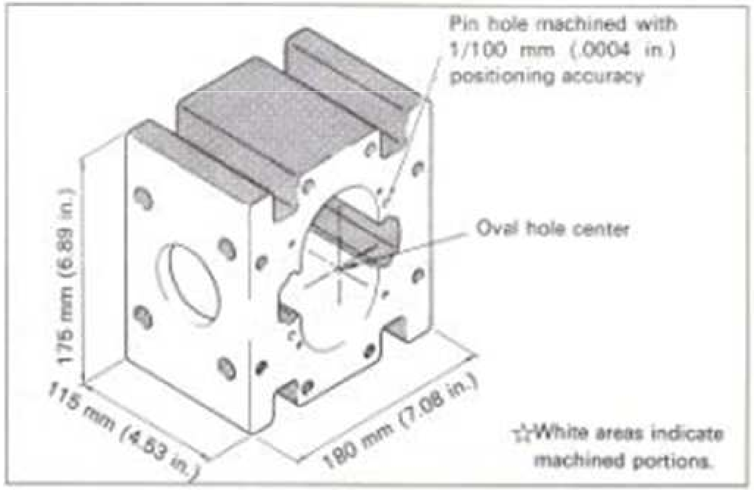
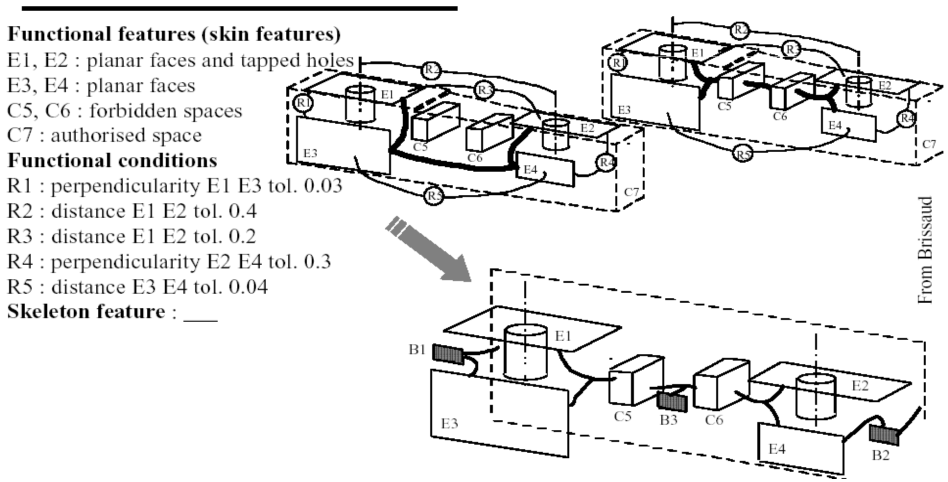
MANUFACTURING DEMAND, FUNDAMENTALS OF MANUFACTURING





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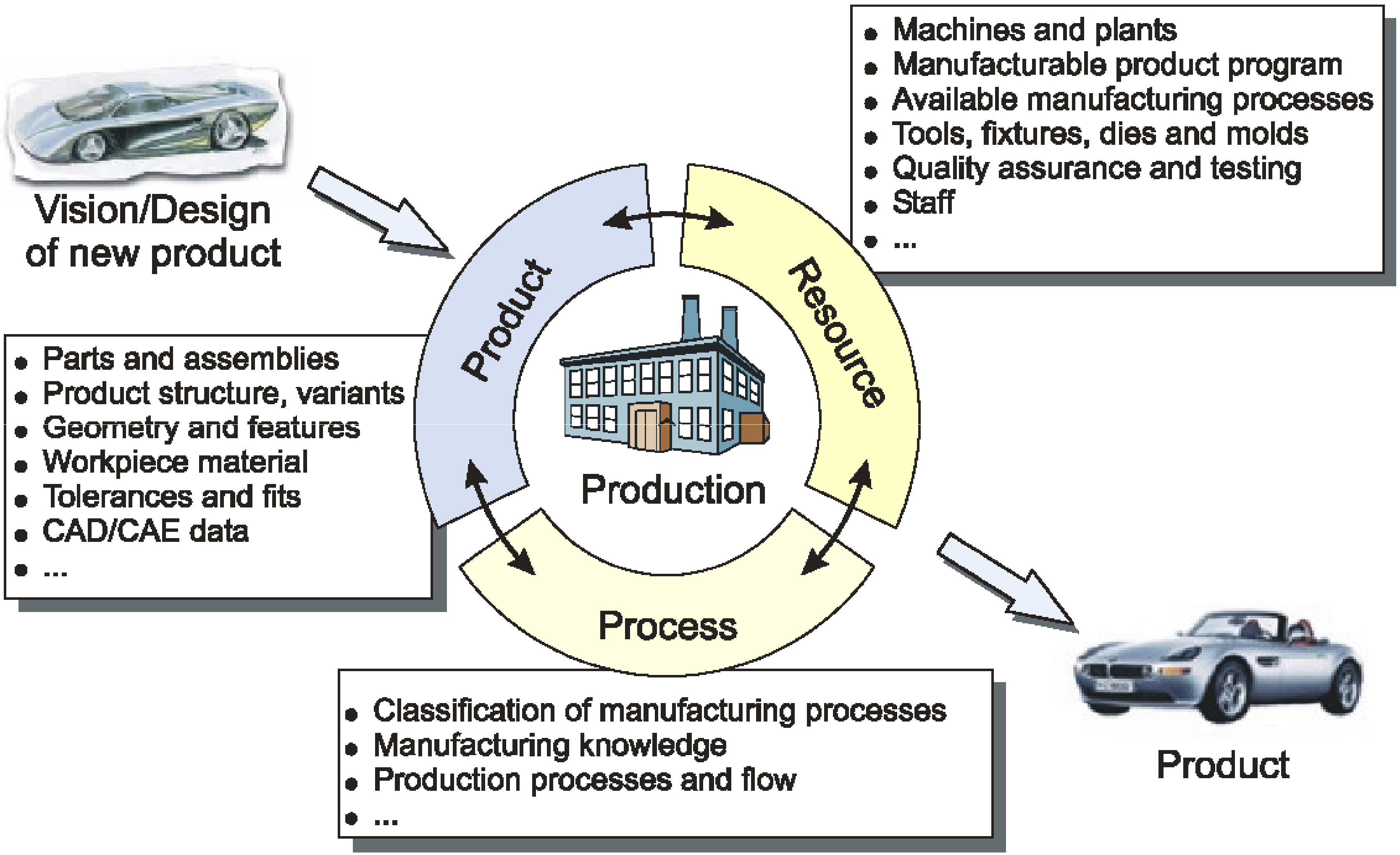
Production technology



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Production process

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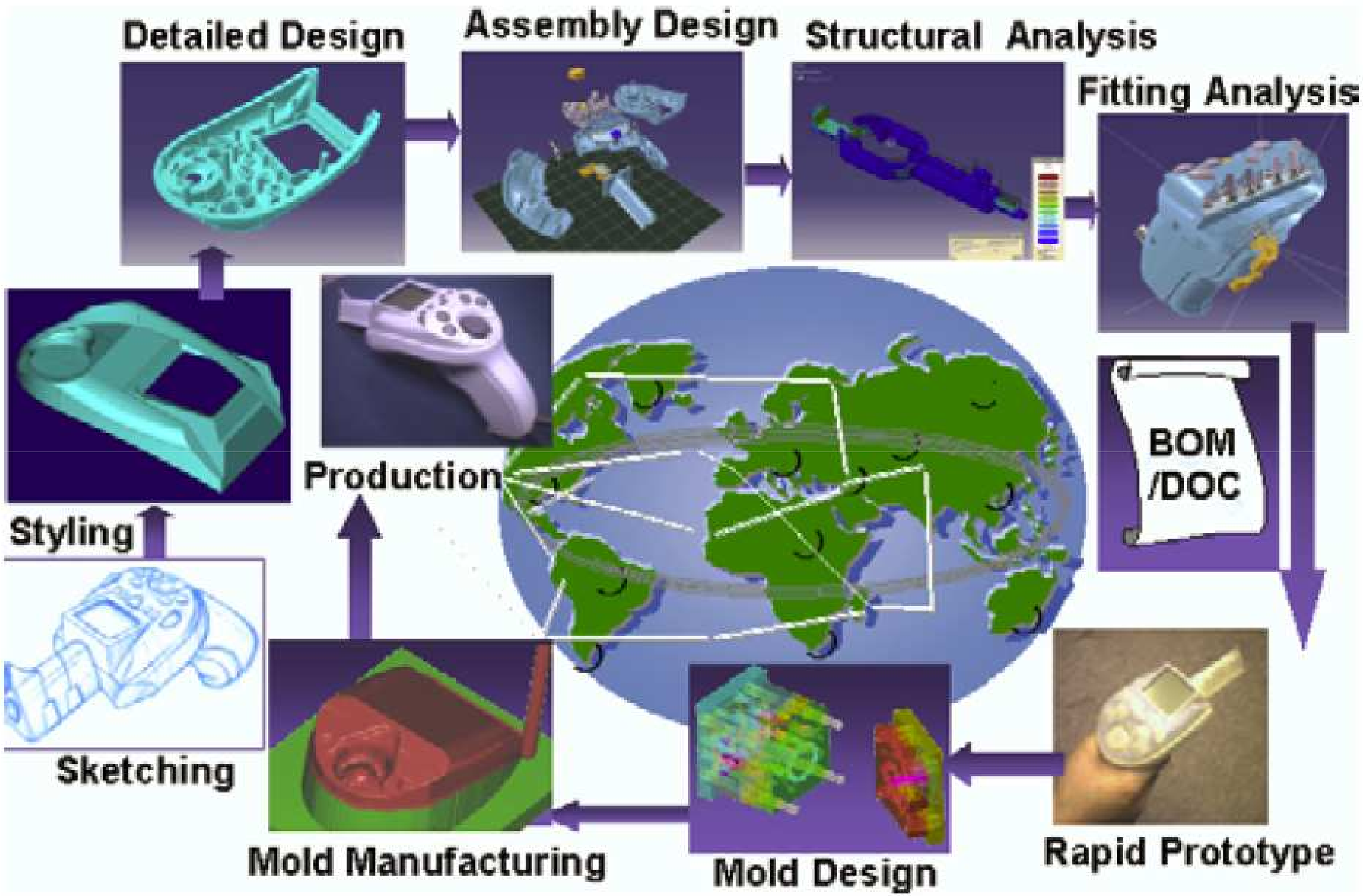
Virtual Production/Manufacturing



