Exercise 1

Manufacturing Technology 2020

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Task 1 - DIN 8580

Name the 6 main manufacturing categories and name two example processes each

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Task 1 - DIN 8580

Shaping	Deforming	Dis-aggregation (cutting)	Joining	Coating	Change material properties
Casting	Rolling	Shear cuting	Bolting	Painting	Hardening
Extrusion	Die forming	Beam cutting	Roller bearing assembly	Electroplating	Tempering
Sintering	Deep-drawing	Milling	Brazing	Thermal spraying	Decarburizing
Electroforming	Stretching	Grinding	Soldering	Vapour deposition	Carburizing
…	…	Spark erosion	Welding	…	Nitriding
		…	…		…

Task 2 - Cutting wedge

Draw the orthogonal cutting wedge showing all the angles. What is the sum of all the angles?

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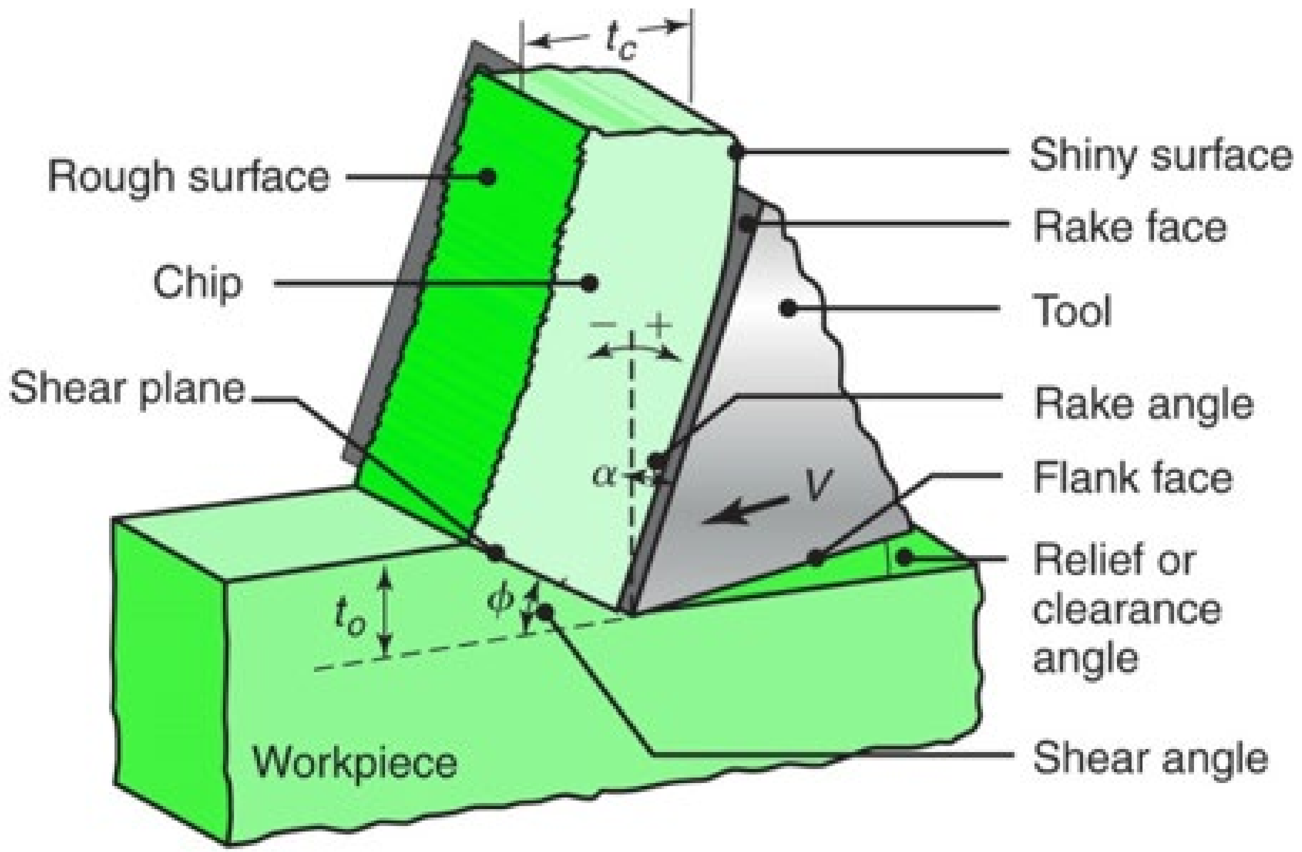

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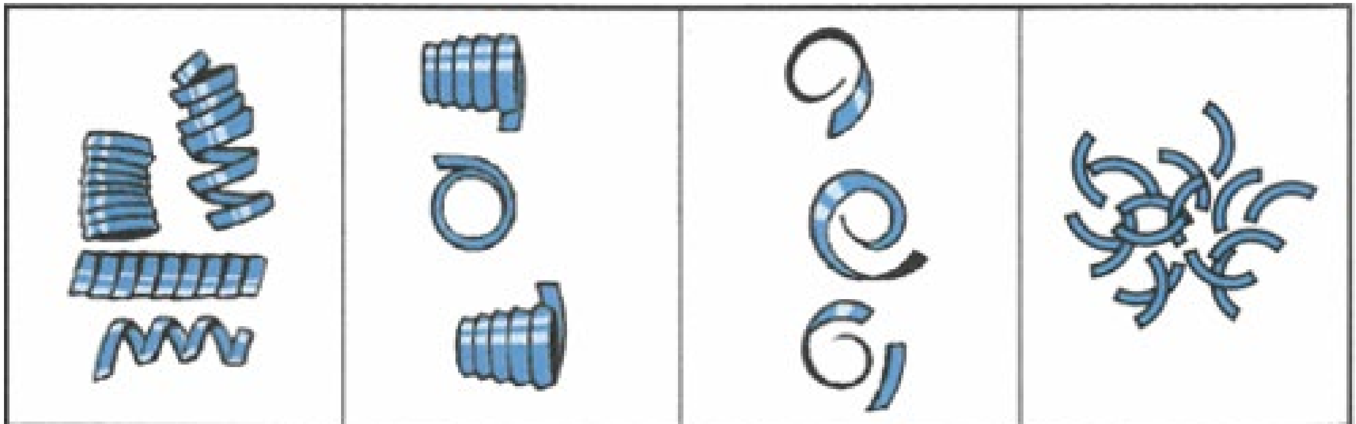
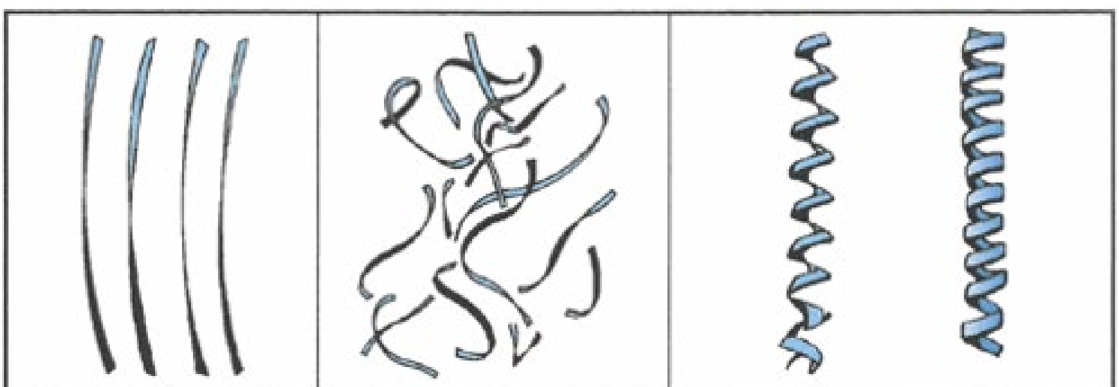
Task 3 - Types of chip formation

Write down the name of the chips and state whether it is favorable or unfavorable.





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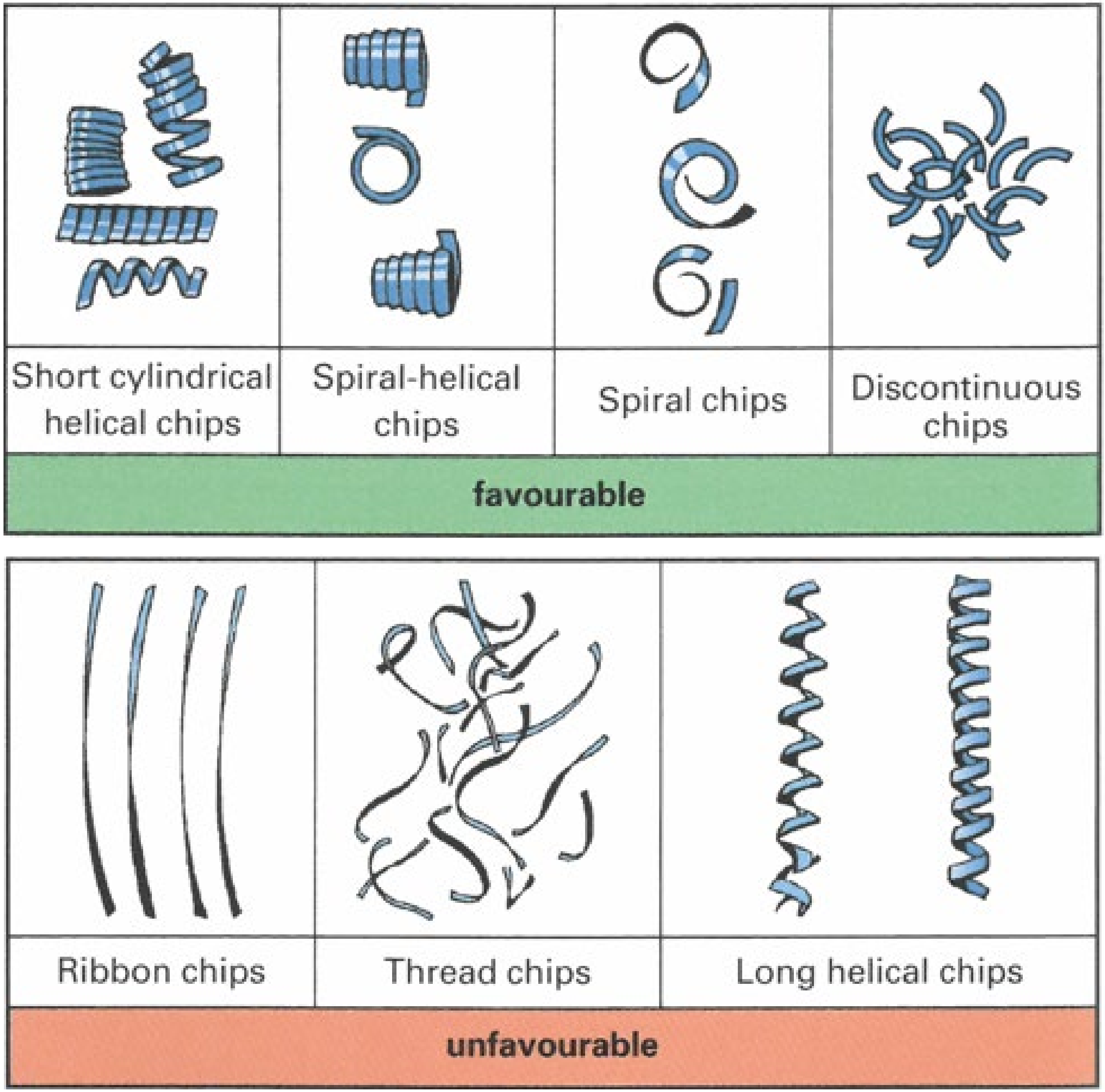

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Input – Metal workpiece materials

Six material groups

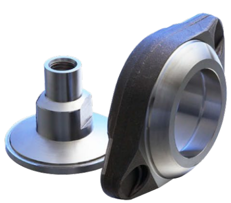
In the metal cutting industry there is an incredibly broad range of component designs made from different materials. Each material has its own unique characteristics influenced by the alloying elements, heat treatment, hardness, etc. This strongly influences the selection of cutting tool geometry, grade and cutting data.

Workpiece materials are divided into 6 major groups in accordance with the ISO-standard, where each group has unique properties regarding machinability.

P Steel

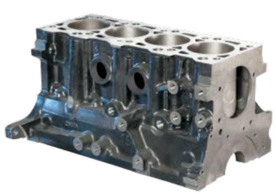
- ISO P – Steel is the largest material group in the metal cutting area, ranging from unalloyed to high-alloyed material including steel castings and ferritic and martensitic stainless steels. The machinability is normally good, but differs a lot depending on material hardness, carbon content, etc.

