jet velocity → high kinetic energy
- Energy of the water jet is adjusted according to the field of application
- Pure water jet is limited to processing of soft materials: paperboard, textiles, foamed material, rubber, leather

Water Jet: Effects

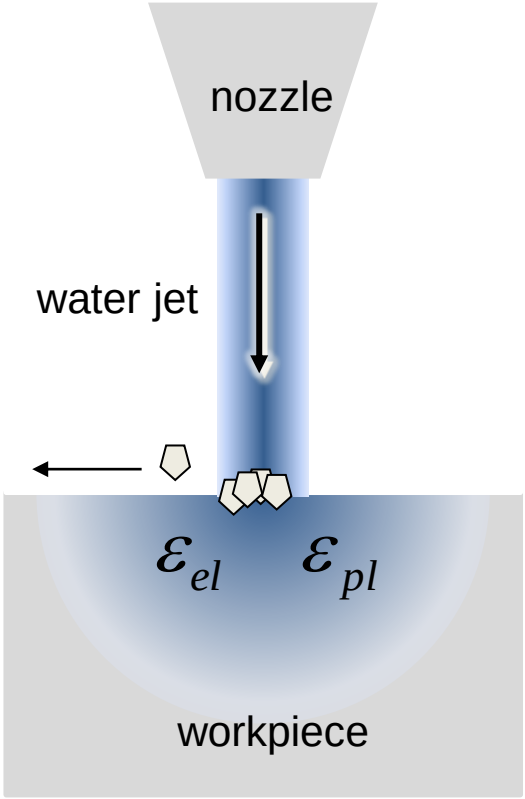




Water Jet: Interaction with Matter

Interaction of the water jet with matter
(at very high pressure)

- The water jet hits the surface of the workpiece with high pressure
- Generation of mechanical stress in the material
- Transition from elastic to plastic deformation
- Locally limited destruction of the workpiece surface
- Ablation of microscopically small workpiece particles
- Jet penetrates into the workpiece



Water Jet Cutting with Pure Water

- Kinetic energy of the water jet is used for cutting
- Exit speed of the water:
  up to 850 m/s
- Nozzle diameter: 0.1…0.35 mm
- Operating pressure at 6200 bar
  → sterility of the water due to the high water pressure
- Cutting speed ~200 m/min (paper)
- Applied for cutting soft materials, food or used as water scalpel