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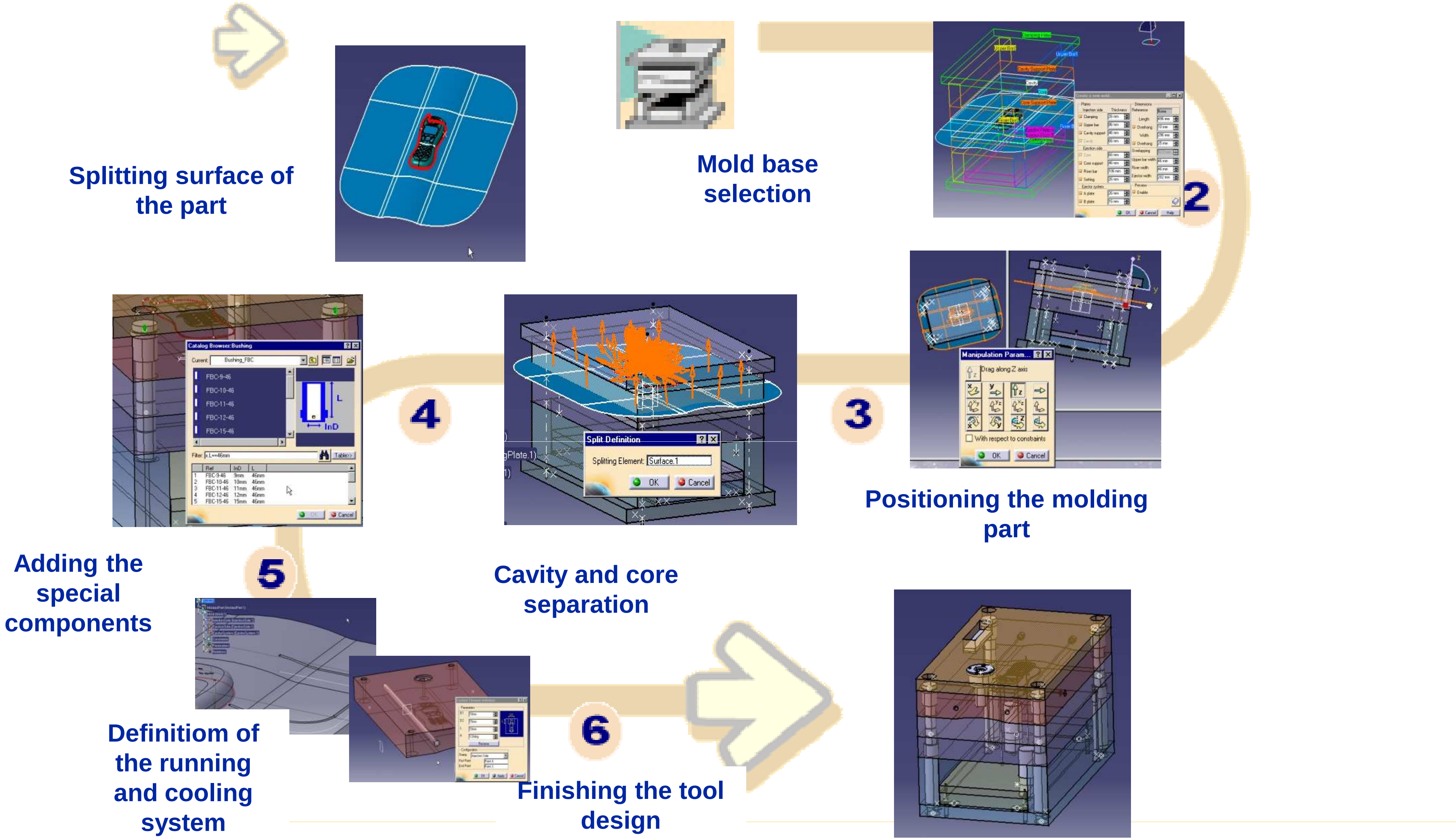
Design in integrated CAD/CAM environment



Interfaces

Manufacturing
- EDGECAM
- NC Post
- NC Tooling

Optimization
- ..
- Nesting

Re-Engineering
- ..
- Point Cloud

Simulation
- ..
- ..

Mechanism
- ..
- ..

STEP / IGES /STL / VRML / XML

Modeling
- SolidEdge
- ..

FE Pre & Post

Meshing
- ..

FE Solver
- ..
- ..
- ..

Design
- ..
- ..

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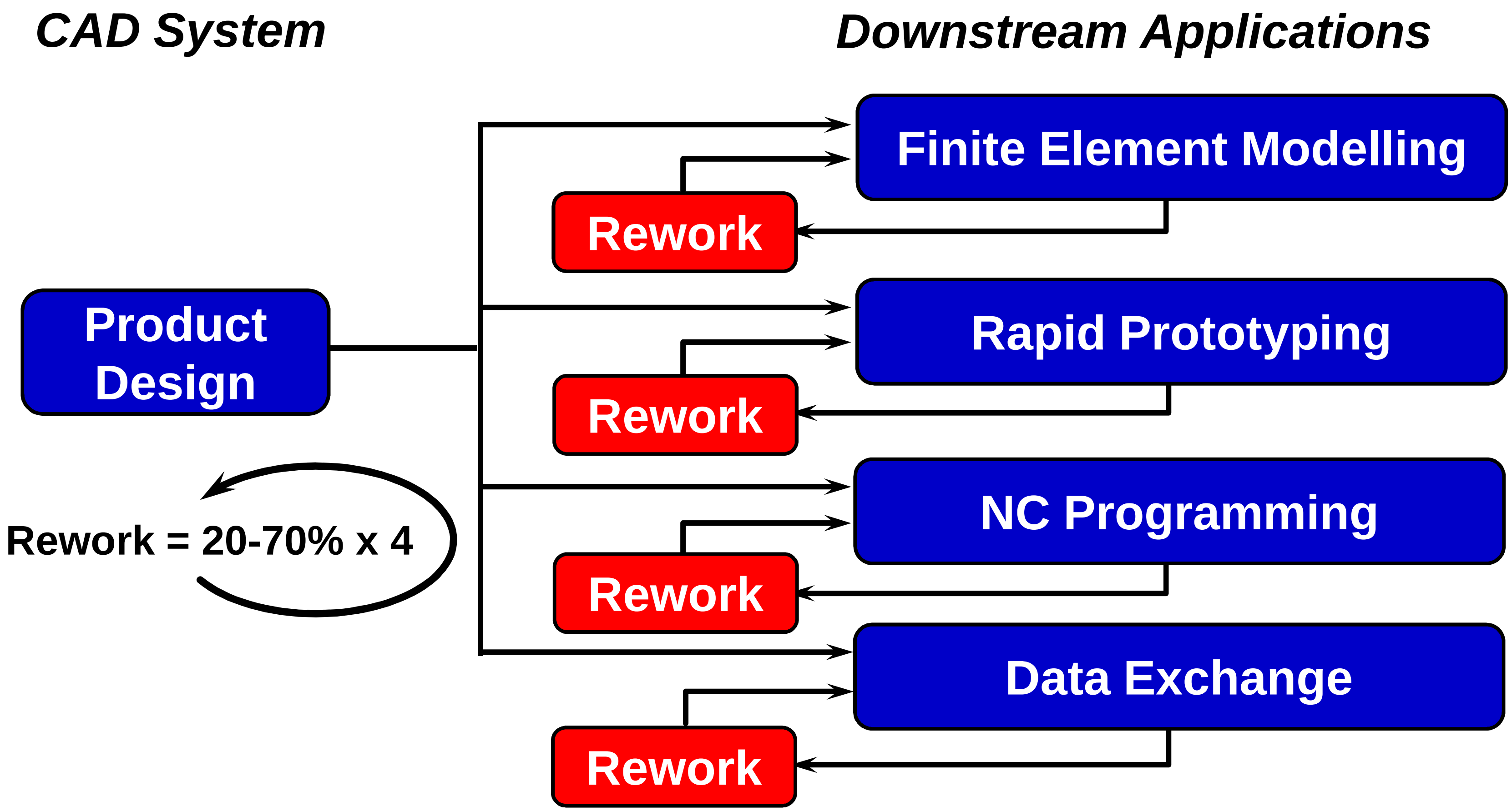
Costs: Downstream Rework Explosion