M Stainless steel



- ISO M – Stainless steels are materials alloyed with a minimum of 12% chromium; other alloys are, e.g., nickel and molybdenum. Different conditions such as ferritic, martensitic, austenitic and austenitic-ferritic (duplex), makes this an extensive material group. Common for all these types are that they expose cutting edges to a great deal of heat, notch wear and built-up edge.

K Cast iron



- ISO K – Cast iron is, contrary to steel, a short-chipping type of material. Gray cast iron (GCI) and malleable cast irons (MCI) are quite easy to machine, while nodular cast iron (NCI), compacted graphite iron (CGI) and austempered cast iron (ADI) are more difficult. All cast irons contain silicon carbide (SiC) which is very abrasive to the cutting edge.

N Non-ferrous

- ISO N – Non-ferrous metals are softer types of metals such as aluminum, copper, brass, etc. Aluminum with a silicon content (Si) of 13% is very abrasive. Generally high cutting speeds and long tool life can be expected for inserts with sharp edges.

S Heat resistant alloys

- ISO S – Heat Resistant Super Alloys include a great number of high-alloyed iron, nickel, cobalt and titanium-based materials. They are sticky, create built-up edge, workharden and generate heat, very similar to the ISO M-area, but they are much more difficult to cut, leading to shorter tool life for the cutting edges.

H Hardened steel

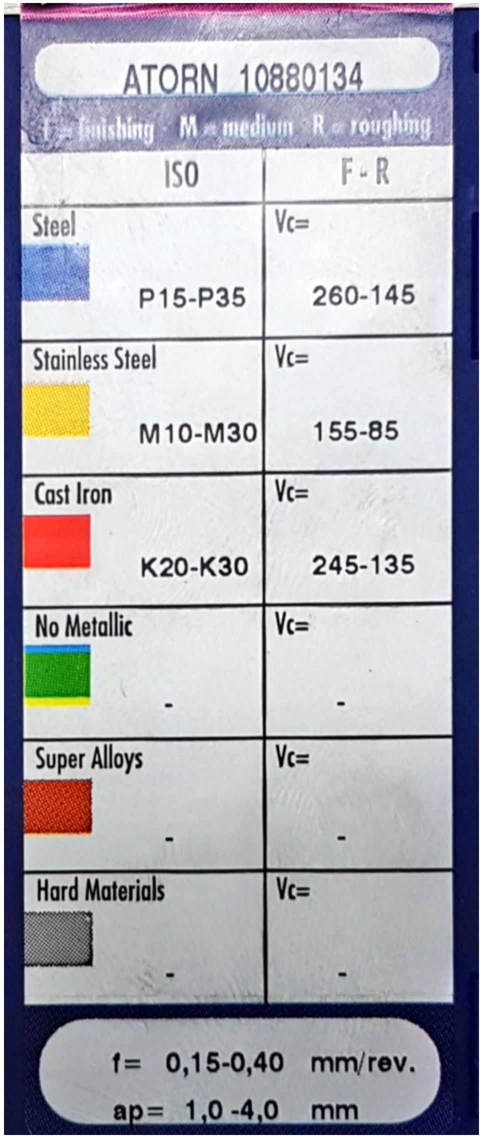
- ISO H – This group covers steels with a hardness between 45-65 HRc and also chilled cast iron around 400-600 HB. The hardness makes them all difficult to machine. The materials generate heat during cutting and are very abrasive to the cutting edge.

Task 4 – Cutting parameter calculation

A shaft made of C35 should be turned in two operations, one roughing operation and one finishing operation.

Initial diameter d = 70 mm
After roughing d = 62 mm
After finishing d = 60 mm

The available cutting insert parameters are given on the right side.



Calculate the required spindle speed.

(Hint: v_c (cutting velocity) = 2 * π * r (radius after operation) * n (spindle speed))

Which spindle speed should be selected on the machine and which influence does this have on the cutting velocity?

Spindle speed steps in RPM:

Task 4: Cutting parameter calculation

Preliminary considerations

v_c (cutting velocity) = 2 * π * r (radius after operation) * n (spindle speed))

$$v_c = 2 * \pi * r * n$$

$$n = \frac{v_c}{2 * \pi * r} = \frac{v_c}{\pi * d}$$

Roughing

- Look up recommended cutting velocity v_c:

$$145\ m/min$$

- Calculation of n:

$$n = \frac{v_c}{\pi \cdot d} = \frac{145\ m/min}{\pi\ \cdot 62\ mm} \sim 744\ min^{-1}$$

- Look up spindle speed (nearest value):

$$880\ RPM = 880\ min^{-1}$$

- Calculate v_c:

$$v_c = \pi \cdot d \cdot n = \pi \cdot 62\ mm\ \cdot 880\ min^{-1} \sim 171\ \ m/min$$

Task 4: Cutting parameter calculation

Finishing

- Look up recommended cutting velocity v_c:

$$260\ m/min$$

- Calculation of n:

$$n = \frac{v_c}{\pi \cdot d} = \frac{260\, m/min}{\pi\ \cdot 60\, mm} \sim 1379\, min^{-1}$$

- Look up spindle speed (nearest value):

$$1350\ min^{-1}$$

- Calculate v_c:

$$v_c = \pi \cdot d \cdot n = \pi \cdot 60\, mm\ \cdot 1350\, min^{-1} \sim 254\ \ m/min$$

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Input - Cutting Insert Forms (ISO 1832)

Code key for cutting inserts according to ISO 1832 (core elements)

Example	*C*	*N*	*M*	*G*	*12*	*04*	*08*
Code position	1	2	3	4	5	6	7

1 - Insert shape
2 - Insert clearance angle
3 - Tolerance class
4 - Insert type (fastening and/or chip beaker form)
5 - Insert size (cutting edge length)
6 - Insert thickness
7 - Nose radius (value shown in 0.1 mm)
...
Further entries are possible. The entries above are mandatory.

ISO 1832

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Task 5 – Kinematic surface roughness

The kinematic surface roughness (difference of the highest and lowest point of the surface material) of a turned workpiece is depending on 2 parameters:

- feed f
- corner radius r_ε of the cutting insert

The surface roughness can be calculated as follows: $R_{th} = \frac{f^2}{8 \cdot r_\varepsilon}$

A shaft should be turned with a requested surface roughness of Rz = 1.6 (µm).
Which of the following tools should be used for the finishing operation?

Insert A	CCMT 060202-FP	f = 0.05 – 0.16 mm
Insert B	CNMG 120408-WP	f = 0.20 – 0.55 mm
Insert C	DNMG 150608-MK	f = 0.25 – 0.45 mm
Insert D	DCET 070201 R-MF	f = 0.03 – 0.1 mm

Surface roughness: $R_{th} = \frac{f^2}{8 \cdot r_\varepsilon}$

Insert A $R_{th} = \frac{(0.05\ mm)^2}{8 \cdot 0.2\ mm} = 1.56\ \mu m$ ✓

Insert B $R_{th} = \frac{(0.2\ mm)^2}{8 \cdot 0.8\ mm} = 6.25\ \mu m$

Insert C $R_{th} = \frac{(0.25\ mm)^2}{8 \cdot 0.8\ mm} = 9.77\ \mu m$

Insert D $R_{th} = \frac{(0.03\ mm)^2}{8 \cdot 0.1\ mm} = 1.13\ \mu m$

Multiple choice

The rake angle of a turning tool is called...

a) Alpha ✓
b) Gamma

In longitudinal turning, increasing the cutting speed will lead to decreasing kinematic roughness (if feed and all other parameters stay constant).

a) Right
b) Wrong ✓

In turning, the feed in roughing is lower than in finishing

a) Right
b) Wrong ✓

Multiple choice

In milling, the relative direction between feed and tool rotation determines whether the process is called "conventional milling" or "climb milling"

a) Right ✓

b) Wrong

Hobbing is...

a) a special milling operation used to make gears ✓

b) a machining technology used to manufacture hubs by pulling a long tailor-made tool through the borehole

The three basic components of a grinding wheel are grit, bonding and....

a) pores (cavities) ✓

b) dressing tiles

What is a frequent motivation to grind a workpiece?

a) to improve the geometrical accuracy ✓

b) to increase the workpiece hardness during the process

Exercise 2

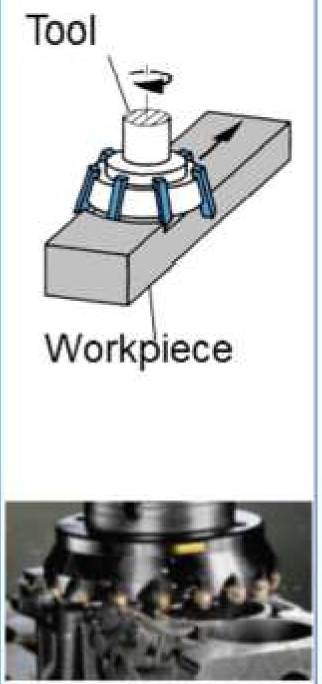
Manufacturing Technology 2020

Task 1 - Milling variants

List the six different types of milling variants.

Task 1 - Milling variants (DIN 8589-3)