Pure water cutting head

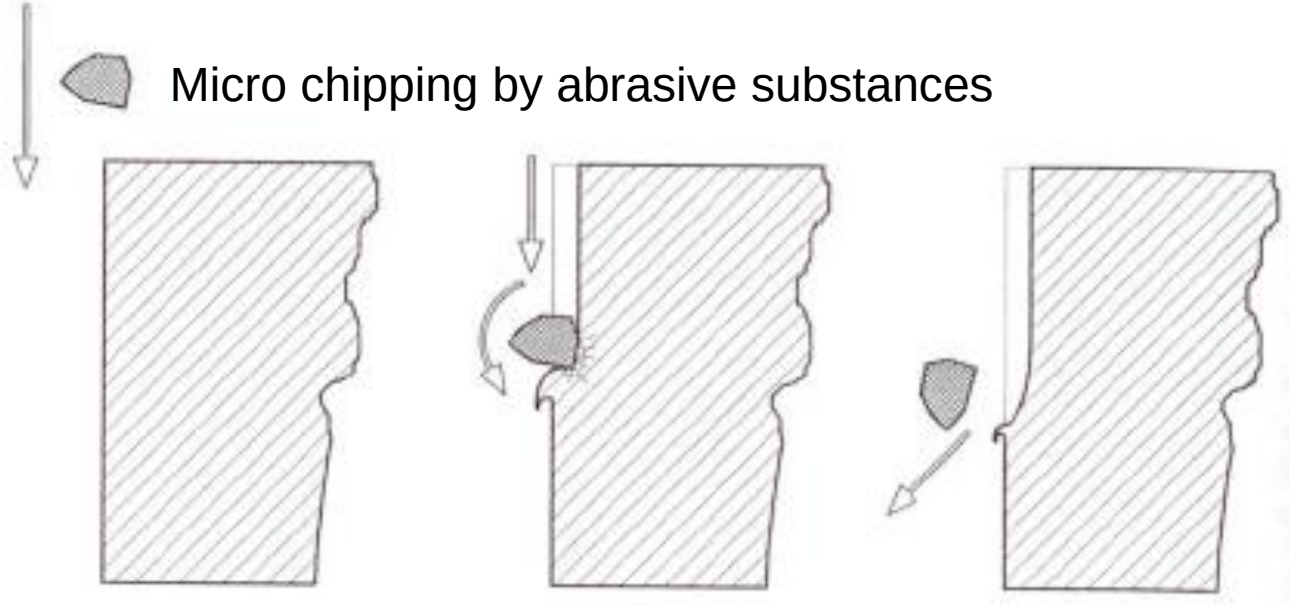
Water jet with abrasive substances

Addition of solid particles (abrasive substances) to the water jet

→ Abrasive Waterjet:
Water jet as carrier medium for acceleration of particles

→ Increase of material ablation by the abrasive effect of the particles

Micro chipping by abrasive substances



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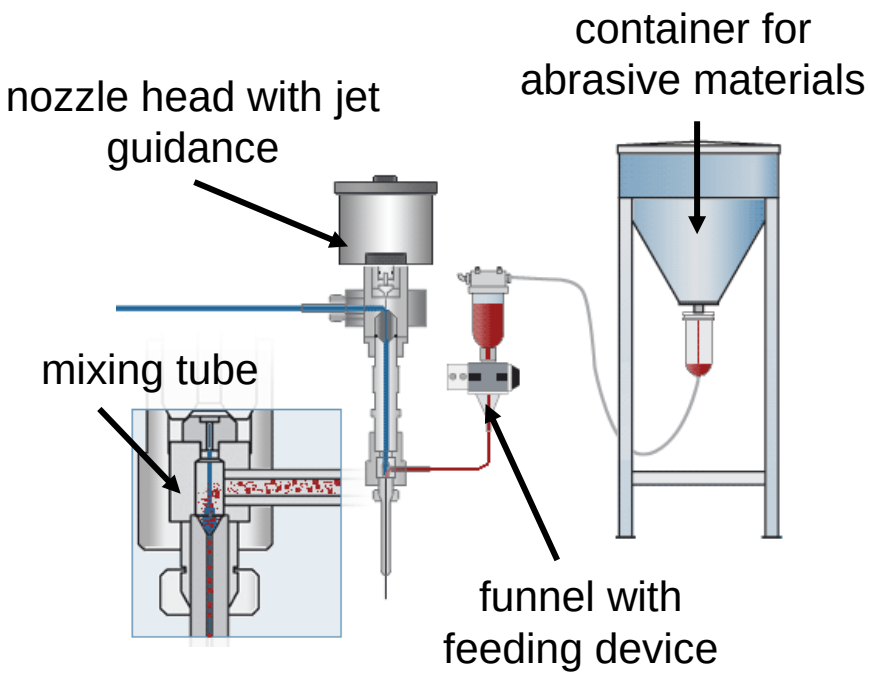
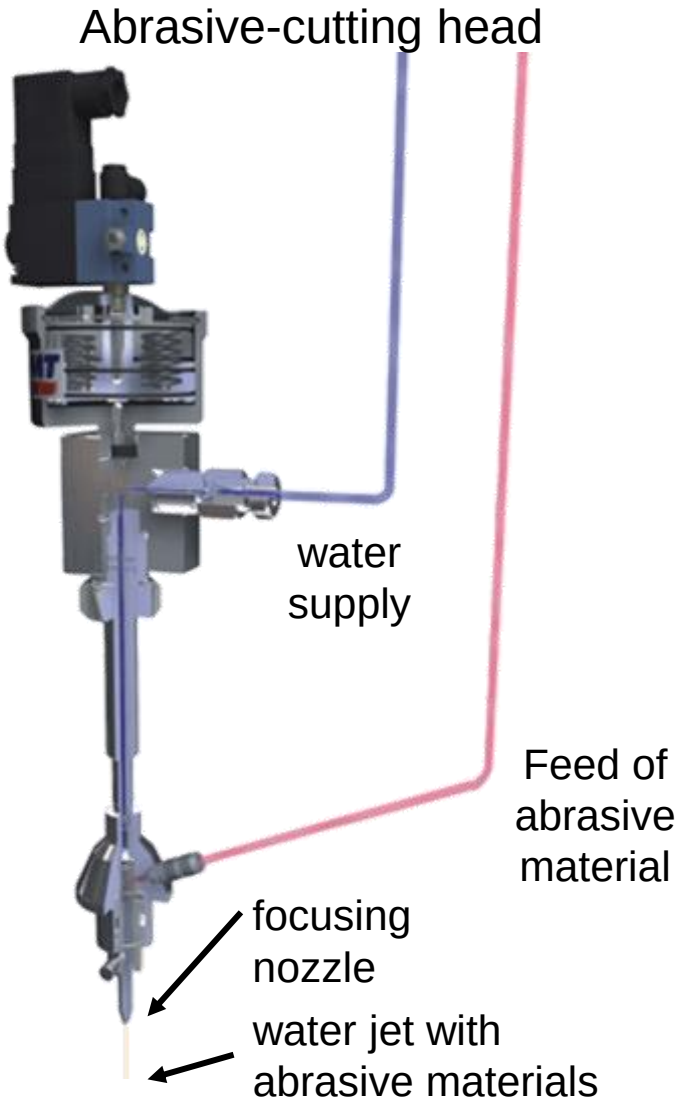
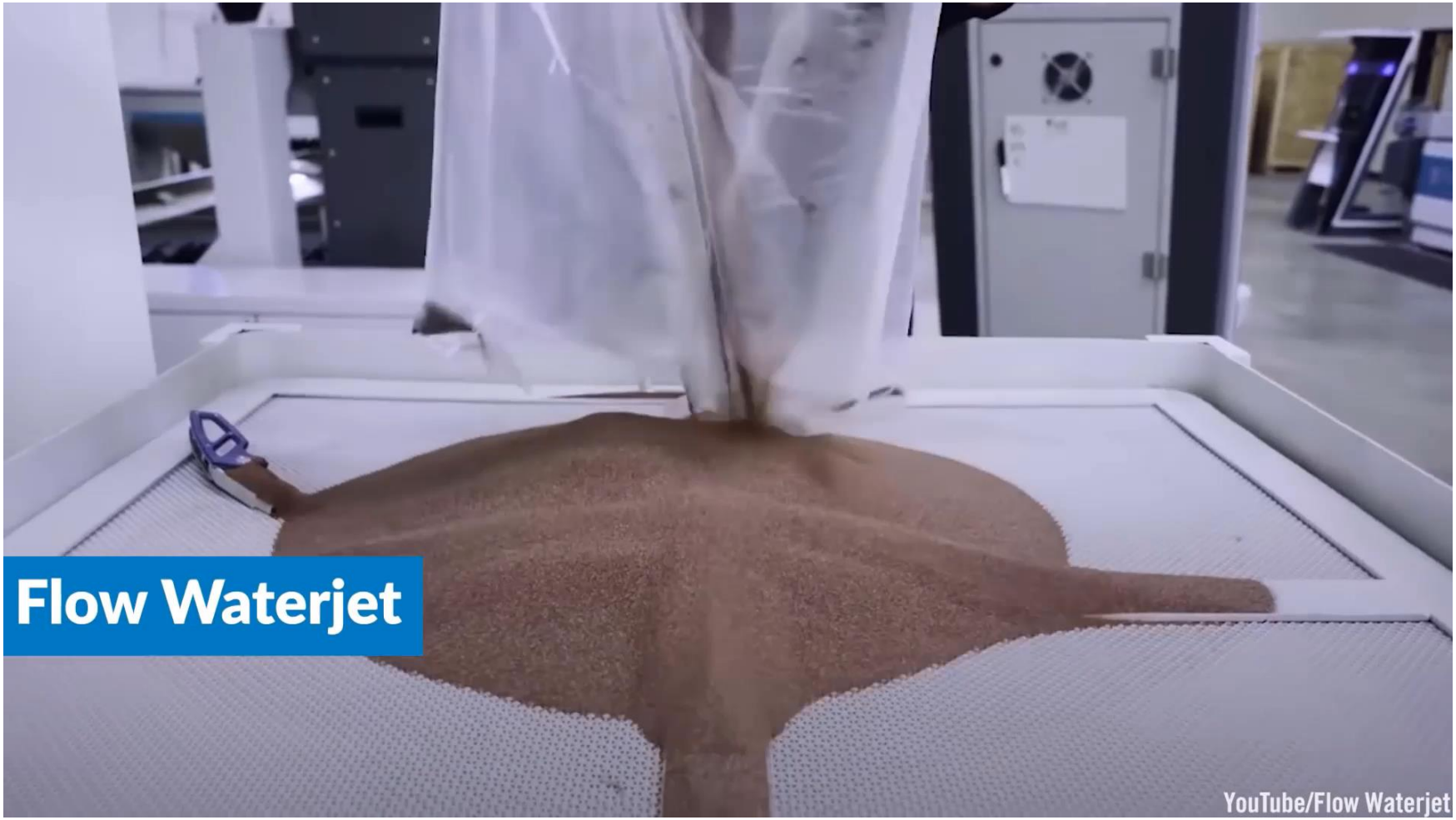
Water Jet Cutting with Additional Particles

- Addition of abrasive materials: granite, olivine, corundum
  → Increase of the cutting power
- Beam diameter: 1 mm
- Operating pressure at 6200 bar
- Application for hard materials: e.g. metal, stone





Water Jet Cutting



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Live-Survey

The use of additives extends the maintenance intervals of water jet cutting systems.

a) true

b) wrong

Result

Water Jet Cutting: Cutting Speed

Cutting speed depends on:

- material thickness
- material
- desired quality
- concentration of abrasive materials
- water pressure

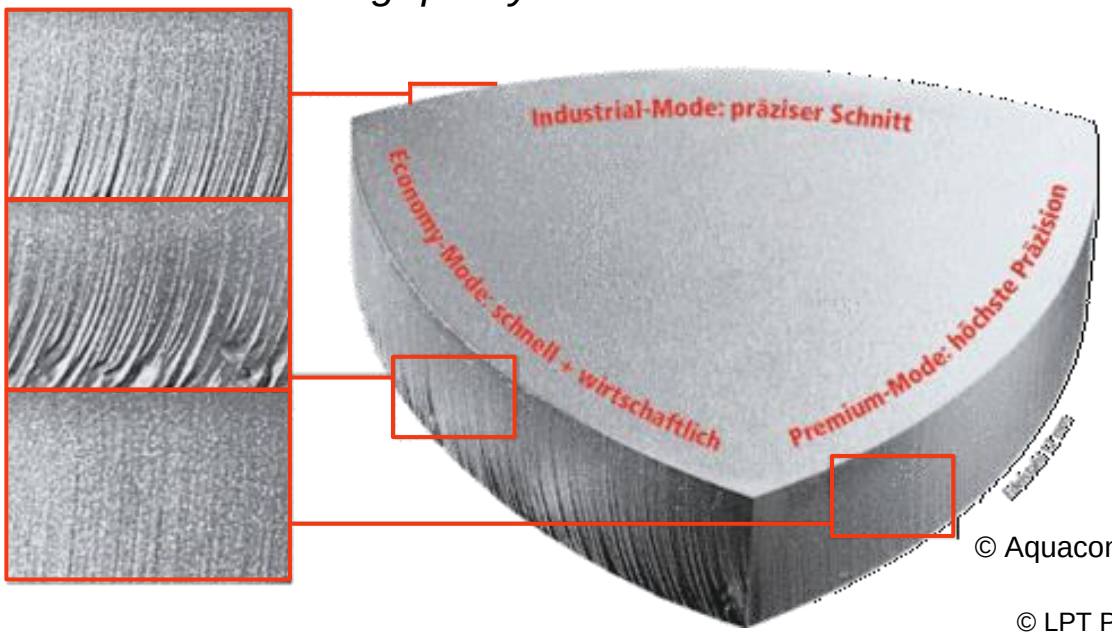
material thickness	Steel (mm/min)	Brass (mm/min)	Marble (mm/min)
2 mm	2800	3300	14500
5 mm	1010	1150	5050
20 mm	205	235	1025
100 mm	32	37	160