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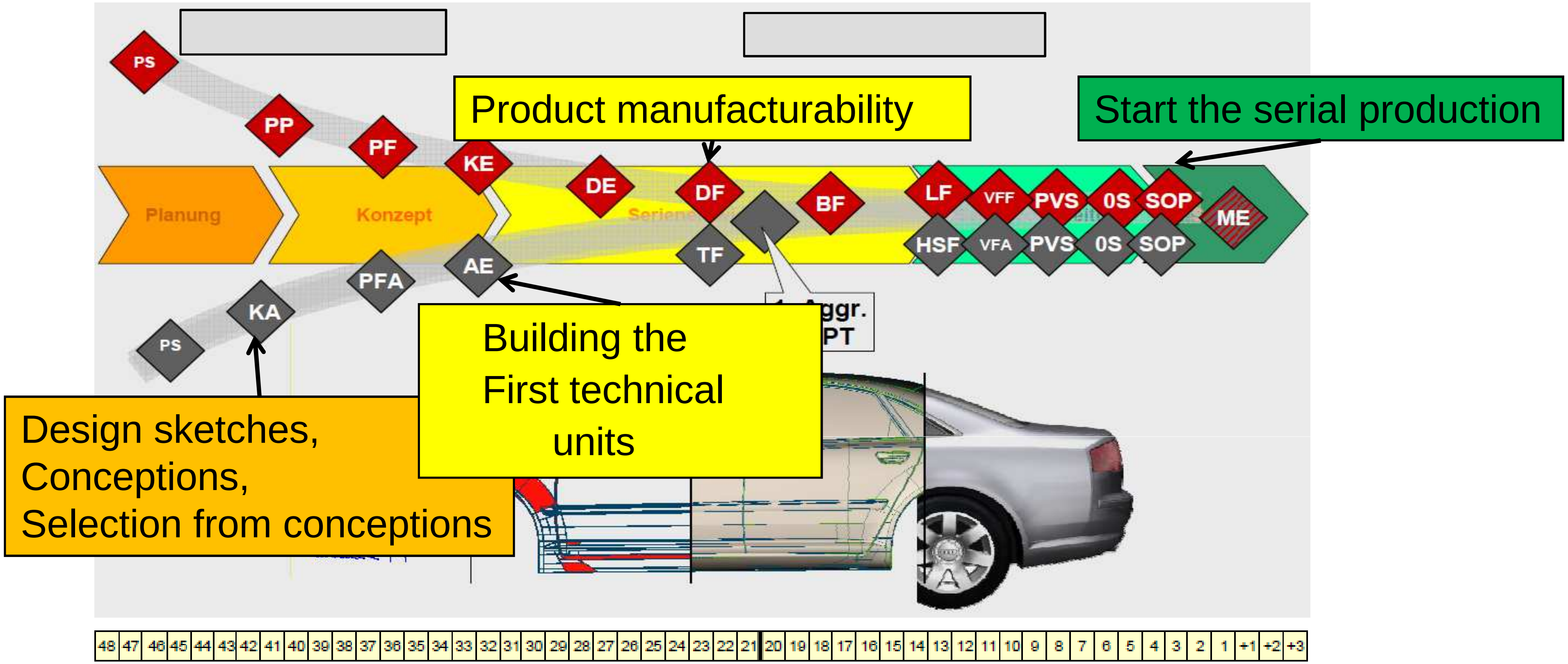
Product development



- **Prototype production**
- **„0" serial**
- The quality of the prototype production defined by the envirenment!

Forrás: AUDI

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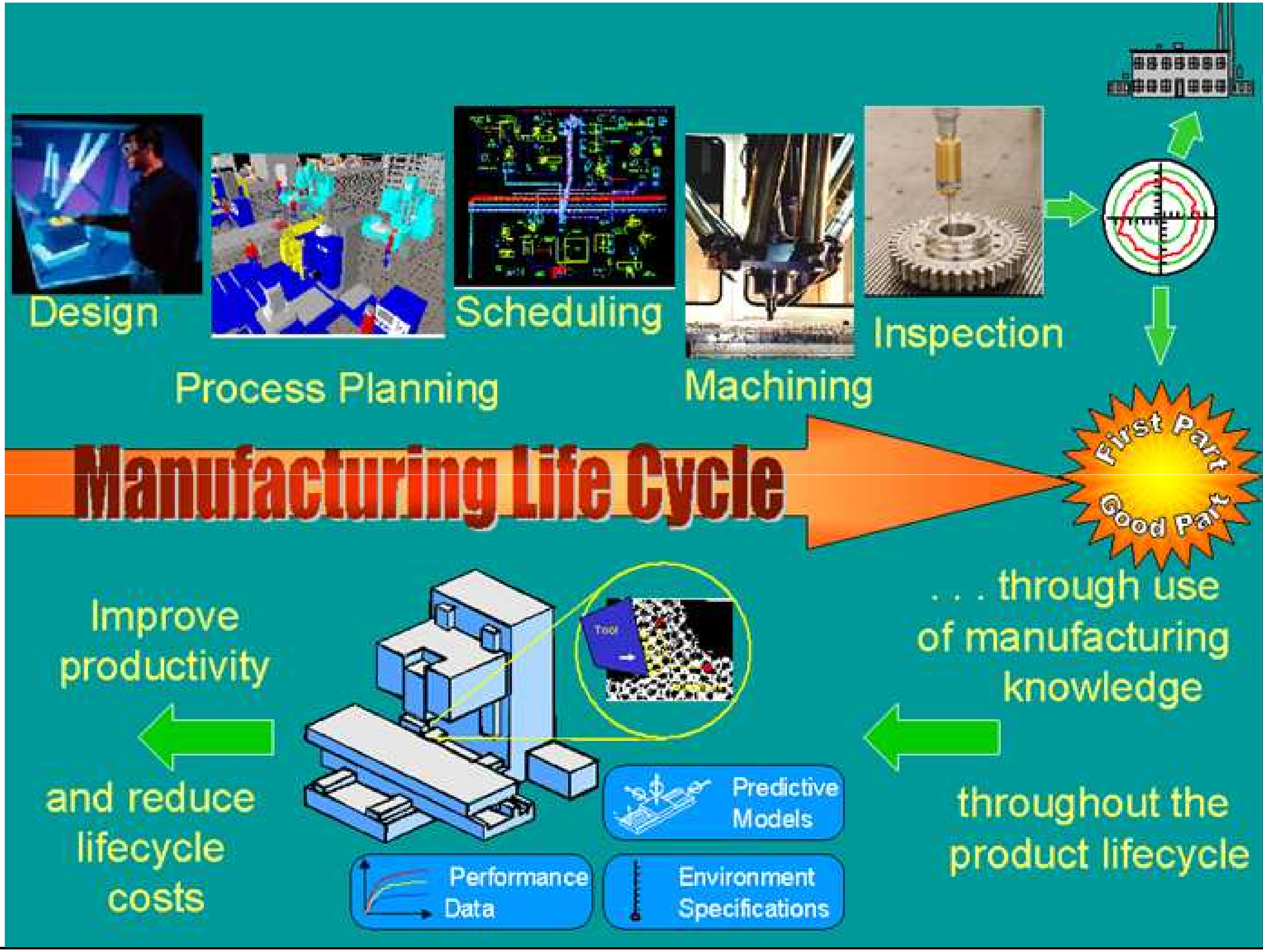
Manufacturing life cycle