Slab Milling



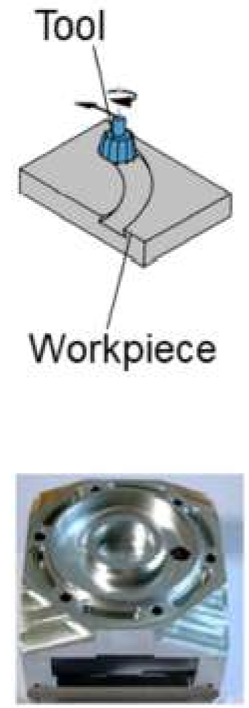
Circular Milling

Helical Milling

Hobbing

Profile Milling

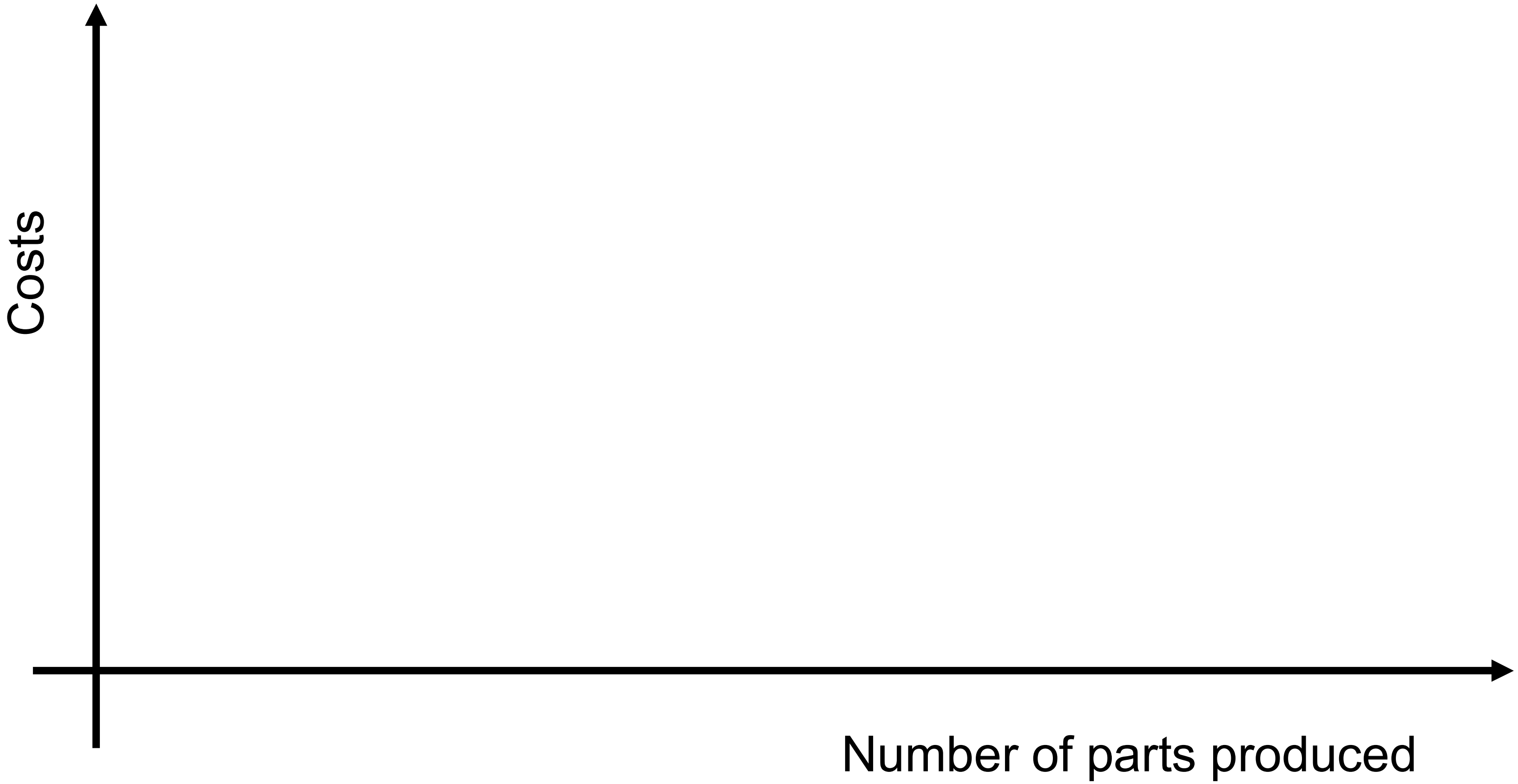
Form Milling



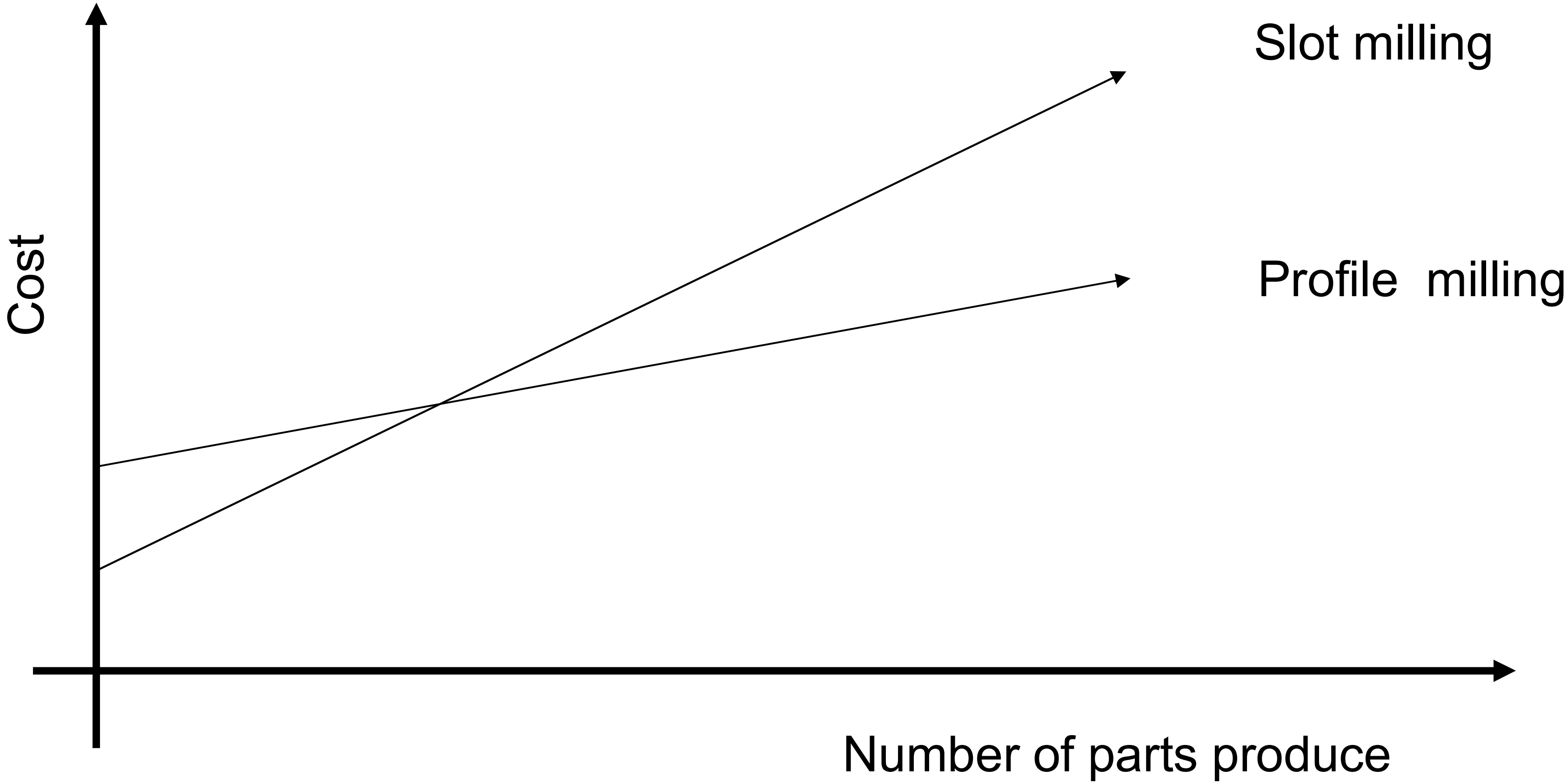
Source: WZL RWTH Aachen University

Task 2 - Comparison of slot milling and profile milling

Imagine there is a certain part, which can be produced either by slot milling or by profile milling. Sketch two graphs – one for slot milling and one for profile milling – which show the respective relationship between the number of parts produced and the production costs. Take into account fixed and variable costs of both processes.



Task 2 - Comparison of slot milling and profile milling



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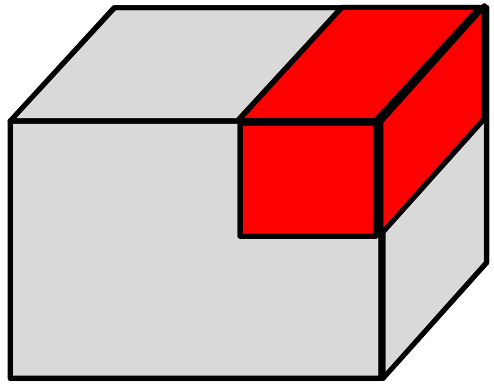
Task 3 – Material removal rate

From a block of steel with (L 100, T 30, W 50) a longitudinal shoulder should be milled (red area). The cut-out is 10 mm deep and 10 mm wide. Please calculate the time for the machining operation with following tool data, if in average one cutting edge is in use:



- Endmill D8
- 3 blades
- v_c= 160 m/min
- f_z= 0.04 mm
- depth of cut a_p= 10 mm
- width of cut a_e = 1.64 mm

Hint: material removal rate MRR = $a_p * a_e * v_f$

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Task 3 - Material removal rate

$$n = \frac{V_c}{\pi * d} = \frac{160\,\frac{m}{min}}{\pi * 8\,mm} = 6366\ min^{-1}$$

$$v_f = f_z * z * n = 0.04\ mm * 3 * 6366\ min^{-1} = 764\,\frac{mm}{min}$$

$$MRR = a_p * a_e * v_f = 10\ mm * 1.64\ mm * 764\,\frac{mm}{min} = 12.5\,\frac{cm^3}{min}$$

$$T = \frac{V}{MRR} = \frac{10\ mm * 10\ mm * 100\ mm}{12.5\,\frac{cm^3}{min}} = \frac{10\ cm^3}{12.5\,\frac{cm^3}{min}} = 0.8\ min = 48\ s$$

Task 4 – Grinding

Show the relationship between the number of cutting edges and the chip thickness from milling to grinding.

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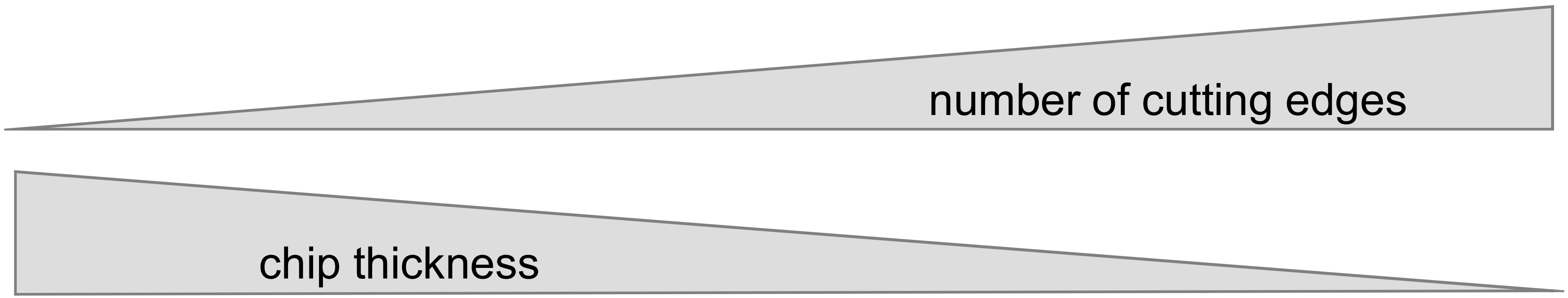

Task 5 – Tool wear

Name four different wear mechanisms in grinding.

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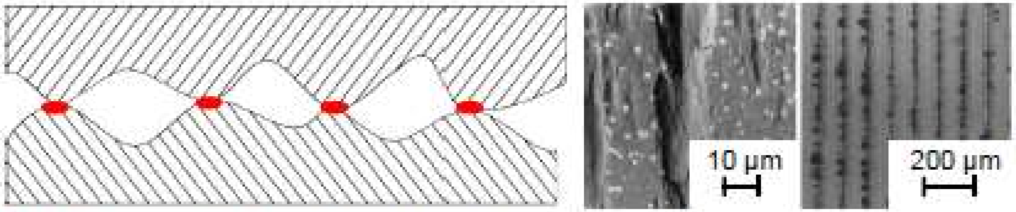
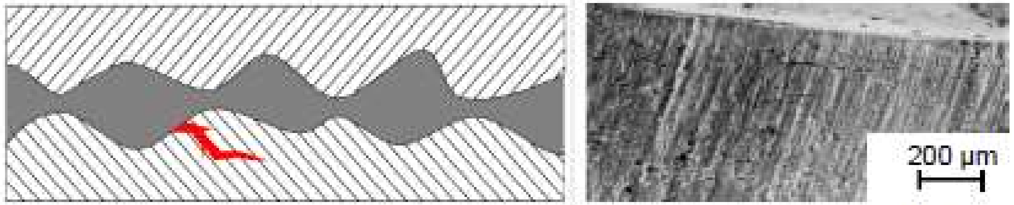
Adhäsion



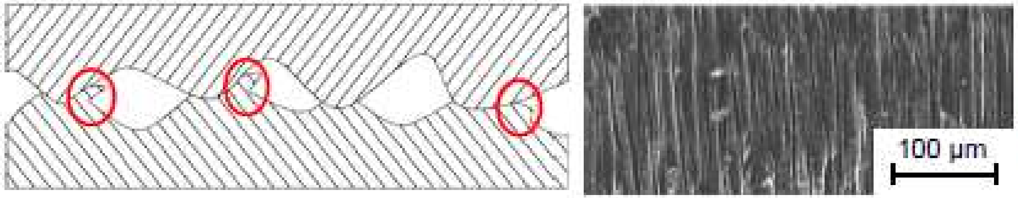
- Smearing on an HSS extrusion punch

Surface fatigue



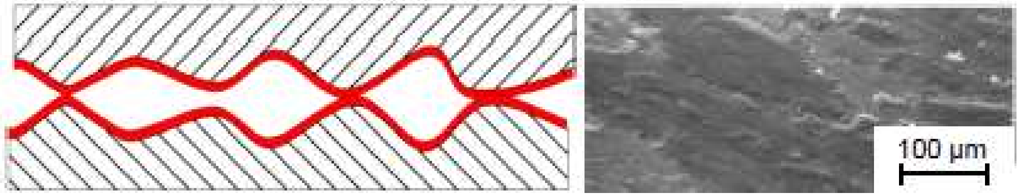
- Fatigued lateral surface of a HSS fineblanking punch

Abrasion



- Abrasion on a ceramic deep drawing ring

Tribochemical wear



- Tribochemical wear on a borated steel

Source: WZL RWTH Aachen University

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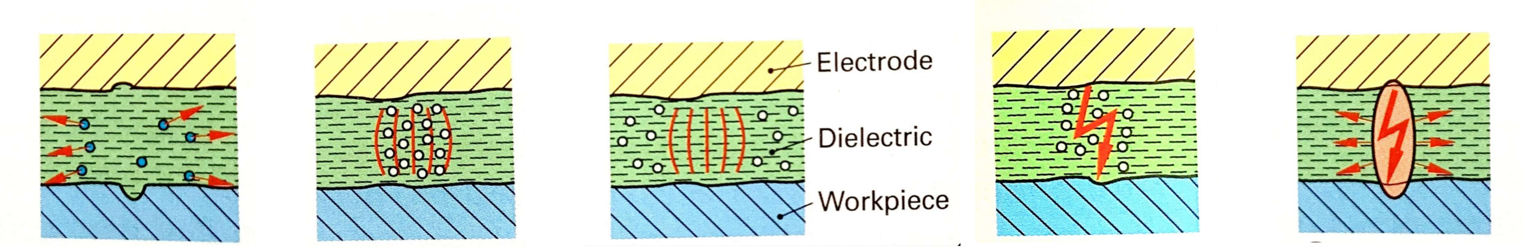
Task 6 – EDM process steps

Arrange the EDM process steps in right order and match them with the picture shown.
Also name five advantages of the EDM process.