maximum cutting speed at 3800 bar and normal cutting quality in mm/min

Industrial Mode:
precise cutting

Economy Mode:
fast & economical

Premium Mode:
highest precision



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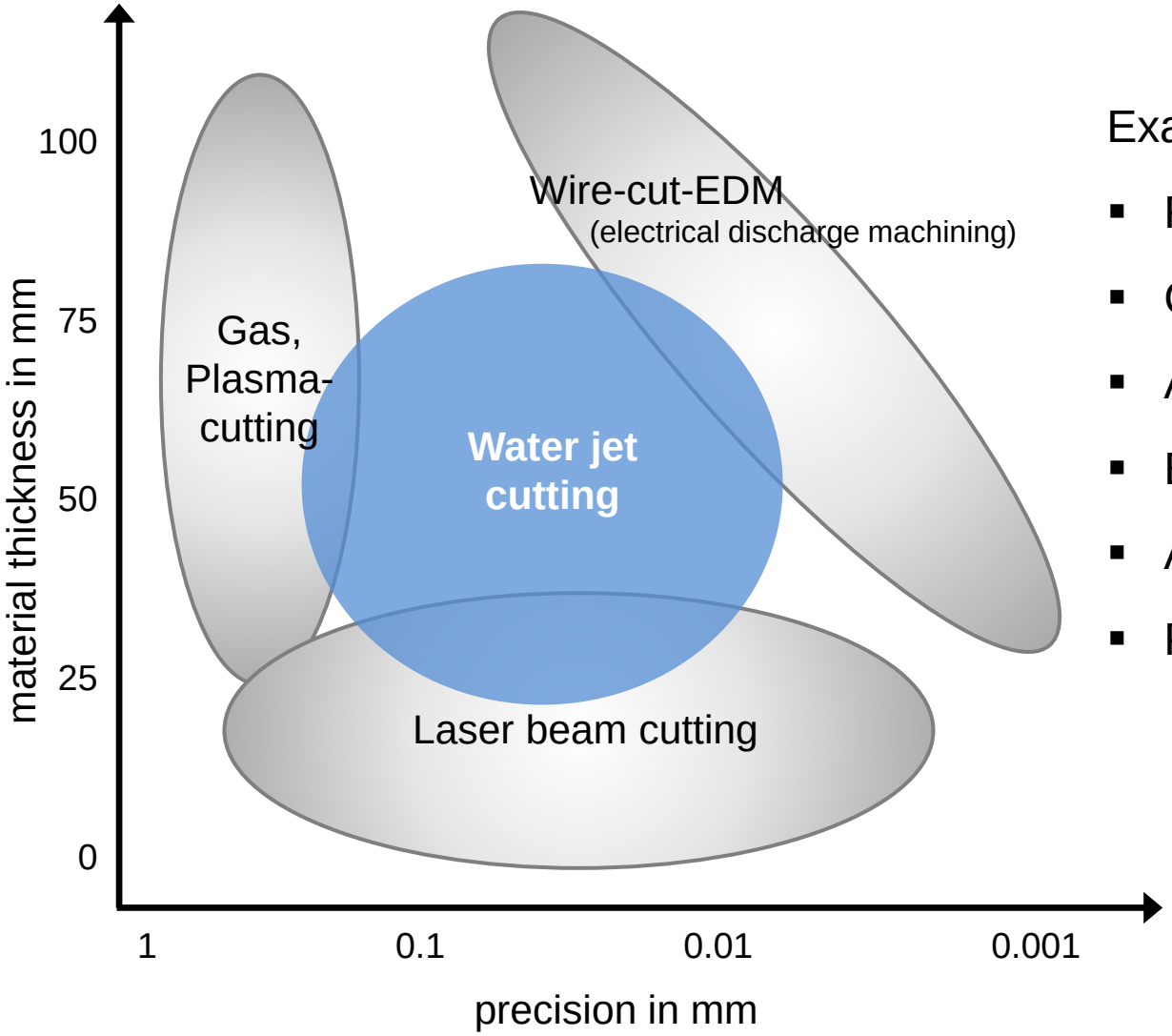
Water Jet: Fields of Application

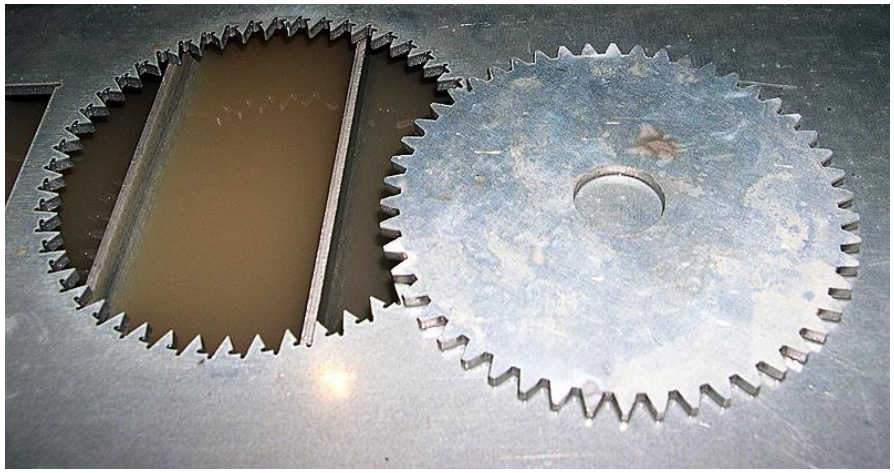


Examples:

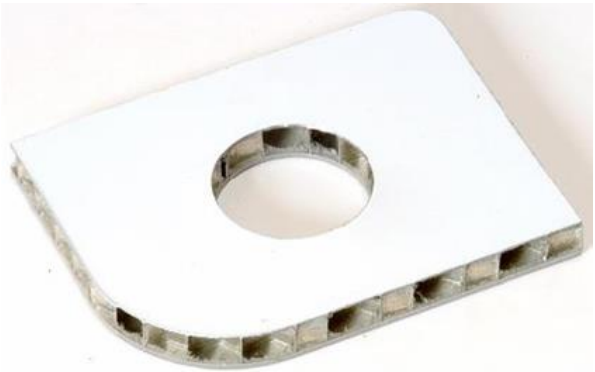
- Food industry
- Consumer industry
- Aircraft industry
- Electrical industry
- Automotive industry
- Plant construction

Water Jet Cutting: Applications (1)

Gear



Aluminium honeycomb fabric
(Alucore 7 mm)



Granite

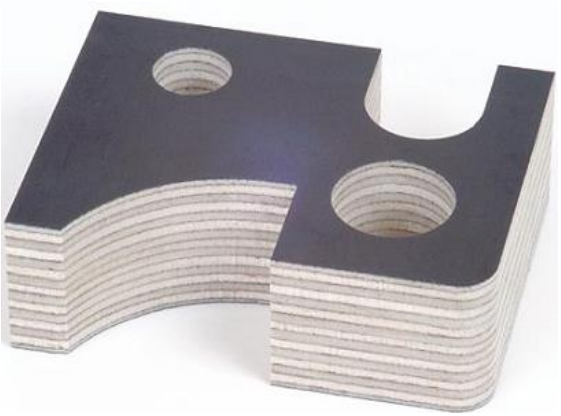
Object made of stone

Water Jet Cutting: Applications (2)