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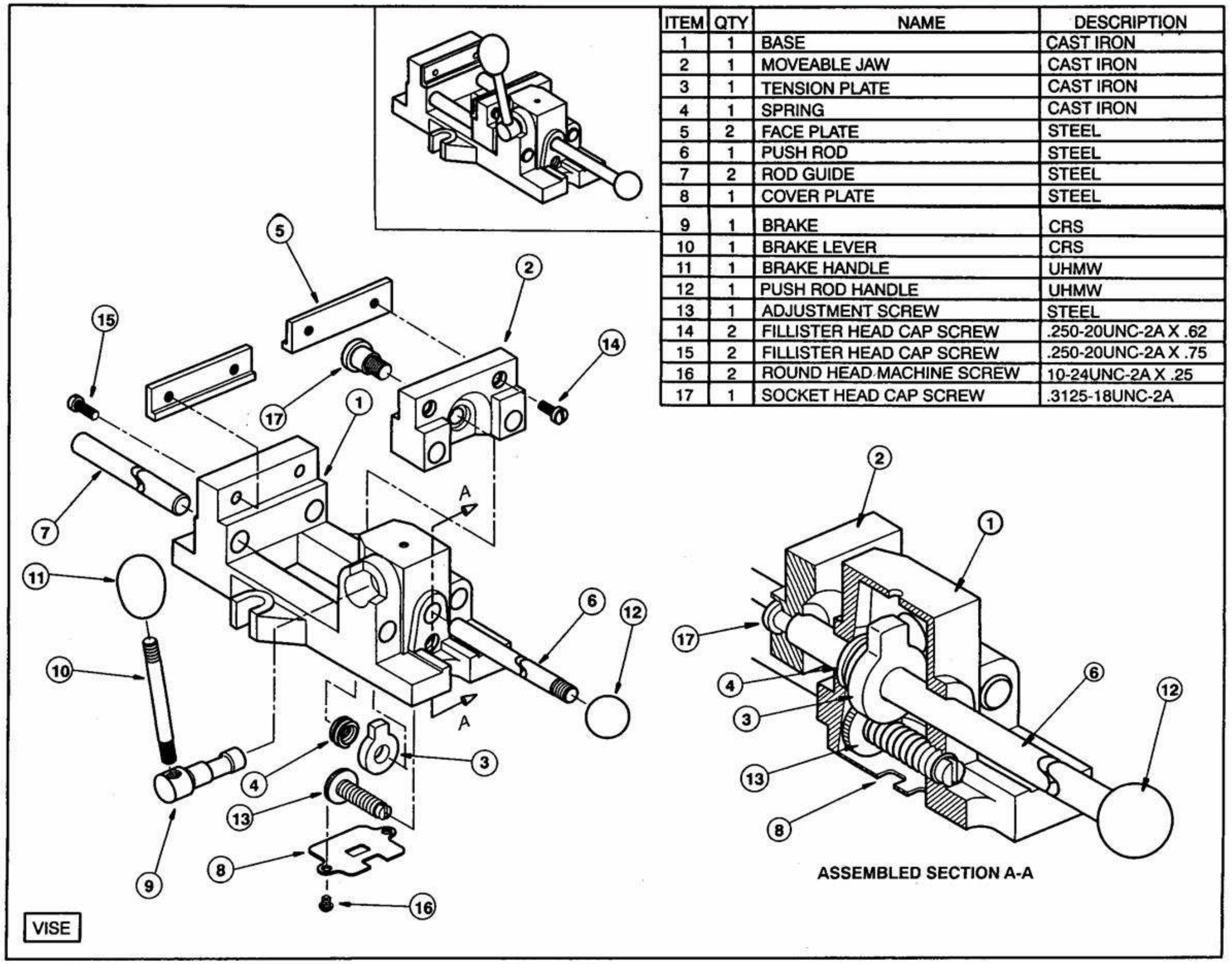
Assembled unit



ITEM	QTY	NAME	DESCRIPTION
1	1	BASE	CAST IRON
2	1	MOVEABLE JAW	CAST IRON
3	1	TENSION PLATE	CAST IRON
4	1	SPRING	CAST IRON
5	2	FACE PLATE	STEEL
6	1	PUSH ROD	STEEL
7	2	ROD GUIDE	STEEL
8	1	COVER PLATE	STEEL
9	1	BRAKE	CRS
10	1	BRAKE LEVER	CRS
11	1	BRAKE HANDLE	UHMW
12	1	PUSH ROD HANDLE	UHMW
13	1	ADJUSTMENT SCREW	STEEL
14	2	FILLISTER HEAD CAP SCREW	.250-20UNC-2A X .62
15	2	FILLISTER HEAD CAP SCREW	.250-20UNC-2A X .75
16	2	ROUND HEAD MACHINE SCREW	10-24UNC-2A X .25
17	1	SOCKET HEAD CAP SCREW	.3125-18UNC-2A

Screwless Vise

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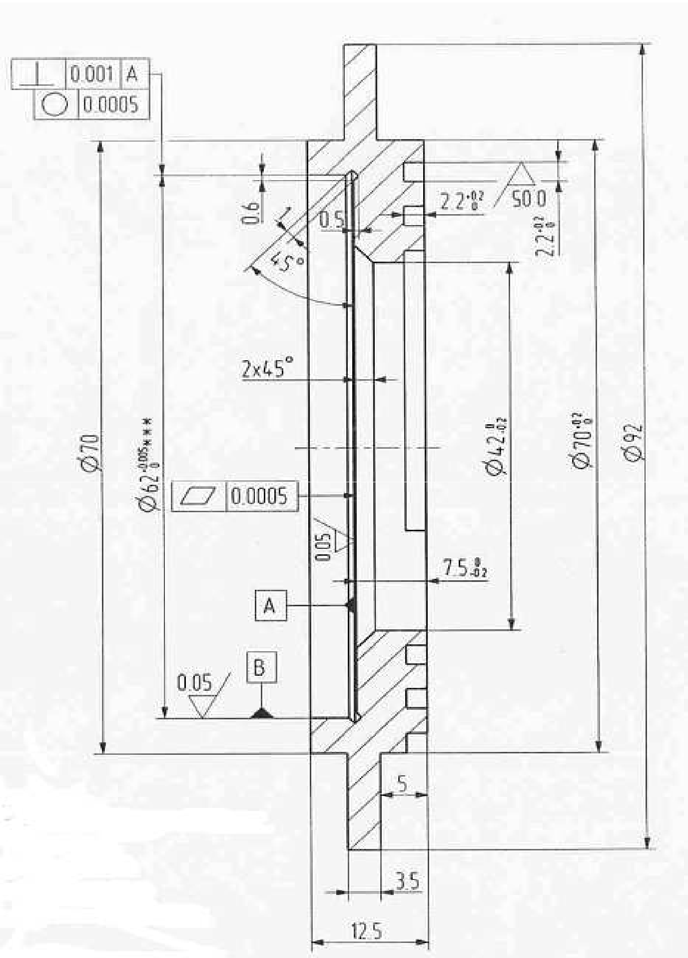
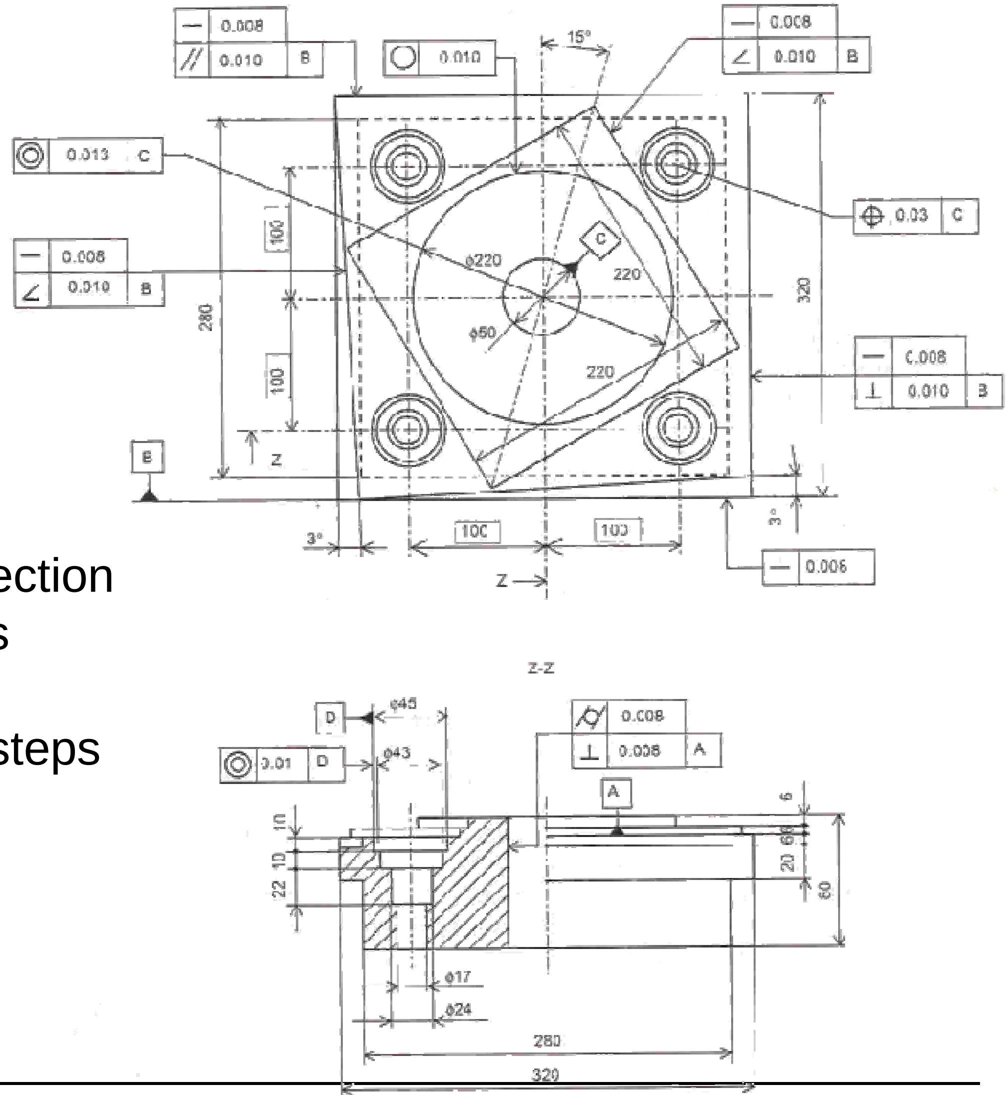
Ability of assembling