- Discharge channel
- Electric Field
- Spark formation
- Removal
- Ion concentration



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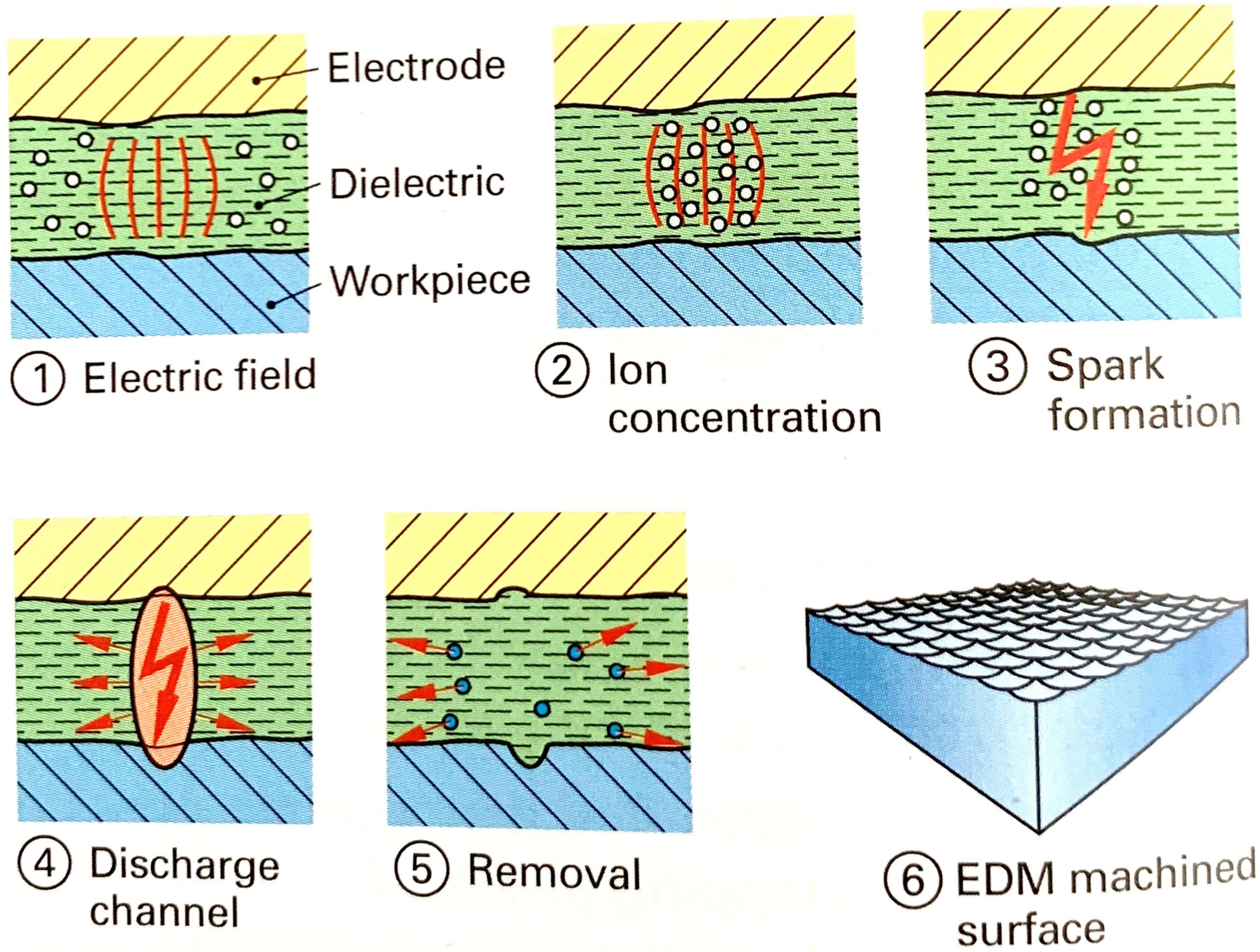

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Task 6 – EDM process steps

Arrange the EDM process steps in right order and match them with the picture shown. Also name five advantages of the EDM process.

- Sharp edges, filigree structures to be manufactured

  (e.g. „rectangular holes and pockets“)
- Material with very low machinability to be machined

  (e.g. cemented carbide, ceramics (with critical electrical conductivity))
- Extremely high surface finish needed
- EDM is of good use in tool and die making
- Roughing and finishing possible in EDM

Multiple choice

Imagine you have a milling process with a spindle speed of 500 rpm, a milling tool with 4 blades, a feed of 0.3 mm per blade and a tool diameter of 200 mm. What is the cutting velocity?

a) approx. 314 m/min ✓
b) approx. 377 m/min
c) Approx. 628 m/min

Which one is a highly productive manufacturing technology for workpieces that need to be produced in high volumes, but that requires a high initial effort for tool making (and/or high tool purchase price)?

a) Helical milling
b) Broaching ✓

Grinding burn" is a collateral damage in manufacturing in which the workpiece material is unintentionally hardened during a grinding process.

a) Right ✓
b) Wrong

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Multiple choice

The typical attribute of gun drilling is that a borehole is created in a very hard workpiece material

a) Right
b) Wrong ✓

The type of tool used during milling and broaching are

a) Single point cutting tool
b) Two point cutting tool
c) Three point cutting tool
d) Multi point cutting tool ✓

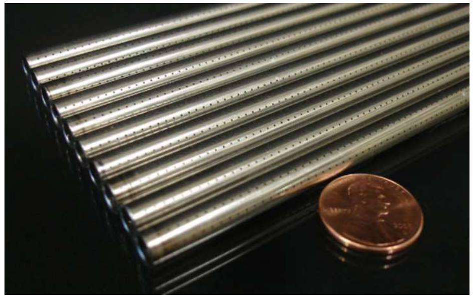
~~Lapping~~ Honing is an operation of

a) Making a cone shaped enlargement of the end of a hole
b) Smoothing and squaring the surface around a hole
c) Sizing and finishing a small diameter hole ✓
d) Producing a hole by removing metal along the circumference of a hollow cutting tool

Exercise 3

Manufacturing Technology 2020

Task 1 – Choosing a process: Turning, Milling, Additive Manufacturing or EDM?

			
Drilling small holes	Thermostat covers for trucks from Mercedes Benz	Battery holder for E-bikes	Rocket motor in copper
			
Keyway shaft	Valve plate part in stainless steel	Holder made from steel	Flow cooler made from aluminum

http://www.wirecutcompany.com
https://www.materialise.com
https://3dprint.com
https://www.absolutemanufacturing.com
http://www.bamatech.de
https://www.heim-metallbau.de

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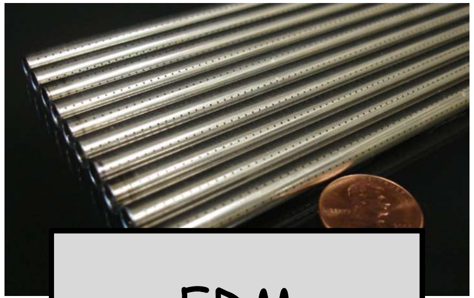
Task 1 – Choosing a process: Turning, Milling, Additive Manufacturing or EDM?

 EDM	 3D PRINTING	 MILLING	 EDM
Drilling small holes	Aluminum thermostat covers for trucks from Mercedes Benz (replacement parts)	Battery holder for E-bikes	Rocket motor in copper
 TURNING	 EDM	 MILLING	 3D PRINTING
Keyway shaft	Valve plate part in stainless steel	Holder made from steel	Flow cooler made from aluminum

http://www.wirecutcompany.com
https://www.materialise.com
https://3dprint.com

https://www.absolutemanufacturing.com
http://www.bamatech.de
https://www.heim-metallbau.de

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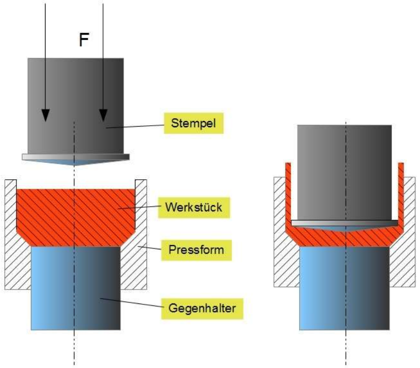
Task 2 – Grouping of forming processes

How can forming processes be grouped? Develop a matrix (2x2) and name at least one example forming process each.

Task 2 - Grouping of forming processes

bulk



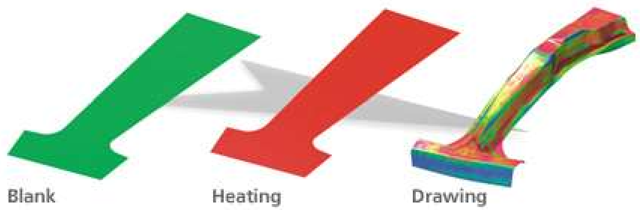
extrusion

forging

cold

hot

bending



High degree of deformation

Sheet metal

http://www.dropforging.net
https://www.minifaber.com
https://www.autoform.com
https://www.ingenieurkurse.de

Task 3 - Deforming

A cylinder (diameter 100 mm, length 100 mm, material S235) should be upsetted to a final length of 60 mm.

a) Calculate the true strain, if this process is done in one step.

b) Calculate the true strain, if this process is done in three steps (15 mm + 15 mm + 10 mm).

Task 3 - Deforming

A cylinder (diameter 100 mm, length 100 mm, material S235) should be upsetted to a final length of 60 mm.

a) $\varphi_t = \ln(\frac{h_1}{h_0})$

$= \ln(\frac{60\ mm}{100\ mm})$

$= -0.511$

b) $\varphi_t = \ln(\frac{h_1}{h_0}) + \ln(\frac{h_2}{h_1}) + \ln(\frac{h_3}{h_2})$