Carbon-fiber-mats

Coupling tube
CFK-Aluminium 7 mm

Composite
Laminated wood 50 mm



Foam

Variety of Material

High variety of materials:

- Steel, stainless steel, aluminium
- Ceramic, glass und armored glass
- Stone, e.g. granite and marble
- Plastics (fiber reinforced plastic, thermoplastic and duroplastic)
- Rigid and flexible foam
- Insulating materials
- Sandwich- and structural material
- Wood, paper und paperboard
- Sealant, e.g. rubber and hard tissue

Advantages of a Water Jet as Processing Tool

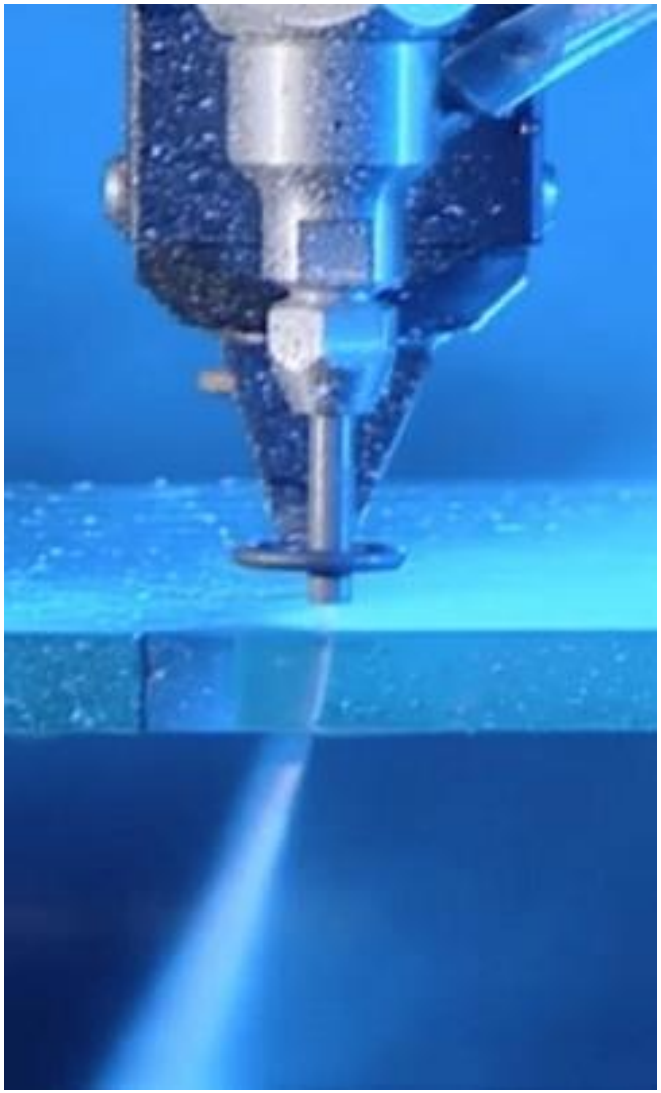
Advantages

- Environmental friendliness

  → No generation of vapour, dusts or fume
- Lower thermal influence on the workpiece compared to mechanical or fusion based cutting

  → No micro cracks or change in microstructure
- Water jet as wearless processing tool
- Lower processing forces compared to mechanical cutting

  → Cutting of pressure-sensitive materials
- Beam dimension smaller with respect to typical cutting widths of mechanical cutting
- Clean and accurate cutting edges / no formation of burrs



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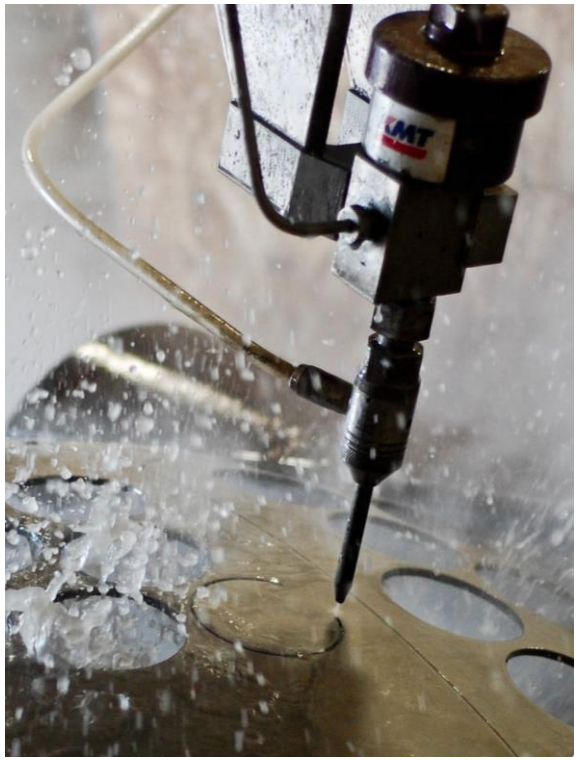
Disadvantages of a Water Jet as Processing Tool

Disadvantages

- Limited precision, no deflection or guidance of the water jet
- Relatively low ablation rate
  - → Lower feed rates than for laser beam cutting
  - → Decreases with hardness, ductility and thickness of the material
  - → no mass production
- Higher maintenance costs compared to laser beam cutting due to wear of nozzles
- Additional costs due to consumption of abrasive material
- Direct water contact of material (corrosion)
  → not suitable for materials susceptible to corrosion



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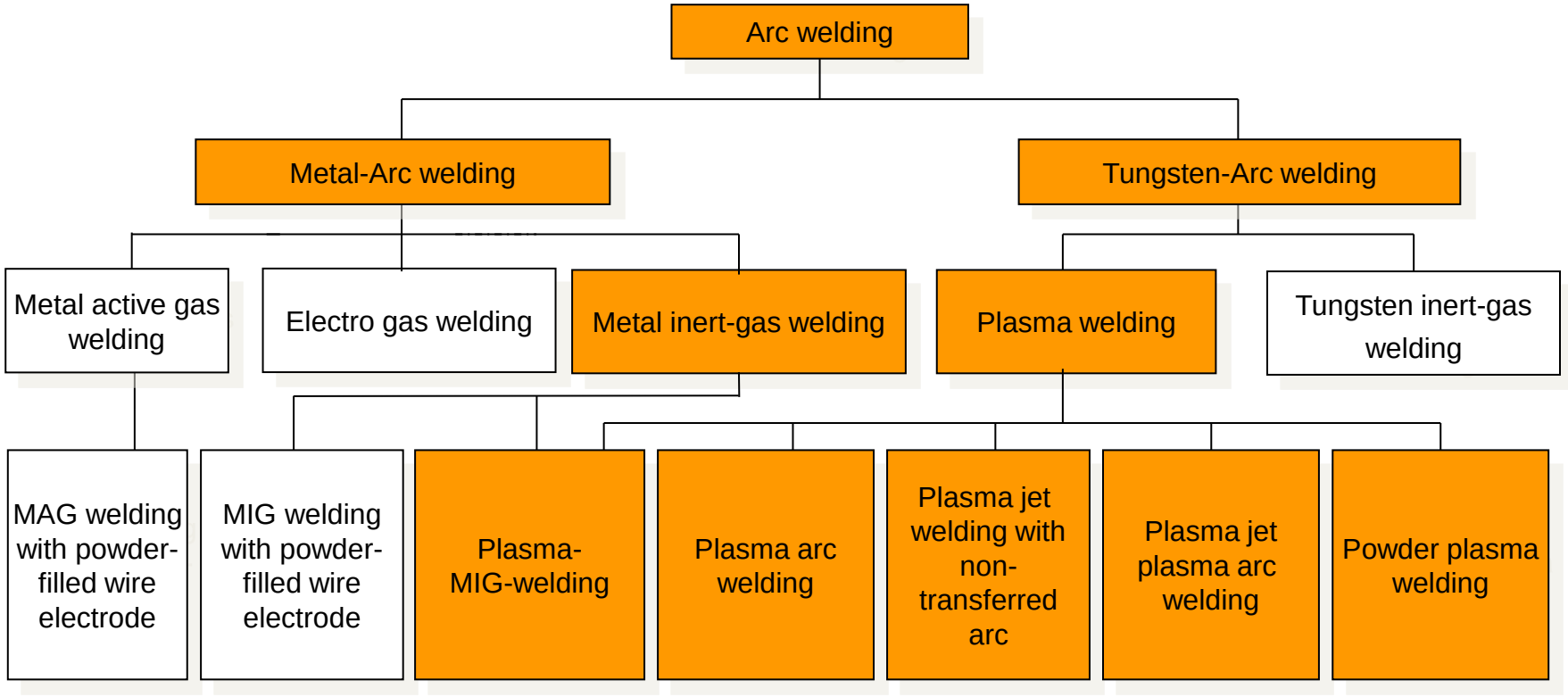
Plasma Jet