- Type of assembling
  - Manual assembling
  - Automatic assembling
  - Assembling by robots
- Analysis of the construction
- Dimension chain analysis, calculation of the closing member
- Assembling root and net
- Setting a minimum number of parts
- Determination of mounting pieces
- Assessment of the automatic assembling capabilities
- Assessment of the robotic assembling capabilities
- Time and cost calculation of the assembling process
- Calculation of efficiency indicators

Drawings, machining demands



- Datum selection
- Allowances
- Machining processes, steps



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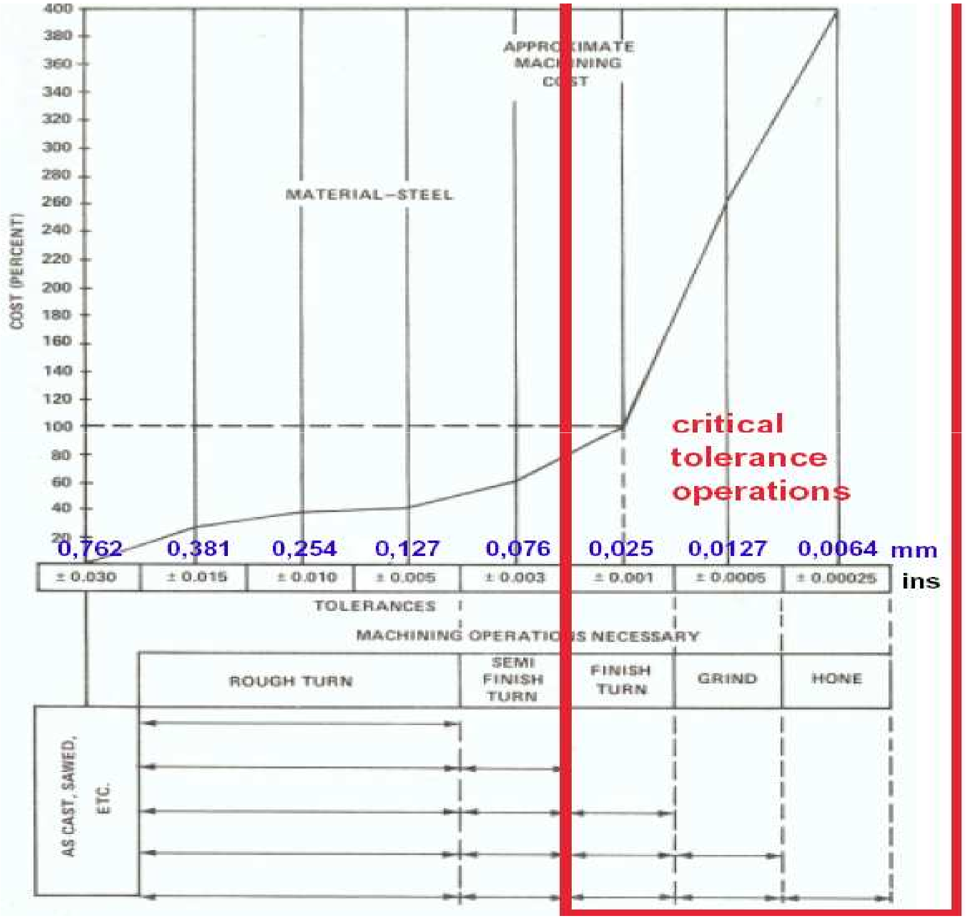
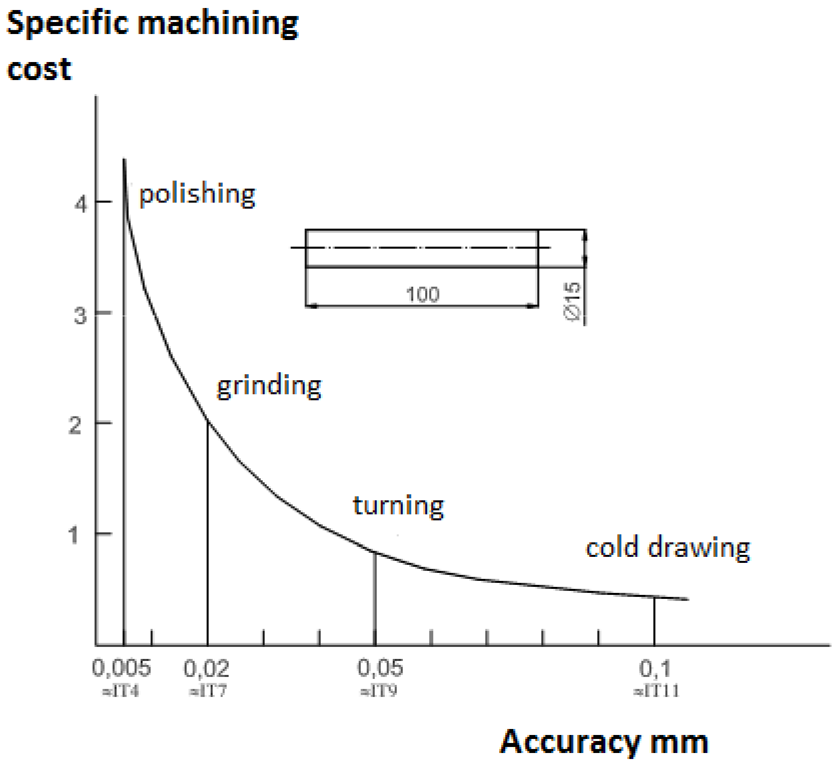
Accuracy requirements, cost





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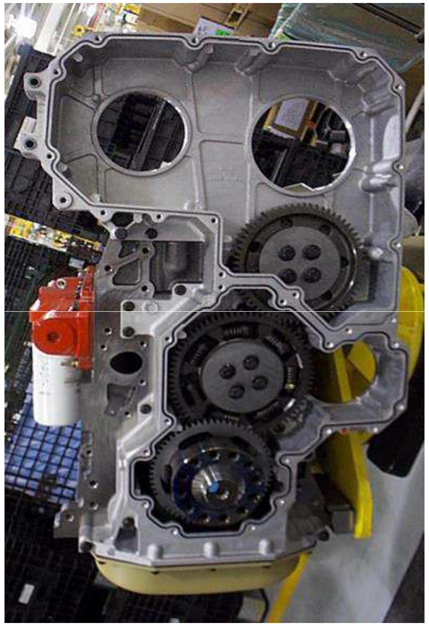
Design for Manufacturing (DFM)

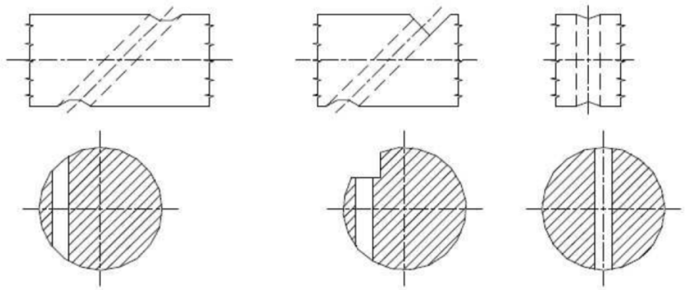
Definition: DFM is the method of design for ease of manufacturing of the collection of parts that will form the product after assembly.