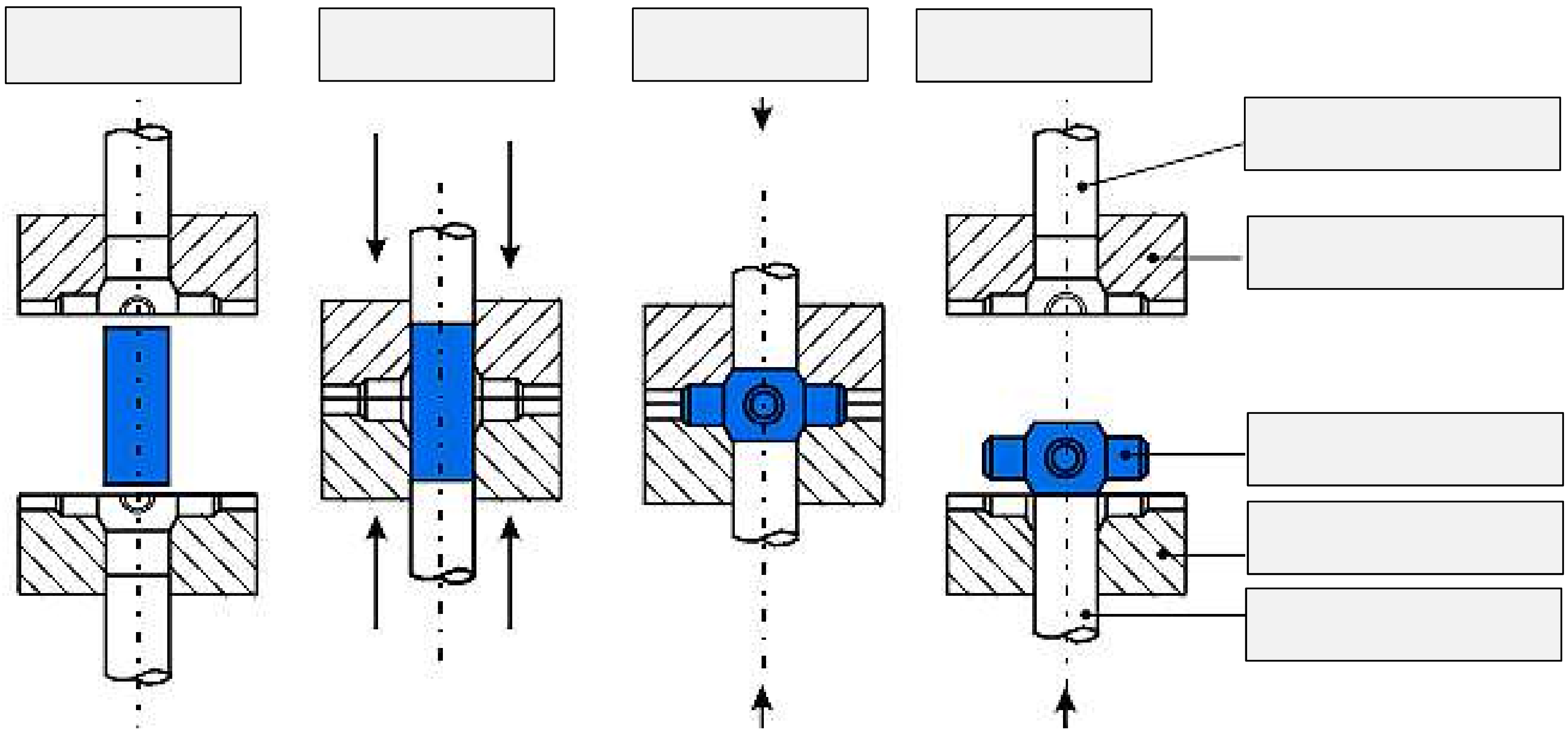
$= \ln(\frac{85\ mm}{100\ mm}) + \ln(\frac{70\ mm}{85\ mm}) + \ln(\frac{60\ mm}{70\ mm})$

$= -0.163 + (-0.194) + (-0.154)$

$= -0.511$

Task 4 – Cold forming

Figure below shows the production steps of cardan joint of the cold forming process. Label the figure.



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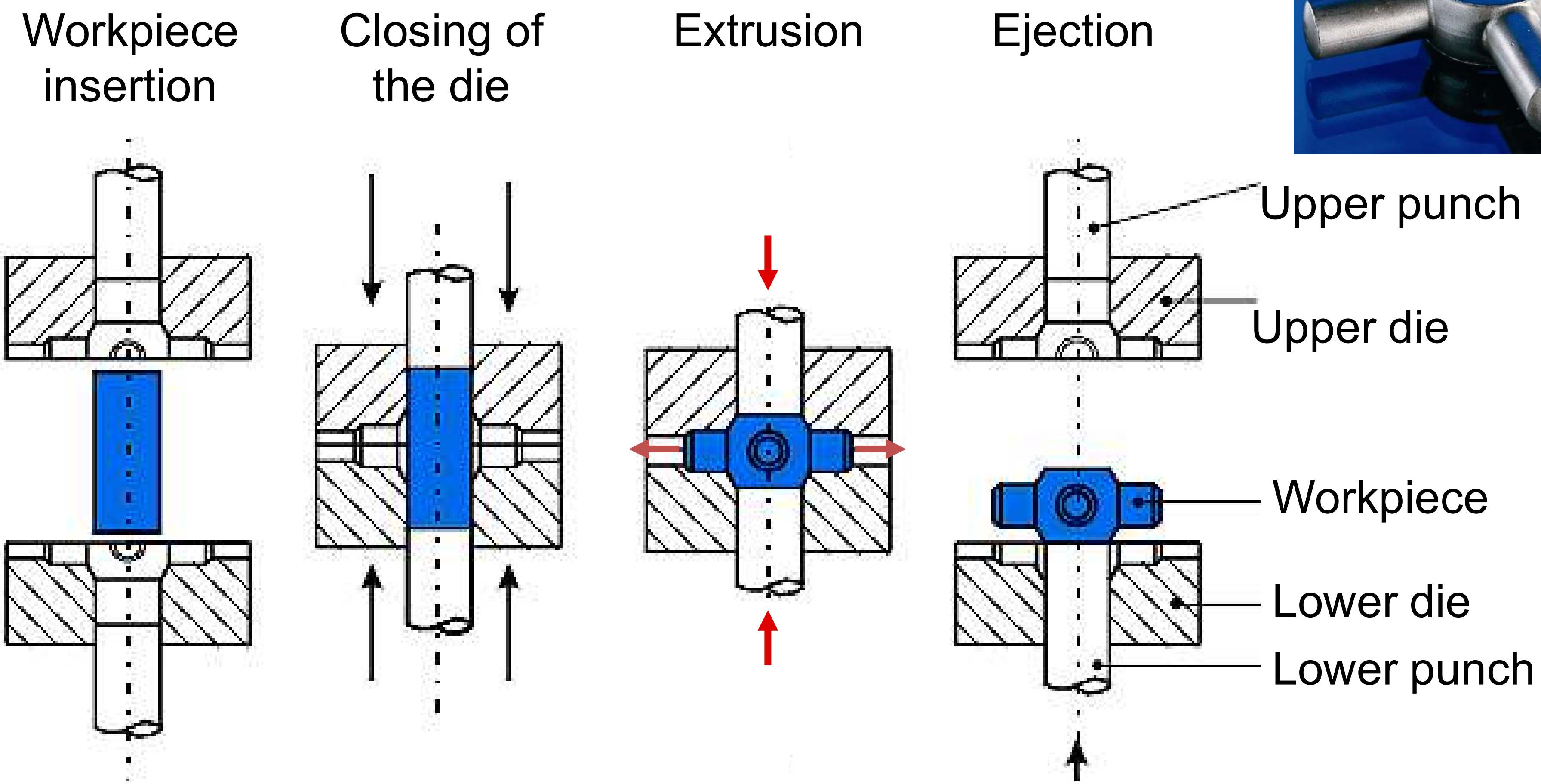
Cold forming
Radial extrusion of a cardan joint



Source: WZL / Fraunhofer IPT

Task 5 – Effect of temperature on recrystallization

Explain the effect of temperature on recrystallization.

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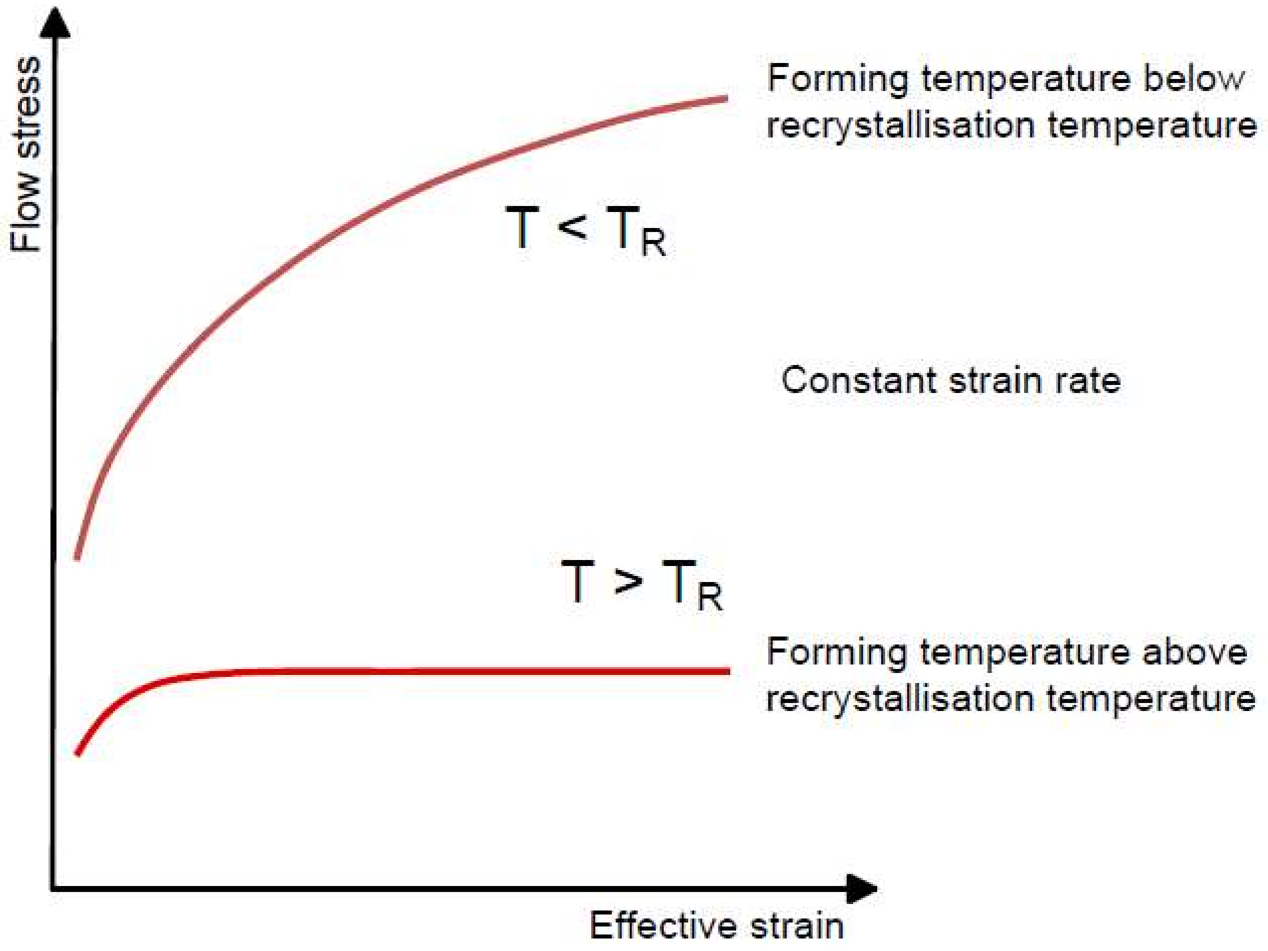
Explain the effect of temperature on recrystallization.



Source: WZL / Fraunhofer IPT

Multiple choice

The basic bulk deforming process which is needed to form a cardan joint is...

a) full forward extrusion

b) radial extrusion ✓

In recrystallization, the flow stress of a workpiece that has just been deformed in cold state is...

a) increased

b) reduced ✓

Ironing is a ...

a) sheet metal forming technology

b) bulk forming technology ✓

Deforming means changing the shape of a workpiece while keeping the volume constant

a) Right ✓

b) Wrong

Multiple choice

Tailored blanks are....

a) workpieces which are deformed close to the final desired workpiece shape which then are milled or grinded to the final shape
b) sheet metal pieces that are welded together from different materials or thicknesses which then are used to produce high-strength lightweight workpieces ✓

What is the most common material to make deforming tools (dies)?

a) Steel ✓
b) ceramics
c) cemented carbide
d) Diamond

How is the true strain of a deforming process calculated (referring to a simple upsetting process as explained in the lecture)? (h. height, index 0 : prior to deforming)

a) phiz = ln (h0/h1)
b) phiz = ln (h1/h0) ✓
c) phiz = (h1-h0)/h1

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Multiple choice

The flow stress of the workpiece in deforming...

a) ...decreases with increasing workpiece temperature ✓
b) ...increases with increasing workpiece temperature
c) ... is not depending on the workpiece temperature

The flow stress (in deforming processes) is ...