Classification of Plasma Welding according to DIN 1910 - 100



Plasma: Basics

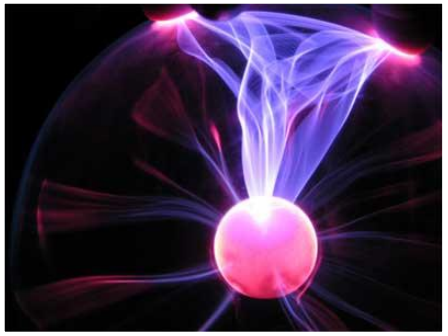
Definition of Plasma

- Absorption of energy leads to ionization of gas atoms
- Electrically conducting gas of electrons and ions

  → if not completely ionized also atoms and molecules
- High kinetic energy of the plasma (ions/electrons)
  → recombination of ions and electrons possible but the plasma is preserved due to new ionizations (dynamic process)

  → Emission of electromagnetic radiation (light) when electron and ion recombine
- No permanent recombination of ions and electrons

  → electrically conducting, while electrically neutral to the outside since equal number of ions and electrons
- When a voltage is applied electrons / ions are accelerated towards the anode / cathode



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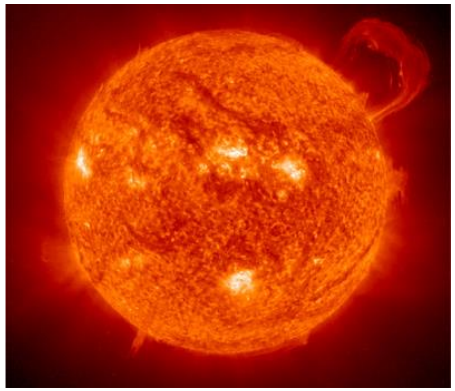

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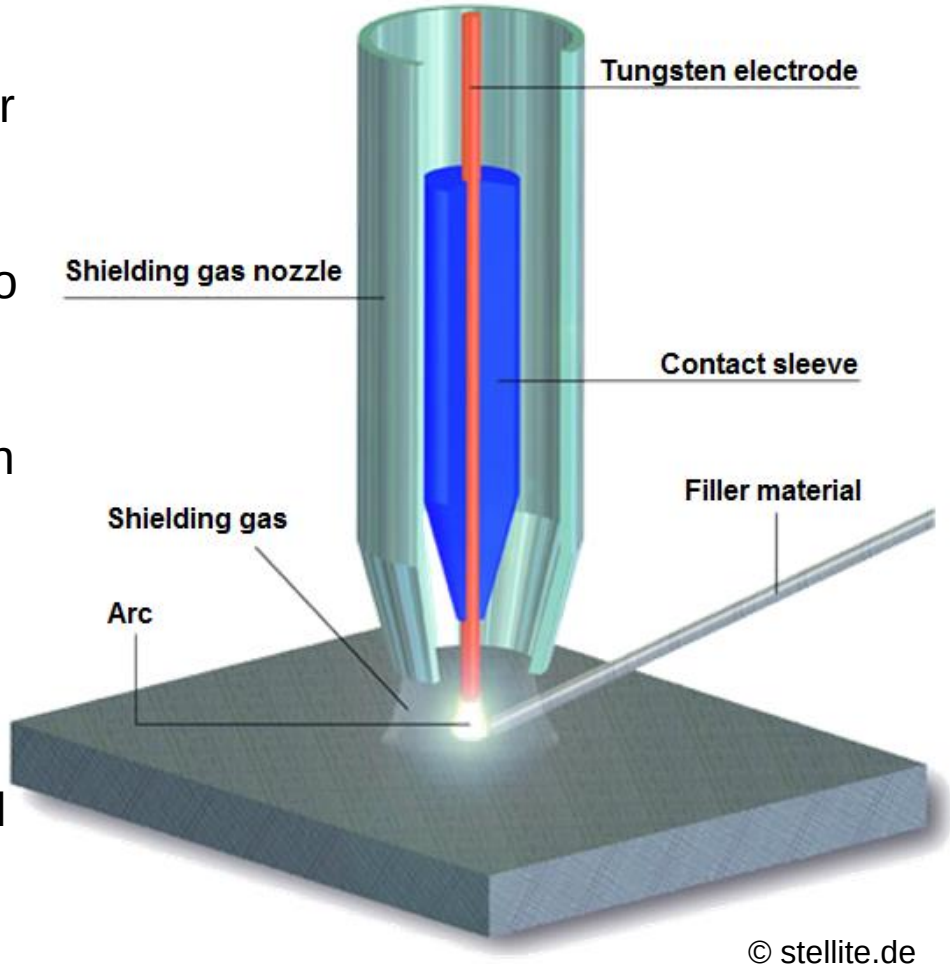
Tungsten Inert Gas Welding: Basics

Tungsten inert gas welding (TIG)

- Application of inert shielding gas for preventing oxidation
- Electric current supply connected to tungsten electrode and workpiece
- Ionization of shielding gas results in ignition of arc
- Arc ignition typically by high frequency high voltage pulses
- Decoupled addition of filler material



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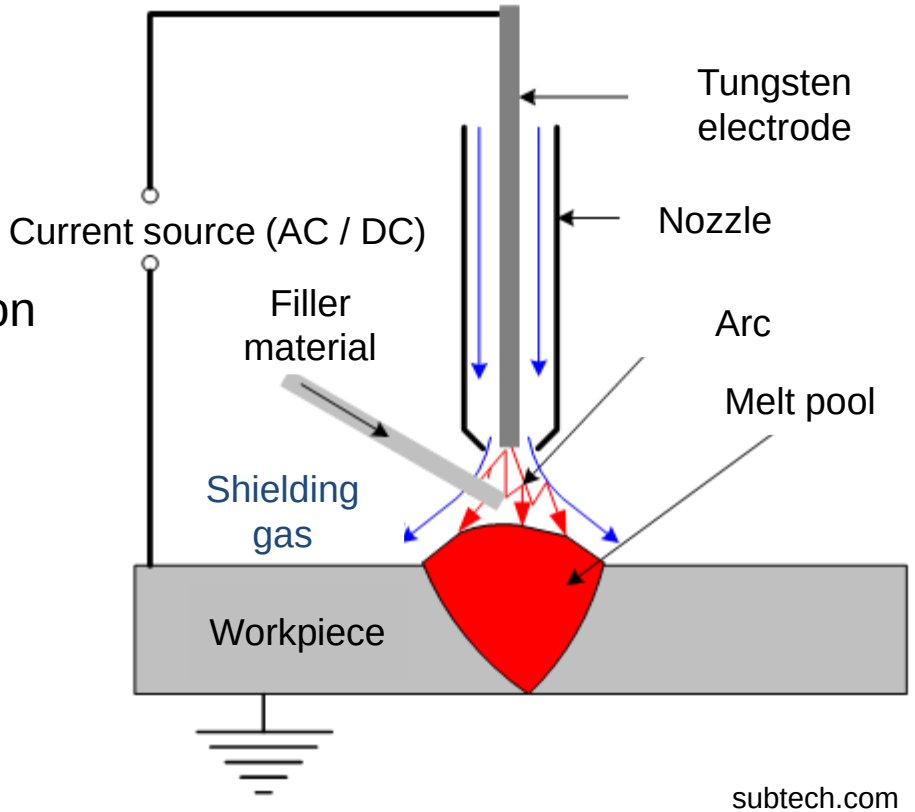
Tungsten Inert Gas Welding: Current Supply