'Optimization of the manufacturing process…'

DFA is a tool used to select the most cost effective material and process to be used in the production in the early stages of product design.

Machining:



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Design for Manufacturability Guidelines

A1) Understand manufacturing problems/issues of current/past products

to learn from the past and not repeat old mistakes

A2) Design for easy fabrication, processing, and assembly

Designing for easy parts fabrication, material processing, and product assembly is a primary design consideration.

P1) Adhere to specific process design guidelines.

It is very important to use specific design guidelines for parts to be produced by specific processes such as welding….,

P2) Avoid right/left hand parts.

Avoid designing mirror image (right or left hand) parts. Design the product so the same part can function in both right or left hand modes.

P3) Design parts with symmetry.

Design each part to be symmetrical from every "view„.

Design for Manufacturability Guidelines

P4) If part symmetry is not possible, make parts very asymmetrical.

The best part for assembly is one that is symmetrical in all views.

P5) Design for fixturing.

Machine tools, assembly stations, automatic transfers and automatic assembly equipment need to be able to grip or fixture the part *in a known position* for subsequent operations.

P6) Minimize tooling complexity by concurrently designing tooling.

Use *concurrent engineering* of parts *and* tooling to minimize tooling complexity, cost, delivery leadtime and maximize throughput, quality and flexibility.

P8) Specify optimal tolerances for a Robust Design.

Design of Experiments can be used to determine the effect of variations in all tolerances on part or system quality.

P9) Specify quality parts from reliable sources.

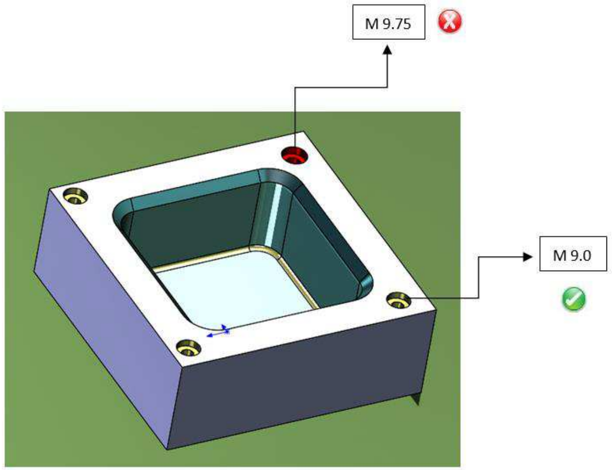
Design for Manufacturability Guidelines

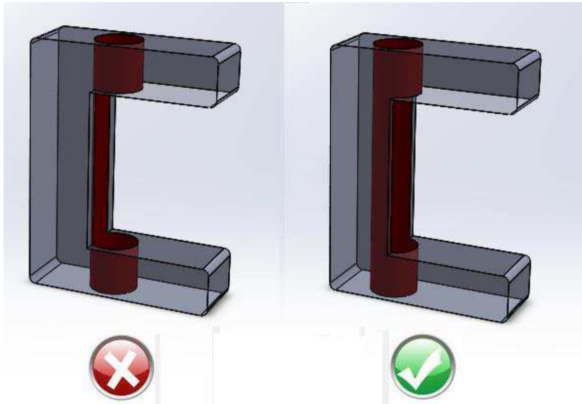
P10) Minimize Setups. For machined parts, ensure accuracy by designing parts and fixturing so all key dimensions are all cut in the same setup (chucking). Removing the part to re-position for subsequent cutting lowers accuracy relative to cuts made in the original position. Single setup machining is less expensive too.

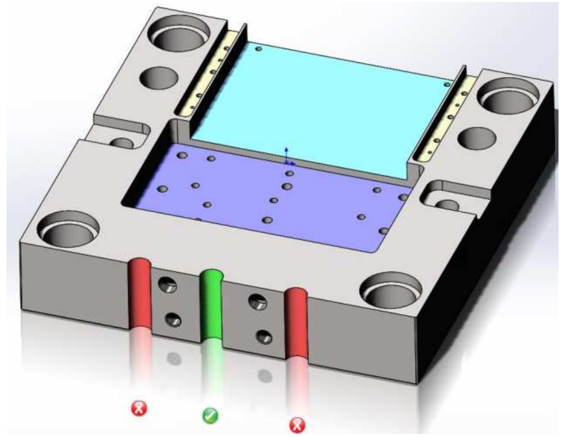
P11) Minimize Cutting Tools. For machined parts, minimize cost by designing parts to be machined with the minimum number of cutting tools. For CNC "hog out" material removal, specify radii that match the preferred cutting tools (avoid arbitrary decisions). Keep tool variety within the capability of the tool changer.

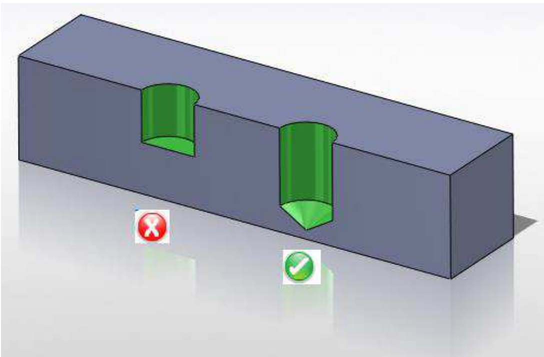
P12) Understand tolerance step functions and specify tolerances wisely. The type of process depends on the tolerance. Each process has its practical "limit" to how close a tolerance could be held for a given skill level on the production line. If the tolerance is tighter than the limit, the next most precise (and expensive) process must be used. Designers must understand these "step functions" and know the tolerance limit for each process.