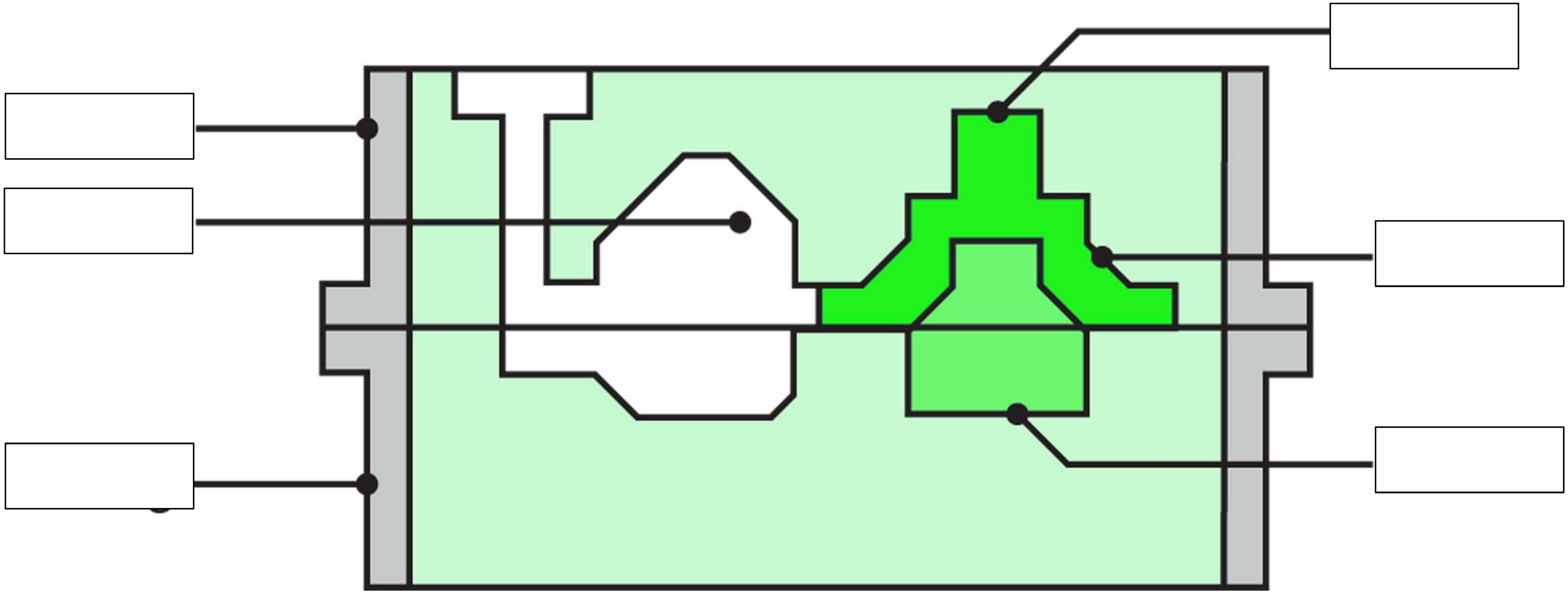
a) ...the load of the hydraulic system in a hydraulic press (which is often a limiting factor in deforming)
b) ...an unwanted stress inside the workpiece that should be avoided in deforming processes
c) ...the stress in the workpiece that is required to initiate and sustain plastic local deformation in the workpiece ✓

Exercise 4

Manufacturing Technology 2020

Task 1 – Sand casting

Label the figure of the sand casting process.



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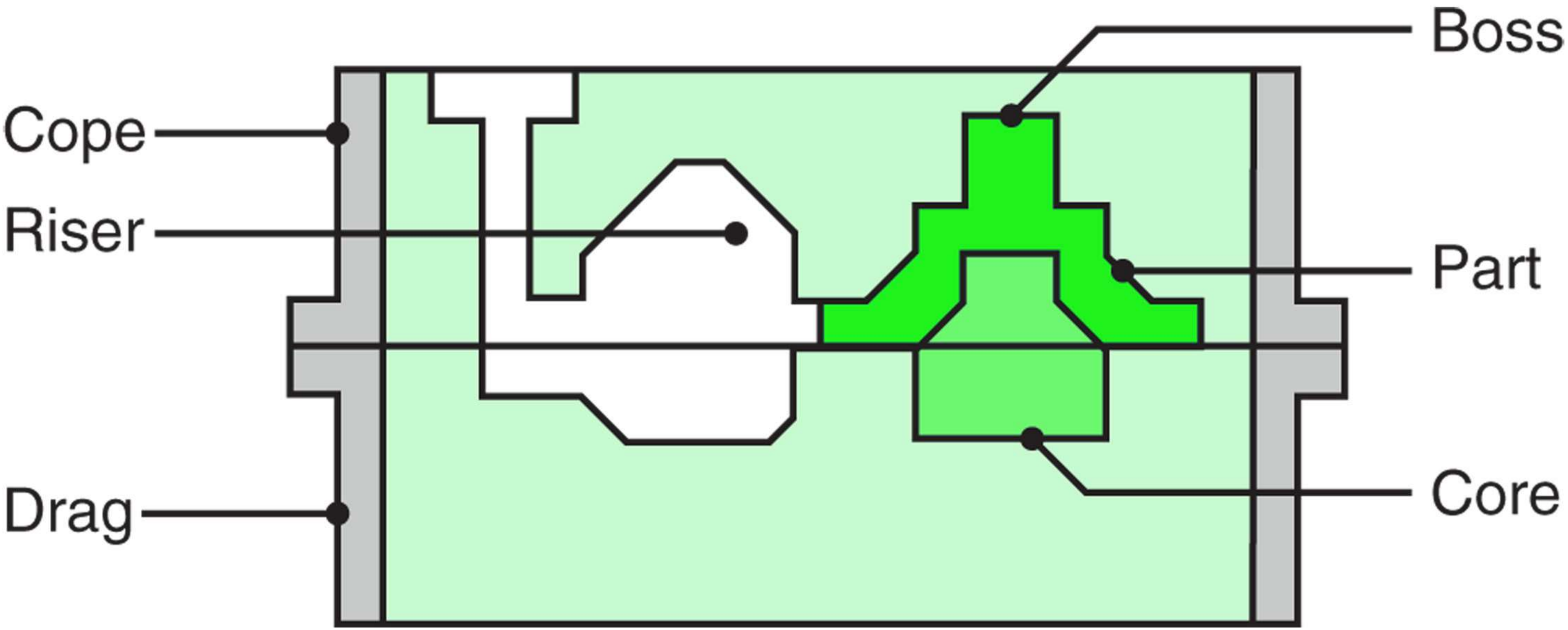
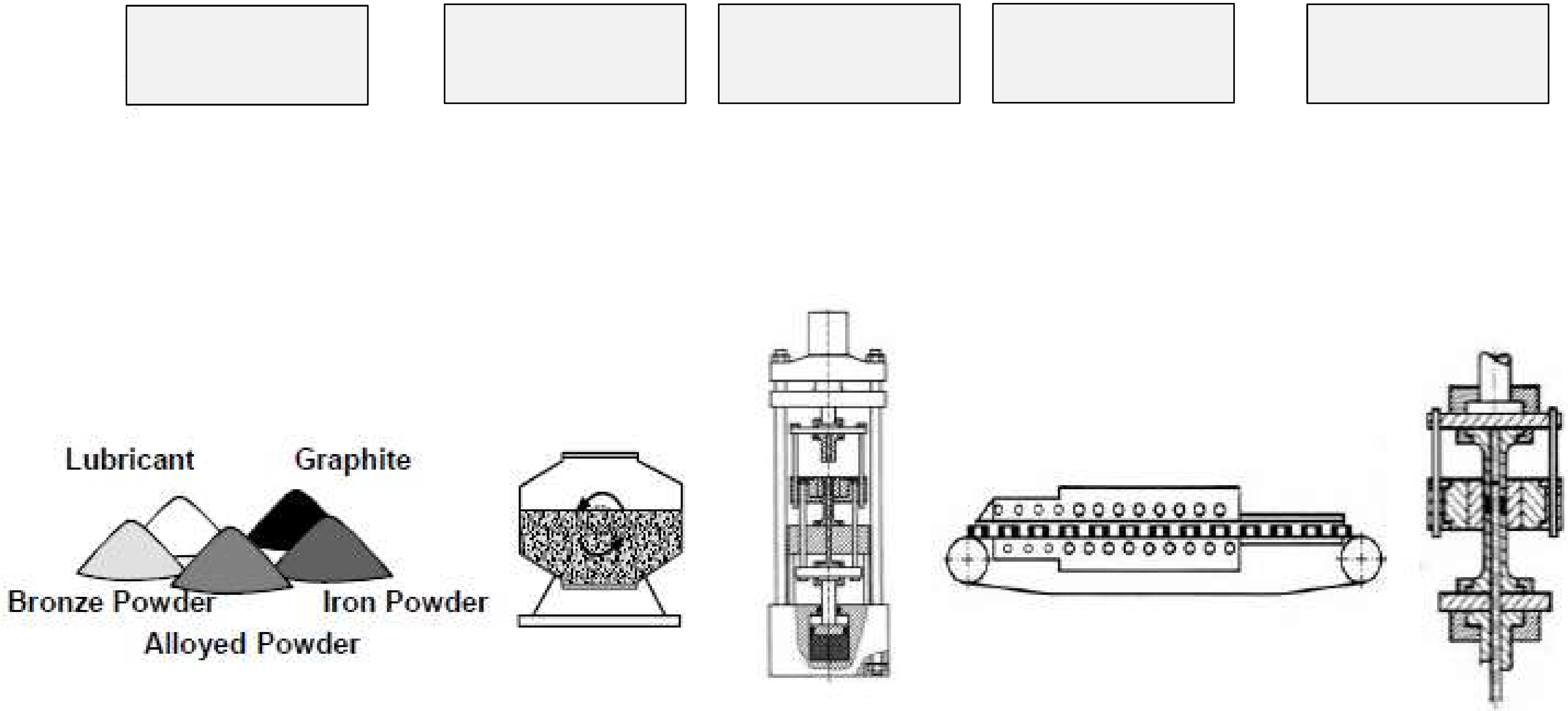
Task 1 – Sand casting

Label the figure of the sand casting process.



Task 2 - Powder technology

Label the figure shown below of powder technology.

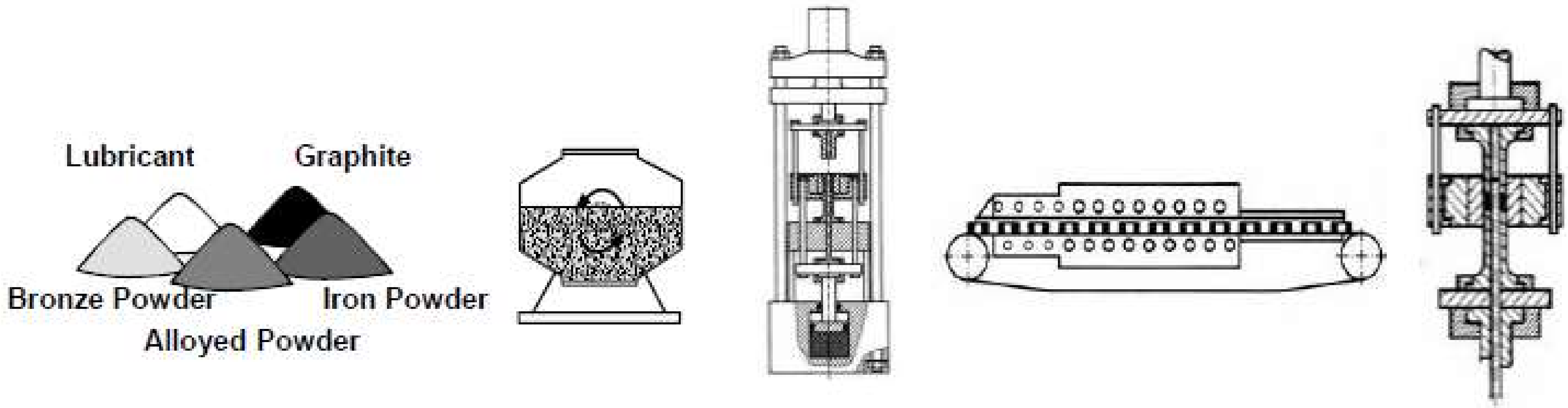


Source: RWTH Aachen University

Task 2 - Powder technology

Label the figure shown below of powder technology.

Powder production | Mixing | Pressing | Sintering | Sizing



Source: RWTH Aachen University

Task 3 – Additive manufacturing

Please name the full names of the following additive manufacturing technologies and name their function principle with a couple of keywords each:

SLS, FLM, 3DP.

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Task 3 – Additive manufacturing

SLS – Selective laser sintering : layerwise local melting of metal powder with laser

FLM – Fused layer modelling : wire/fibre from reel is melted with heated nozzle

3DP – 3D printing : layerwise ink jet printing with glue on powder

Task 4 – Additive manufacturing vs. cutting

Name at least four differences between additive manufacturing and cutting.