Tungsten inert gas welding

- Direct Current: Electrode on negative pole
  - Most common application
  - Joining of alloyed steels and non-iron metals
- Alternating Current: Electrode on positive pole
  - Breaking of oxide layer on surface
  - Joining of light metals (aluminium and magnesium)

TIG-Welding



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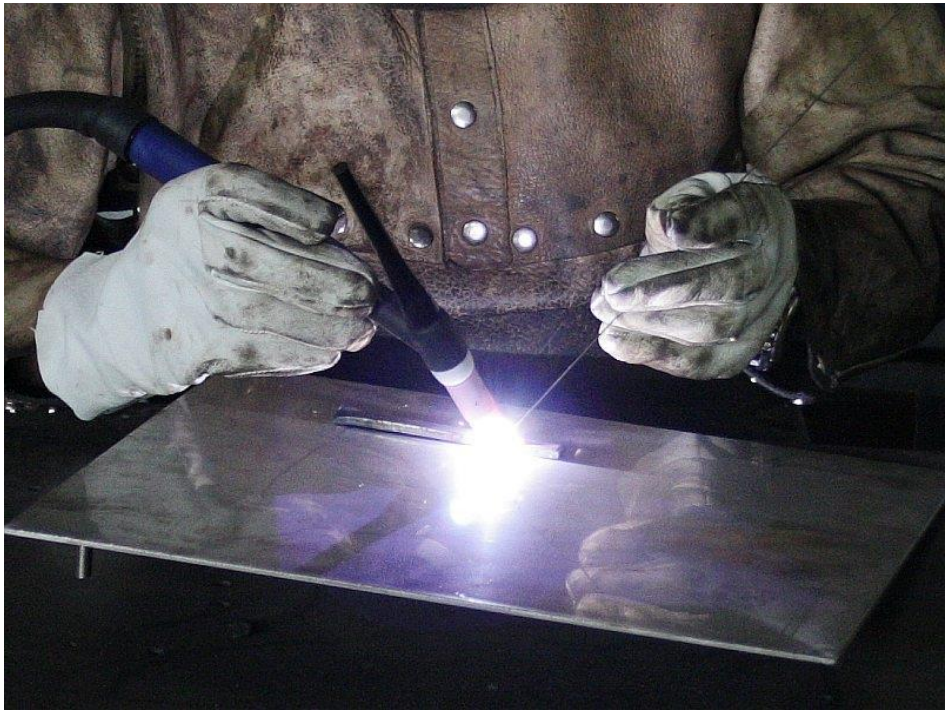
TIG-Welding: Examples of Application