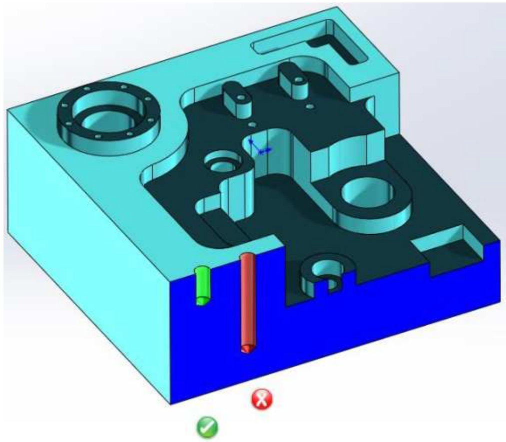
DFM Examples

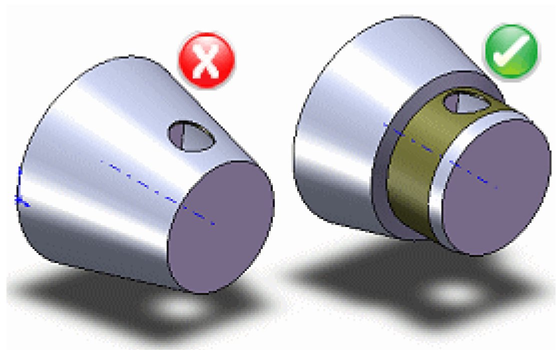












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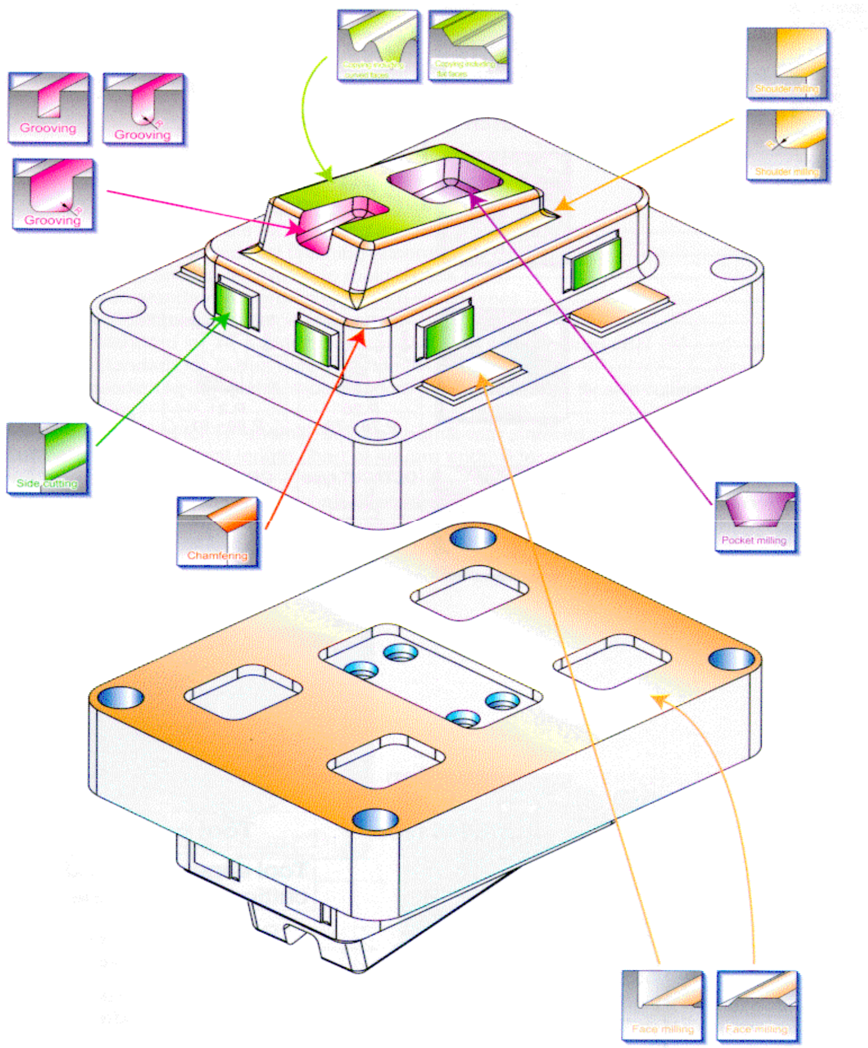
Machining demands (requirements)



- Milling (plane, pocket, groove, contour, surface, screws, rest…)
- Sparking (sinking, wire, orbital)
- Grinding (plane, cylindrical groove, screws..)
- Polishing
- Surface treatment (sand blasting, “skinning”..)
- Surface coating

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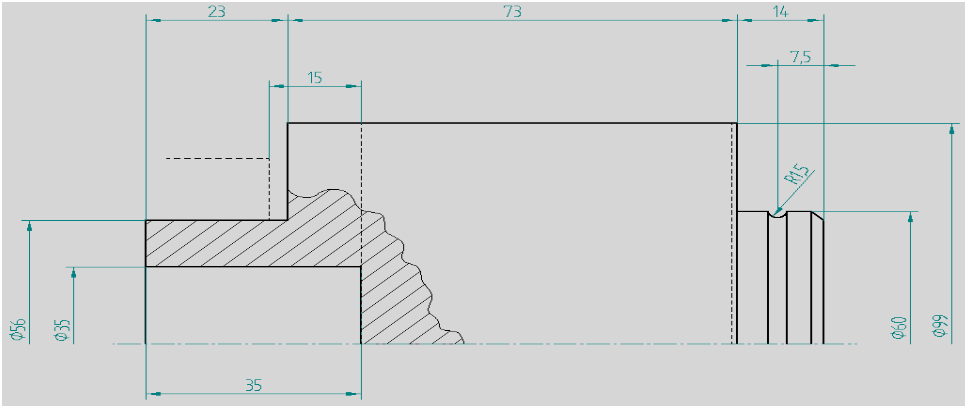
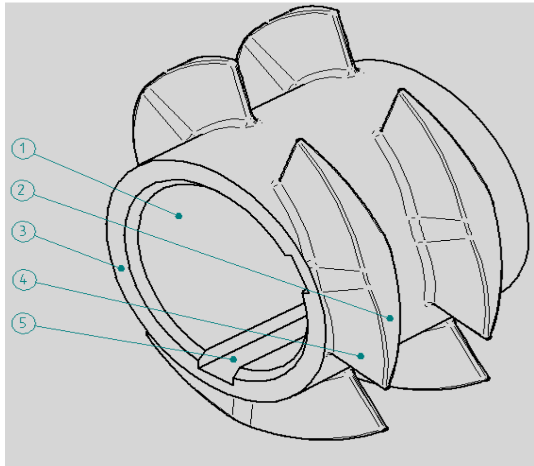
Analysis of the machining demands





No	Name	Dimension	Tolerance	Ra	Machining
1	Fixing hole	∅65±0.02		3.2	Drilling Boring Chamfering
2	Outside diameter	∅99±0.01		1.6	Rough turning Fine turning
3	Face	60±0.02	p ±0.03	1.6	Rough turning Fine turning
4	Extruder wing			0.025	Rough milling Fine milling Rounding Polishing
5	Keyways 2 times.	10.2 +0.05 0	p ±0.1,	3.2	Shaping

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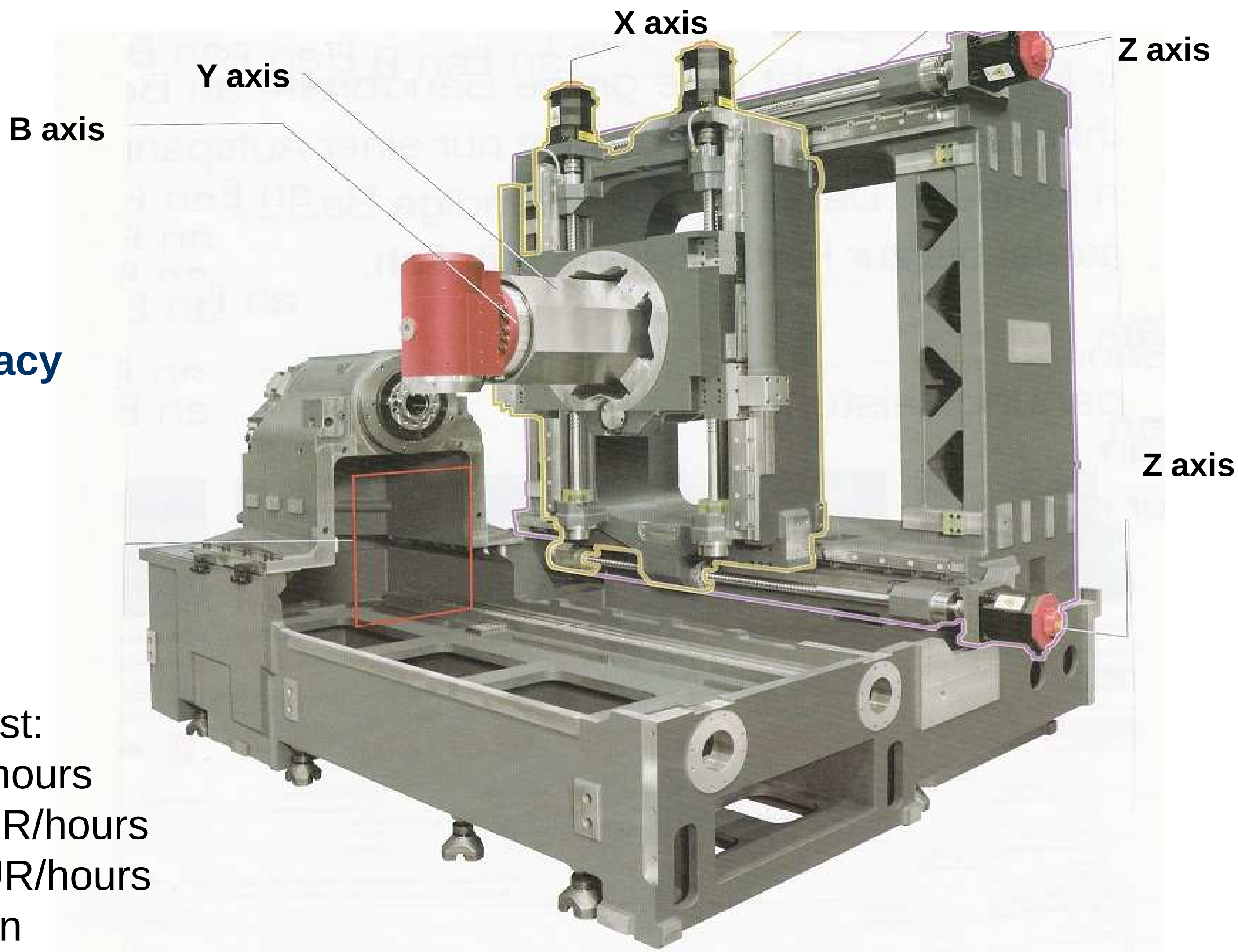
Manufacturing, machining environment

Compliance:

- ❑ **Functionality**
- ❑ **Flexibility**
- ❑ **Positioning and repetition accuracy**
- ❑ **Spindle speed**
- ❑ **Rigidity**
- ❑ **Damping**



Specific machine cost:
Classical: 15 EUR/hours
3 ax NC: 20 - 40 EUR/hours
5 Ax NC:40 - 70 EUR/hours
Depent on dimension