Task 4 – Additive manufacturing vs. cutting

Criterion	**Additive Manufacturing**	**Subtractive Manufacturing**
Process	Material is added layerwise	Material is removed
Final workpiece surface	Often rougher surface from layers; can be finished by e.g. sandblasting	Finishing directly possible on machine if required
Possibility of complex geometries	Possible	Difficult
Size of workpieces	Better suited for smaller parts	Depending on machine size big parts are possible
Workpiece materials	Especially plastic, but also metal, ceramics, glass	Especially metal, also e.g. wood, plastics, ceramics
Final part strength	Weaker (often small pores)	stronger
Speed of manufacturing	slow	fast
Training required	Often no machine operator necessary, training rather simple	CNC machinist required

http://www.manufacturinglounge.com/additive-vs-subtractive-manufacturing-whats-the-difference/

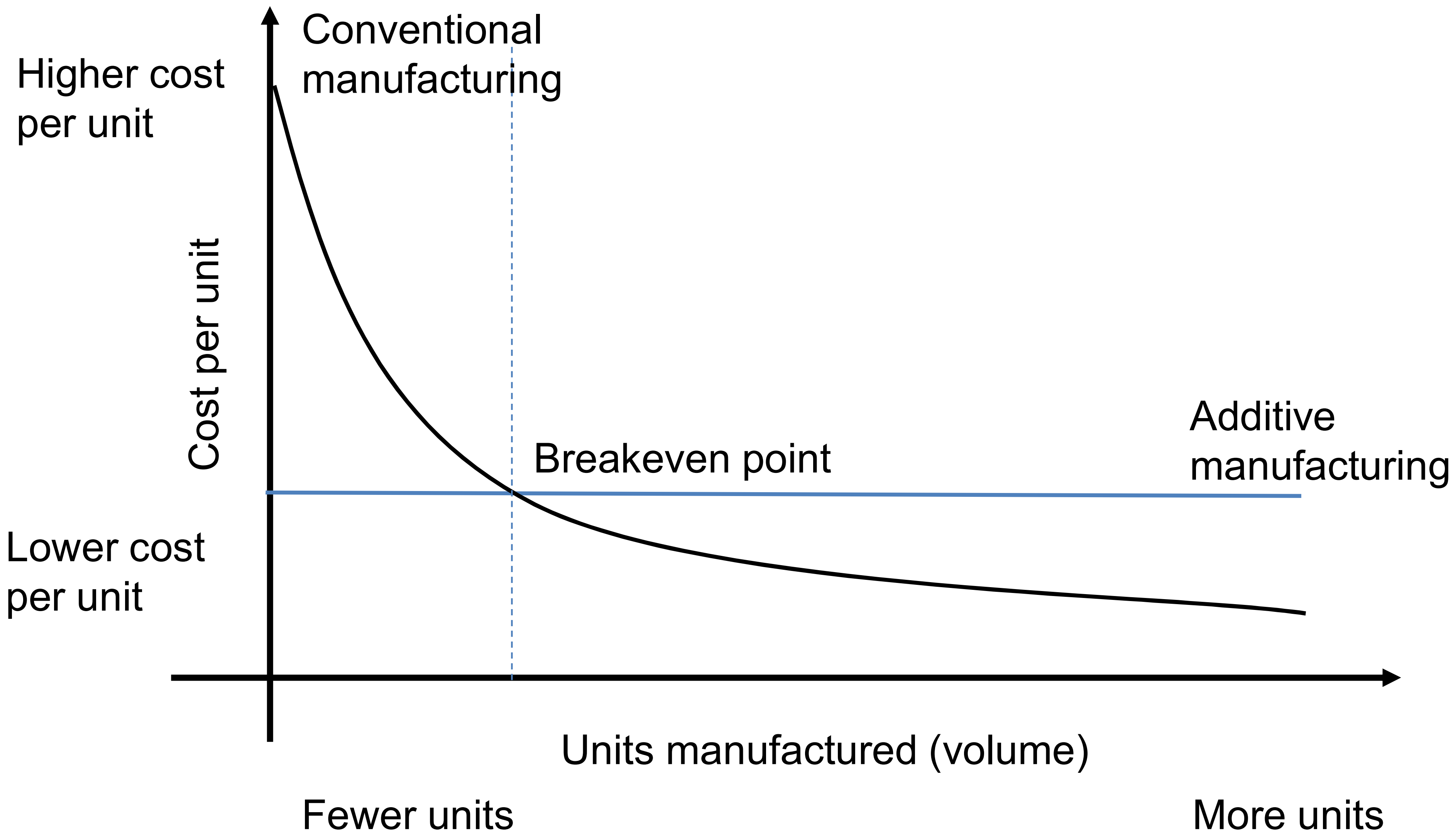
Task 5 – Cost comparison: additive vs. conventional manufacturing

Please reproduce and label the chart that describes the manufacturing cost per piece as a function of the number of units manufactured* for additive manufacturing and conventional manufacturing (as explained in the lecture).

Explain why the curves look like this (in brief words).

* Corrected on 18 June 2020 (earlier version: „geometrical part complexety“ instead of „number of units manufactured“)

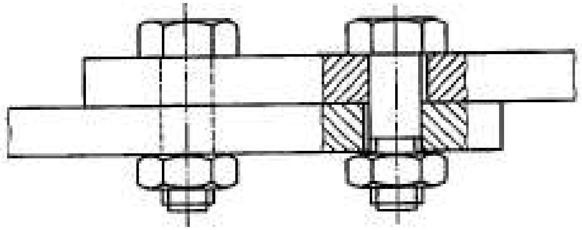
Task 5 – Cost comparison: additive vs. conventional manufacturing

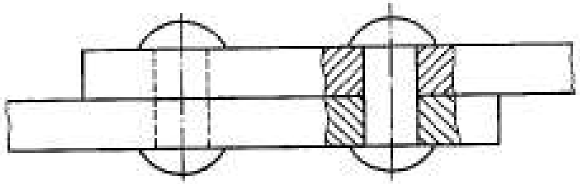


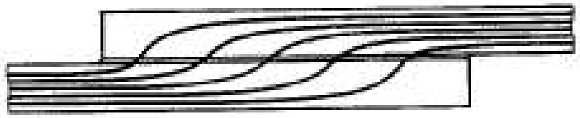
Source: Manufacturing technology, Introduction to additive manufacturing, Prof. Dr. Stephane Danjou, HSRW

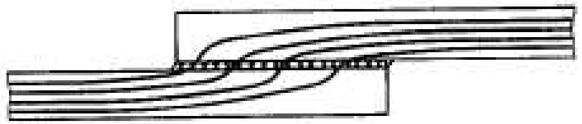
Task 6 - Joining

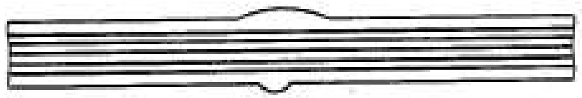
Name different connection types.







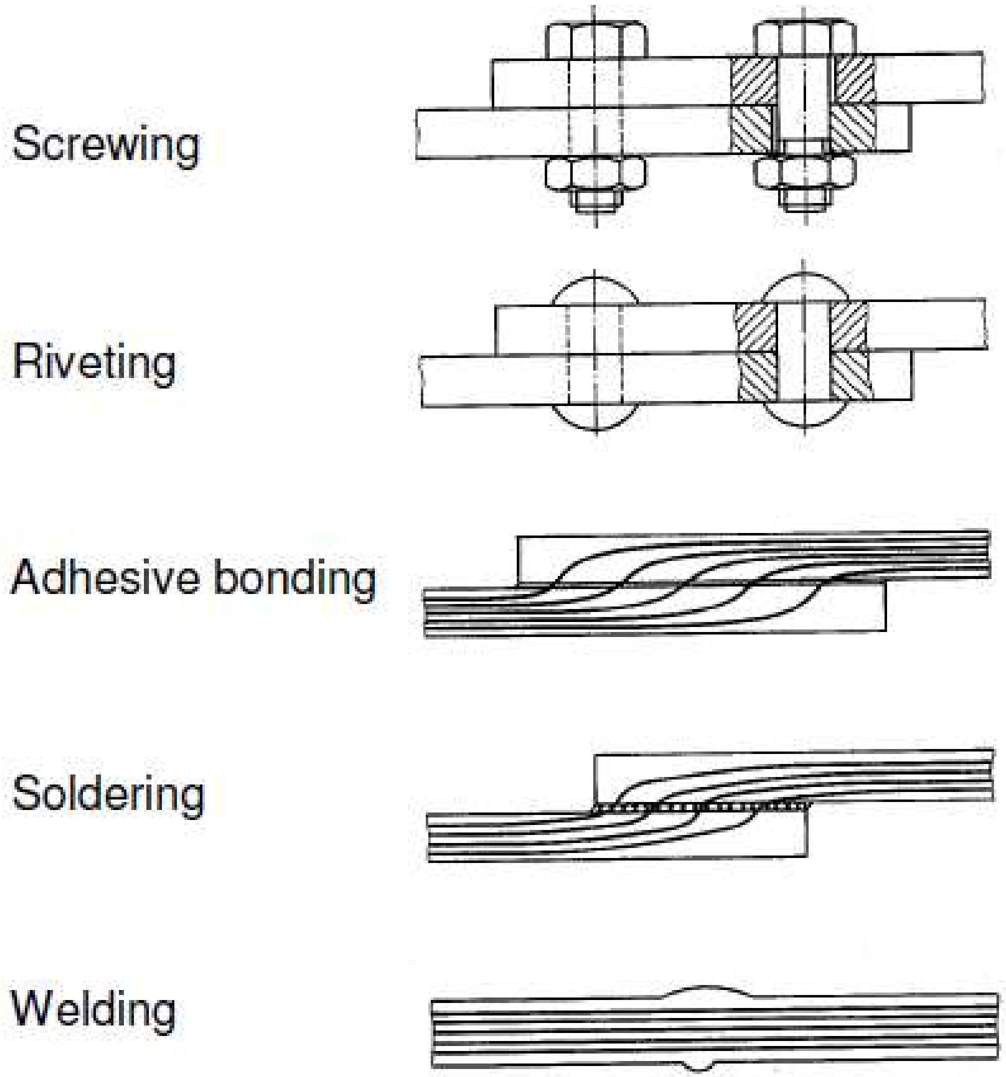




Source: RWTH Aachen University

Task 6 - Joining

Name different connection types.



Source: RWTH Aachen University

Multiple choice

What is one of the main advantages of additive manufacturing compared to subtractive manufacturing?

a) high degree of freedom with regard to workpiece geometry ✓

b) high strength of workpieces that can be achieved (e.g. compared to milled workpieces with same workpiece dimensions)

A typical sand casting process in which wooden patterns are used for mold making is a casting technology with...

a) reusable pattern and reusable mold

b) reusable pattern and lost mold ✓

c) lost pattern and reusable mold

d) lost pattern and lost mold

Injection moulding is....

a) ... a casting operation with lost mold

b) ... a casting operation with reusable mold ✓

c) ... a mold-making process based on addictive manufacturing (fused deposition modeling)

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Multiple choice

A thermal process for joining and coating material with a liquid phase obtained by filler material or by diffusion on boundary surfaces is called…

a) bonding
b) brazing ✓
c) riveting

Which of the following alloys' weldability is comparable to the weldability of stainless steel?

a) aluminium alloy
b) copper alloy
c) nickel alloy ✓

Fused deposition modeling is an additive manufacturing technology in which ...

a) powder is used as raw material the raw material is fed into the process as a vapor.
b) a fiber is used as raw material the raw material has liquid state (ink jet technology) ✓

Exercise 5

Manufacturing Technology 2020

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Task 1 – Machine tools

1) Name two examples of machine tools which have been designed for manufacturing of a very special workpiece (name workpiece and manufacturing technology)
2) What is the main advantage of such a machine?
3) What is the main disadvantage of such a machine?

Task 1 – Machine tools

1) Name two examples of machine tools which have been designed for manufacturing of a very special workpiece (name workpiece and manufacturing technology)
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3) What is the main disadvantage of such a machine?