Manual TIG-welding



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Arc welding

© produktion.de

Aluminum bicycle frame

© mtb-news.de

Live-Survey

Plasma is an electric

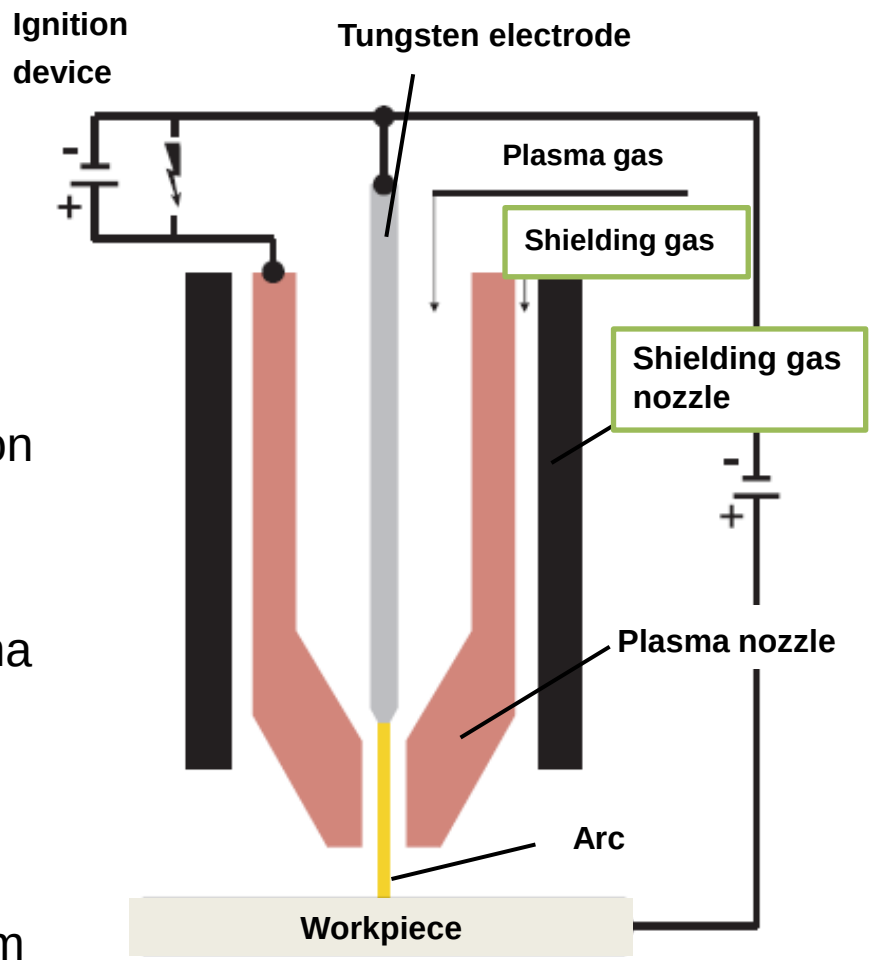
a) isolator

b) conductor

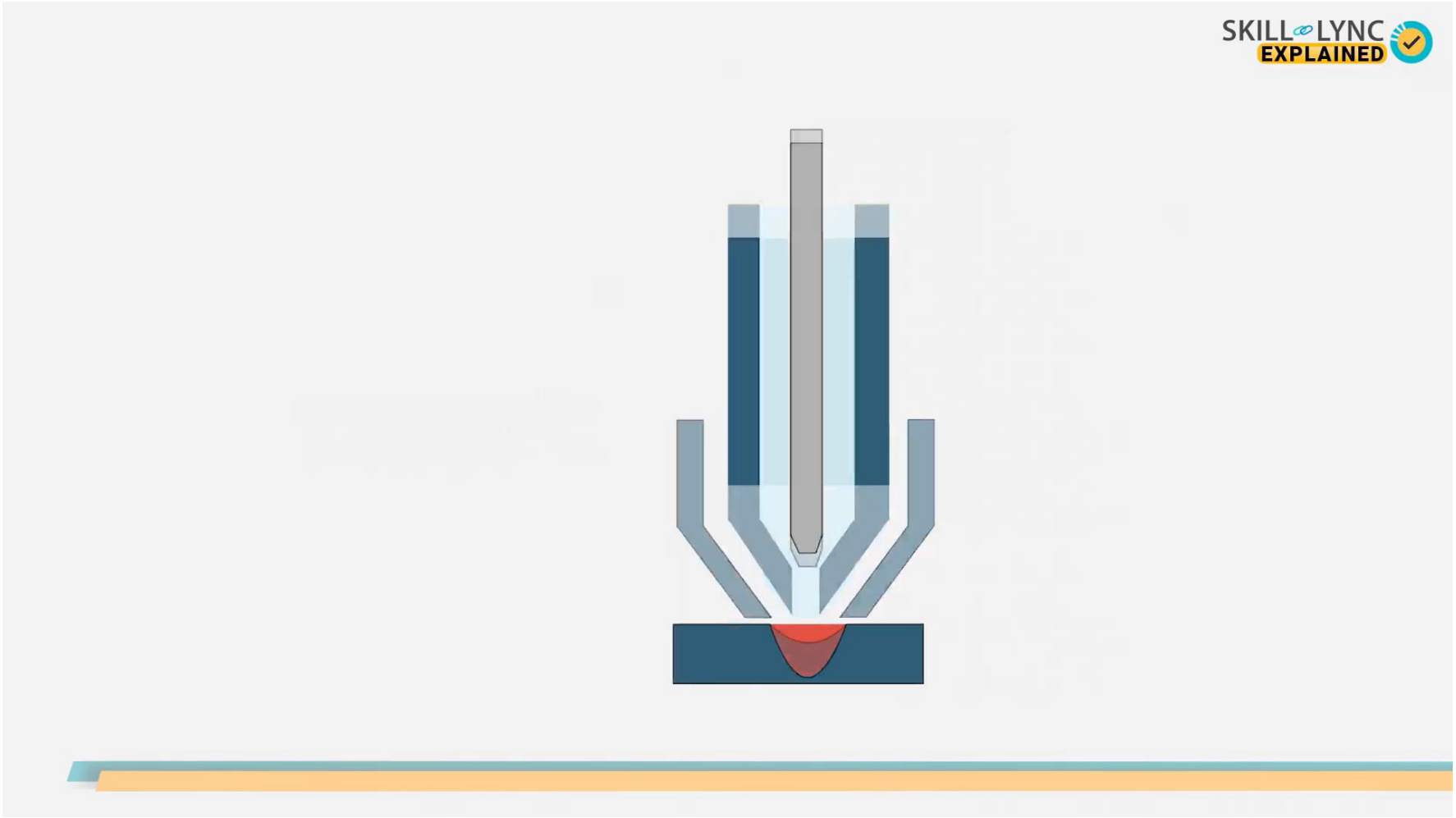
Result

Plasma Welding: Principles

- Plasma generated inside plasma nozzle
- Application of two gas streams
  - → Plasma gas (argon) for generating the arc between nozzle and workpiece
  - → Shielding gas for preventing oxidation
- Expelled by overpressure through water-cooled nozzle (e.g. copper) to achieve a defined stream of hot plasma
  - → Higher intensity by lower beam divergence
- Conversion of the kinetic energy into thermal energy when the plasma beam hits the workpiece surface



Plasma Arc Material Processing



Live-Survey

Between the nozzle and the workpiece, the plasma beam gets

a) accelerated

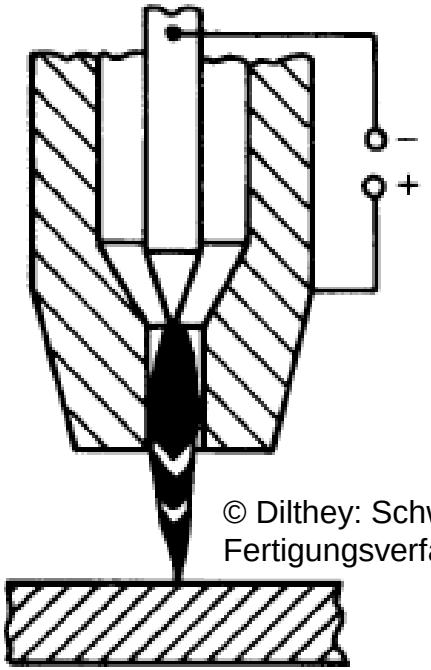
b) widened

c) accelerated and widened

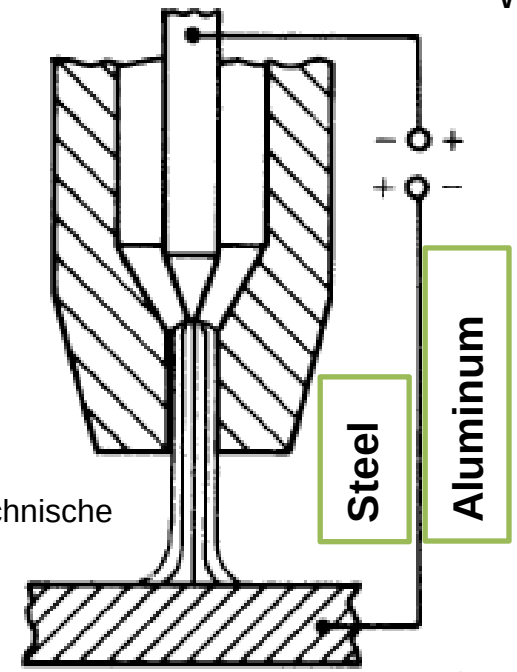
Result

Plasma Welding: Process Variants

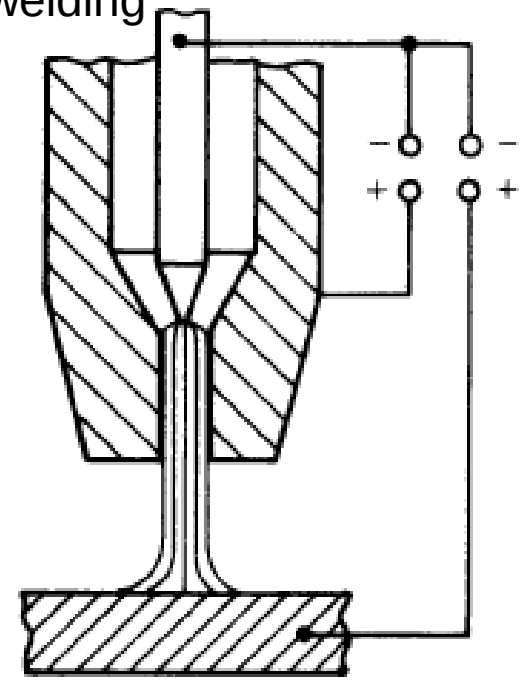
Plasma jet welding



Plasma arc welding



Plasma jet – Plasma arc welding



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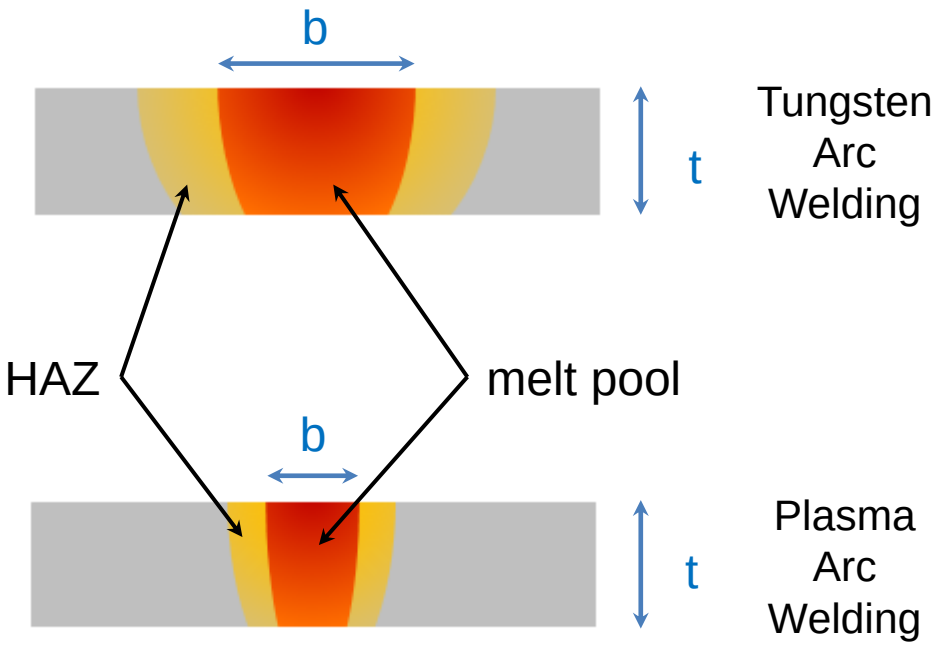
- Arc ignition between electrode and copper nozzle
- Heating of the plasma gas while passing the arc between electrode and nozzle
- Arc inside the burner. Ejection of a hot gas jet