1) e. g. camshaft grinding machine, gear hobbing machine
2) highest productivity
3) low flexibility/ only for this workpiece type

Task 2 - Machine tool components (Label the picture)

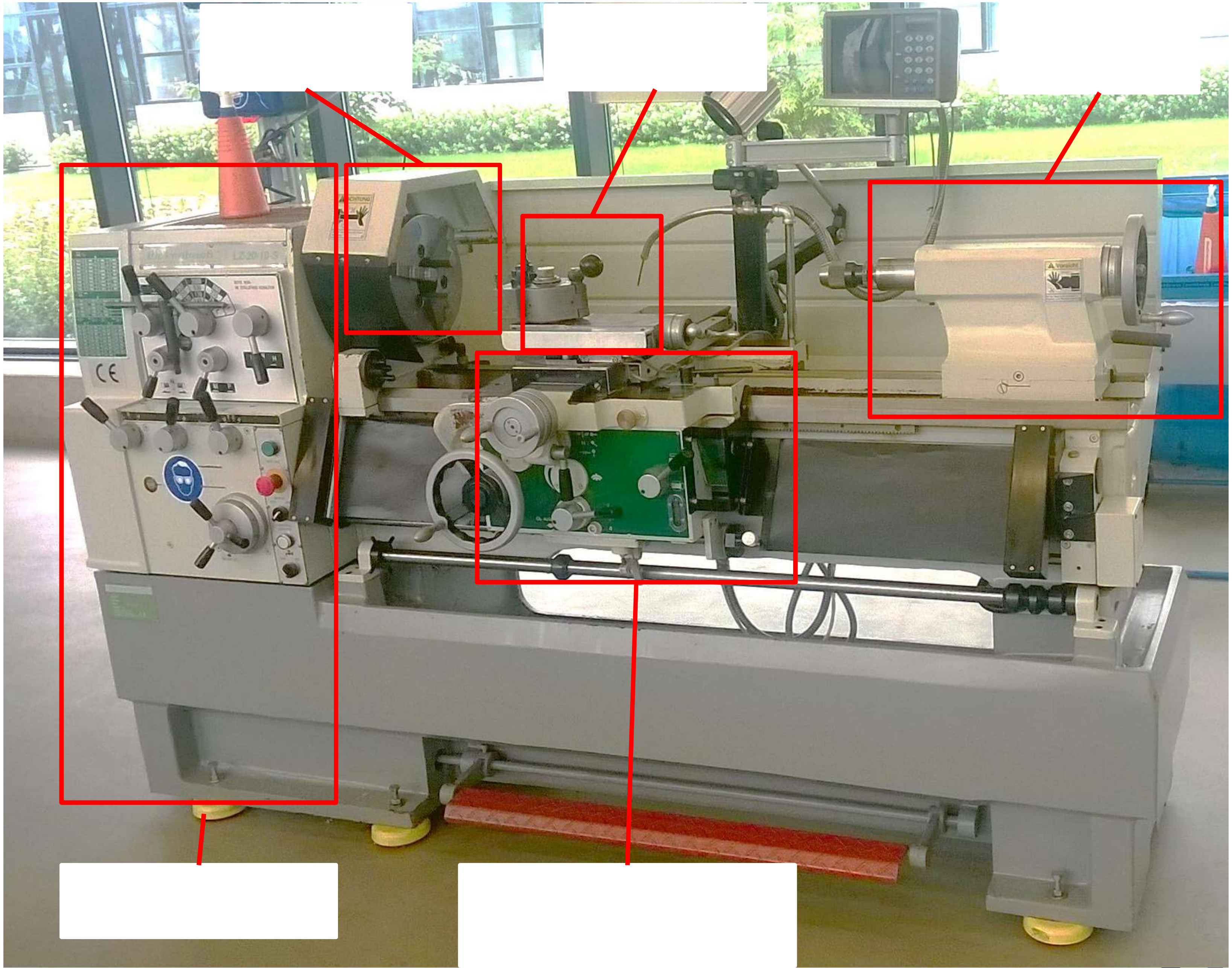

Photo: Rhine Waal University of Applied Science

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Rhine-Waal University of Applied Sciences

Task 2 - Machine tool components (Label the figure)

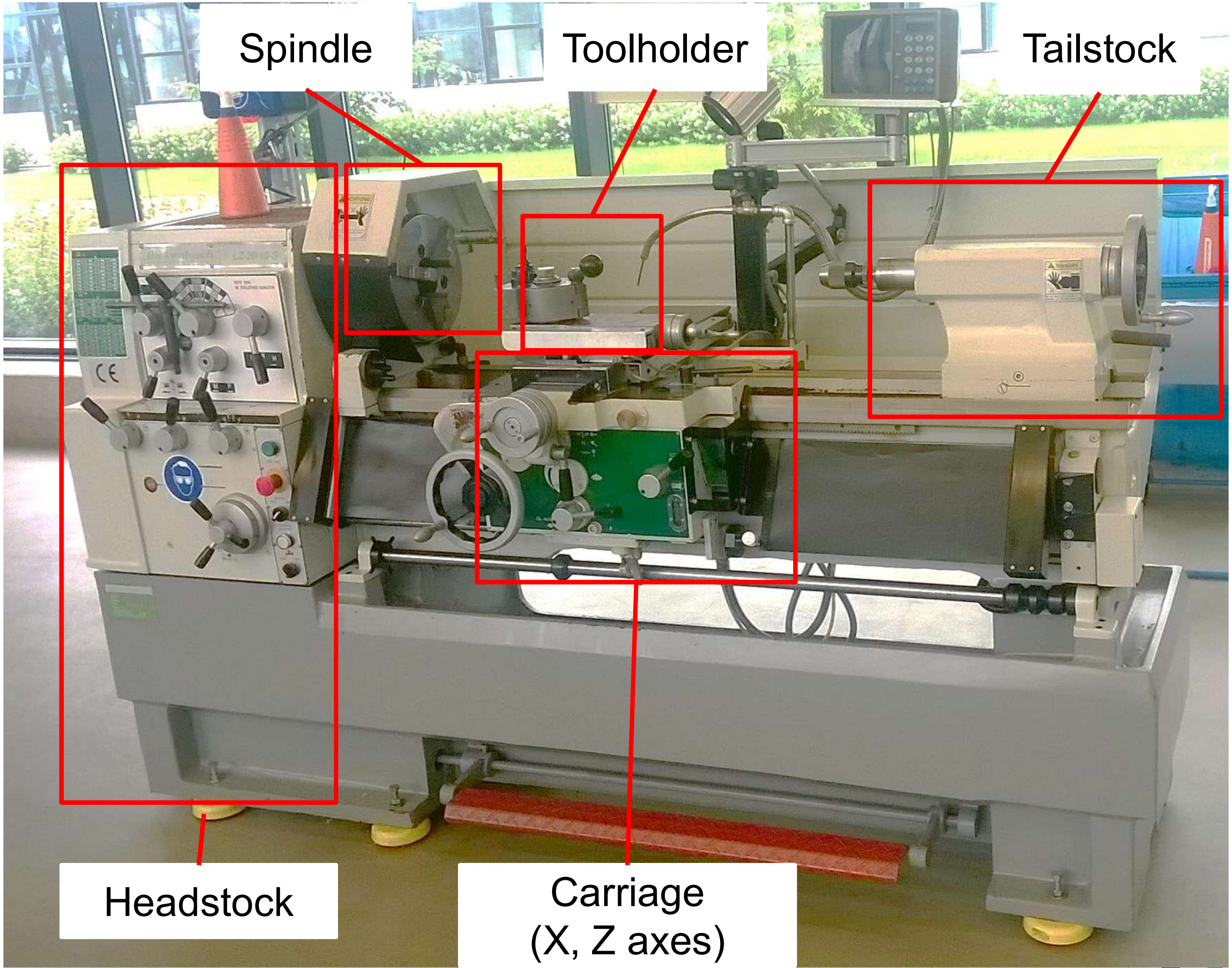


Photo: Rhine Waal University of Applied Science

Task 3 - SPC

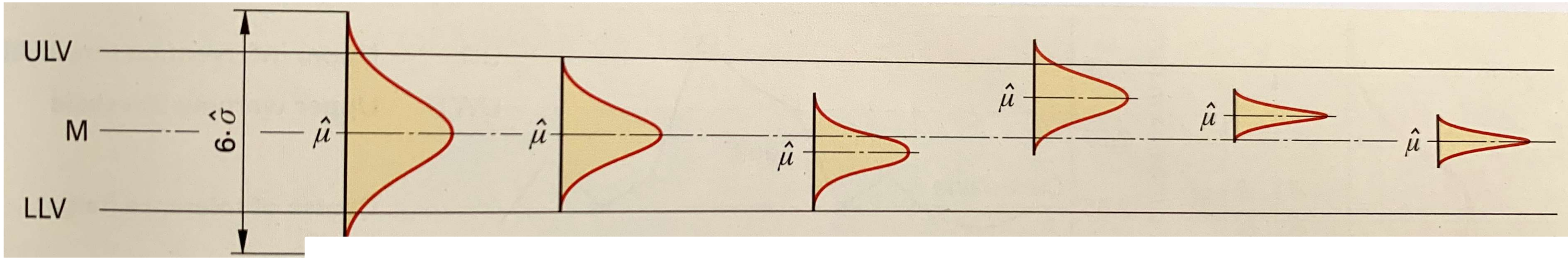
1) Explain the idea of "SPC" in quality assurance.
2) Also explain what the letters "SPC“ stand for.

Task 3 - SPC

1) Explain the idea of "SPC" in quality assurance.
    - measure dimension / features while batch is being manufactured
    - detect trends, runs, patterns etc.
    - react before scrap is produced
2) Also explain what the letters "SPC“ stand for.
    - statistical process control

Task 4 – Process capability

Which of these process capability curves indicate a good process?



Task 4 – Process capability

Which of these process capability curves indicate a good process?

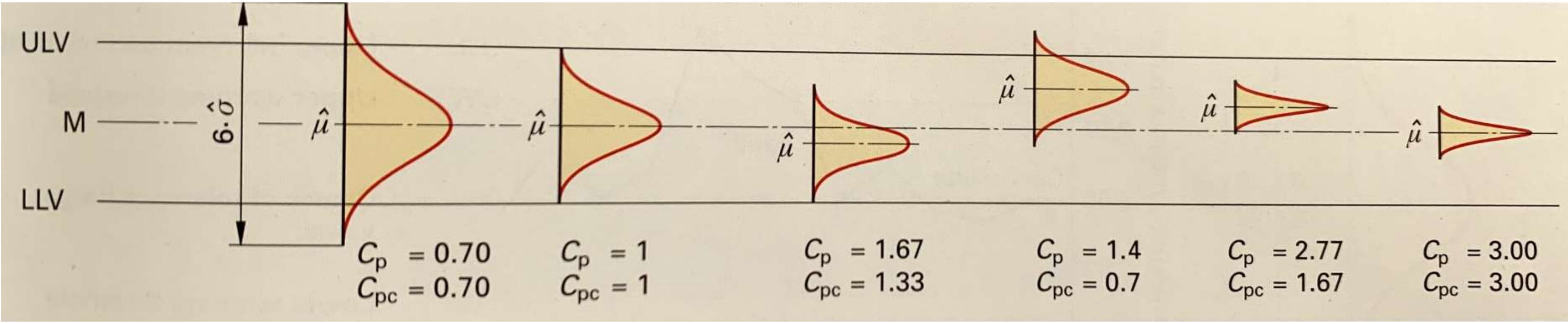
$$C_p = \frac{T}{6 \cdot \hat{\sigma}}$$

$$C_{pc} = \frac{\Delta_{crit}}{3 \cdot \hat{\sigma}}$$

Minimum requirements

$C_p \geq 1.33$

$C_{pc} \geq 1.33$



Multiple choice

The coating technology "electro plating" can be considered as a reversed...

a) PVD process
b) CVD process
c) ECM process ✓
d) EDM process

SPC allows to ....

a) ... change something in the process before the first piece of scrap is produced ✓
b) ... determine the cause of a problem in a very fact-based way

A process is called "cold forming" if...

a) the workpiece does not become warmer than 250 °C
b) the tool does not become warmer than 250 °C
c) the workpiece is not heated prior to the deforming process ✓

Multiple choice

The temperature range for recrystallization of steel is approximately...

a) 470-600 °C

b) 600-700 °C ✓

In the cutting tool material properties dilemma, what are the relevant material properties of the cutting material?

a) Hardness and toughness ✓

b) Thermal conductivity and hardness

Which material has the better machinability?

a) Steel ✓

b) Titanium

Dielectric is used in

a) Electro discharge machining ✓

b) Laser machining

c) Ultrasonic machining

d) Electrochemical machining

Multiple choice

Imagine you have a milling process with a spindle speed of 1500 rpm, a milling tool with 4 blades, a feed of 0.3 mm per blade and a rake angle of 12°. What is the feed rate?

a) 2160 mm/min
b) 1800 mm/min ✓

The type of tool used for turning is

a) Single point cutting tool ✓
b) Two point cutting tool
c) Three point cutting tool
d) Multi point cutting tool

The sum of rake, clearance and wedge angle is

a) 45 degree
b) 90 degree ✓
c) 180 degree
d) None