- Pilot arc between electrode and copper nozzle for arc ignition (Plasma jet/plasma arc welding)
- Welding circuit between electrode and workpiece while arc is transferred
- Polarity (DC) depending on workpiece material (alternative: AC polarity possible)

Comparison of Tungsten Arc Welding and Plasma Arc Welding

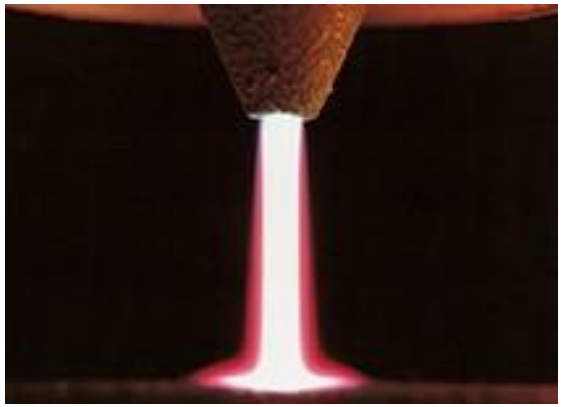
Plasma arc

- Higher intensity for Plasma Arc Welding
  → Higher welding speed
  → Small heat affected zone (HAZ)
  → Smaller welding seams
- Magnetic pinch effect for plasma arc welding (if voltage is applied)
  → Constriction of the arc



TIG-arc

Plasma arc



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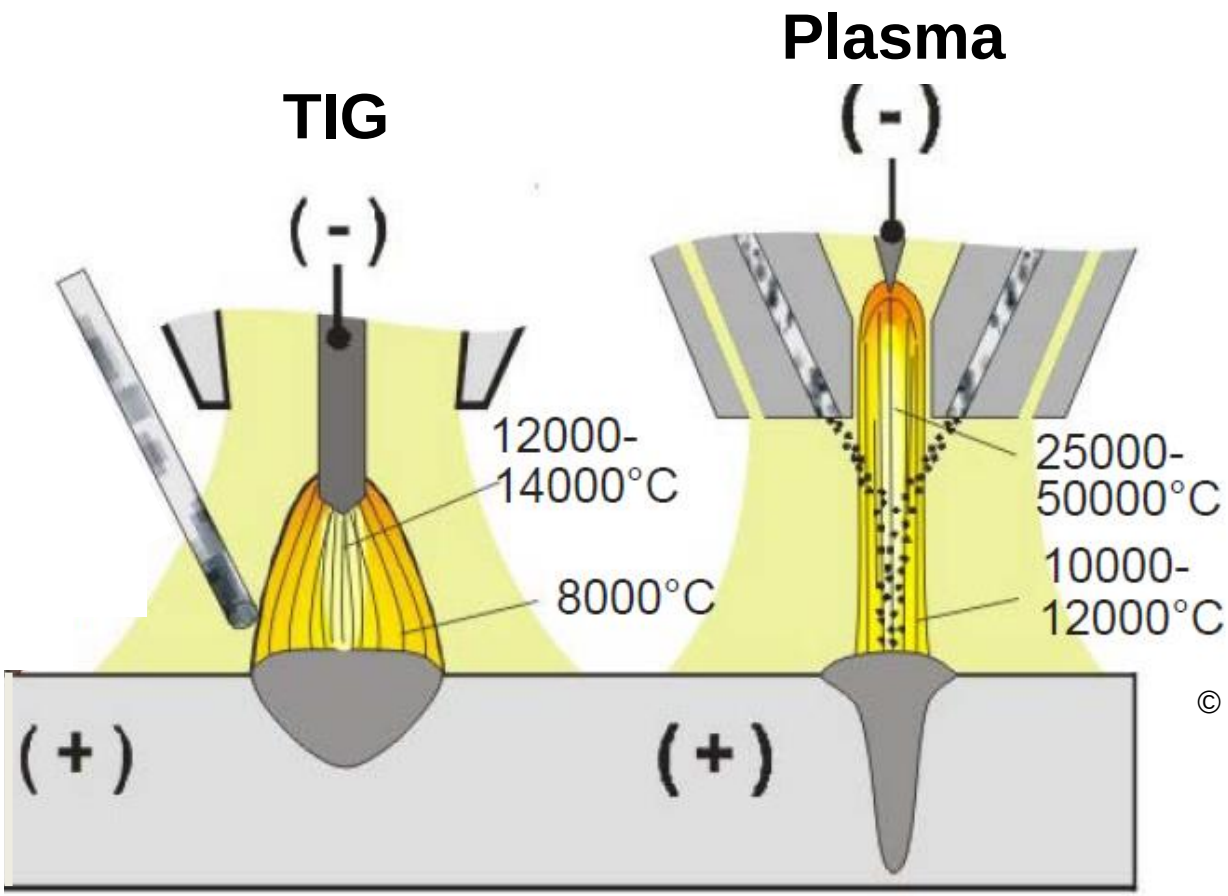
TIG-Welding and Plasma Arc Welding: Comparison



- Plasma arc welding: bundling of the arc on a smaller area by tungsten electrode inside the nozzle

  → Higher temperature in the process zone

  → Active cooling of the nozzle is necessary

Plasma Welding: Applications

Plasma welded pipe elbow

Switch control box

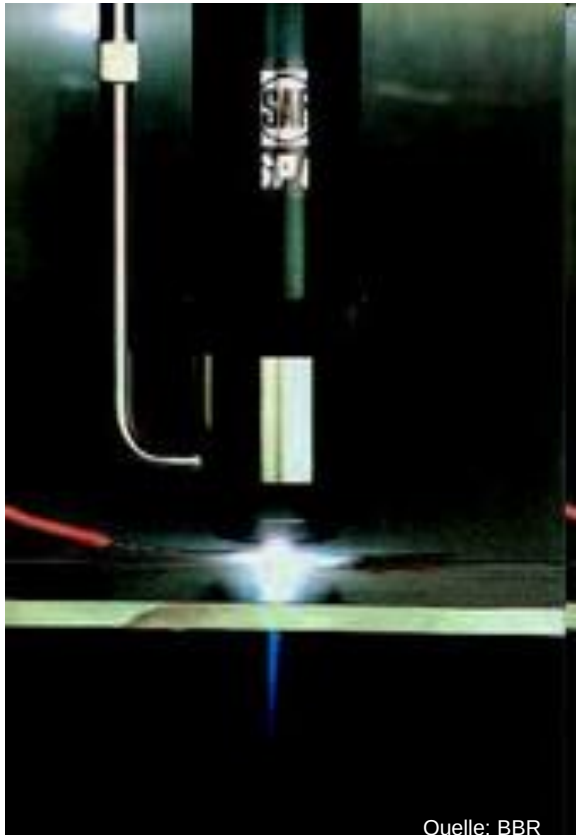
Valve housing

Plasma welded connection between a pressure vessel and its connection nozzle

Advantages and Disadvantages of Plasma Welding

Advantages

- Exact process control
- High stability of the arc even at low currents (0.1 A)
- Smaller melt pool dimensions and heat-affected zone compared to TIG welding (but larger than for laser and electron beam welding)
  → low distortion, favorable weld seam shape
- Large sheet metal thicknesses (butt joint 8 mm) possible
- Addition of powdered filler material possible
- Low seam convexity, low sagging of the root
- High welding speeds


Quelle: BBR

Disadvantages

- More cost intensive welding equipment and maintenance compared to TIG welding
- No gap bridging possible
- Two inert gases required