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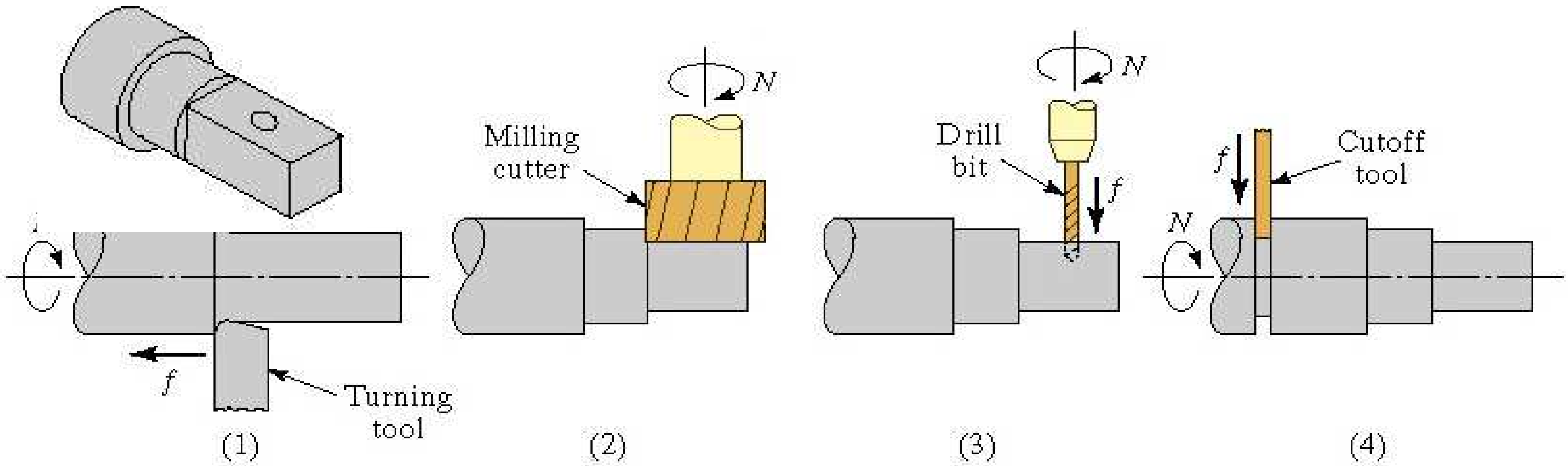
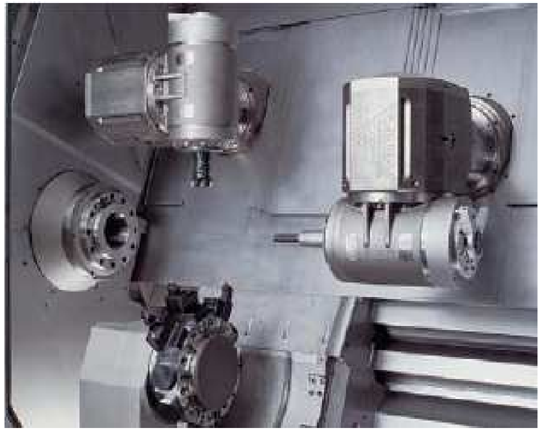
Integrated manufacturing

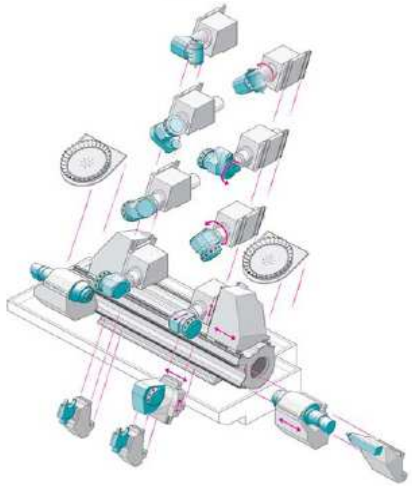
- Drill - Chamfering – Thread milling tools
- Boring bars
- …..
- Milling – Drilling
- Milling – Drilling – Turning
- Milling – Drilling – Turning – Grinding
- Milling – Drilling – Turning– Grindings – Laser „milling"
- …..
- Turning – Drilling
- Turning – Drilling – Milling
- Turning – Drilling – Milling – Gearing
- Turning – Broaching - Milling
- ….
- Wire EDMing
- Wire EDMing– Water jet machining
- ..

Integration of machining processes





1. Turning
2. Plane milling
3. Drilling
4. Grooving



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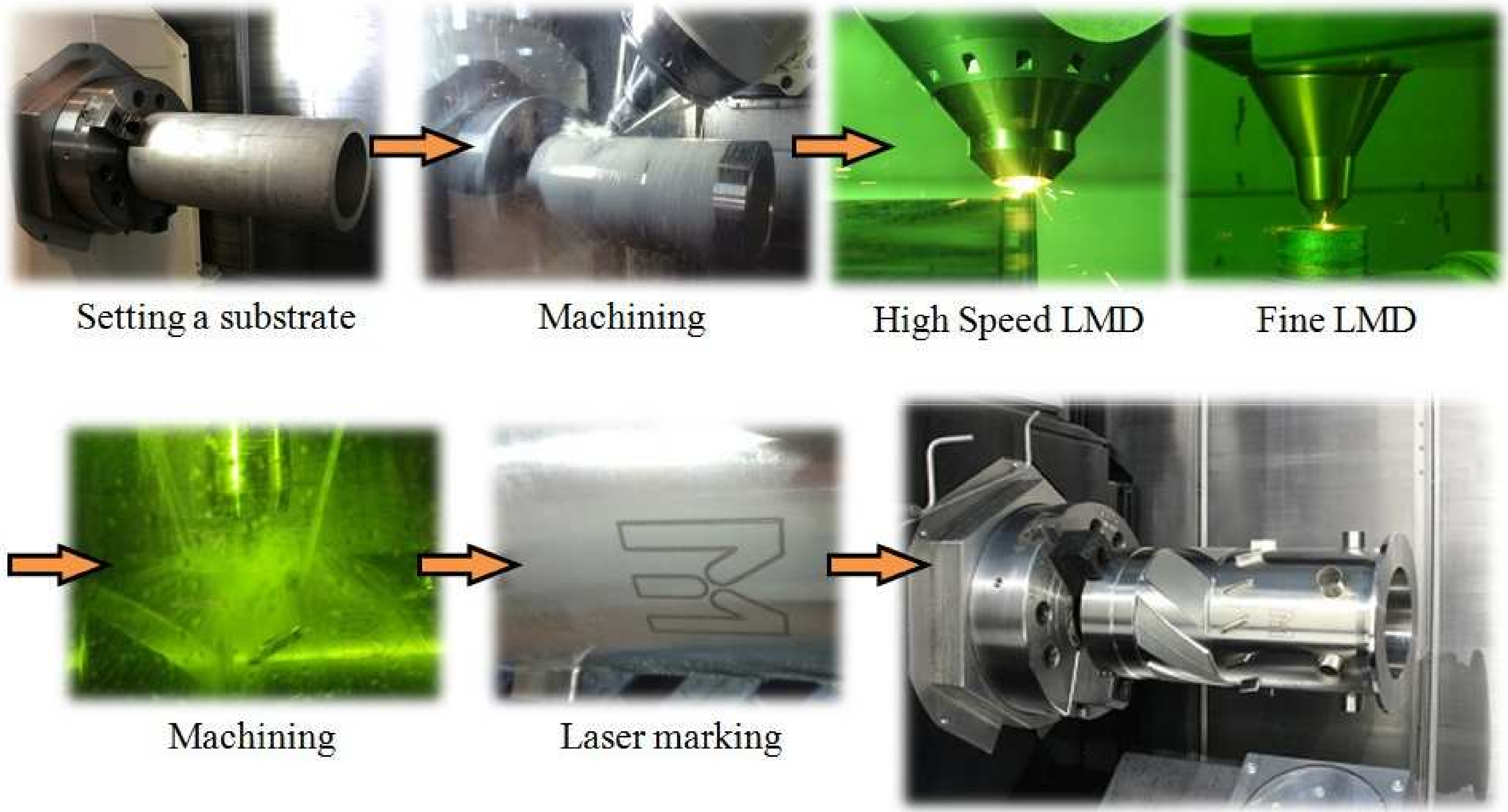
Hybrid machining



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Manufacturing

Types of manufacturing:

Single: $T_0 = t_{ü}/t_n > 20$ one or some workpiece production, by using universal machines, cutting tools and fixtures (NC, CNC, e.t.g.)

Series: **20 <** $T_0 = t_{ü}/t_n > 2$ small- medium or large series part production using revolvers, semi-automatic machines, or NC, CNC machine tools

Mass: $T_0 = t_{ü}/t_n < 2$ more hundred of thousands workpiece production, special machine tools, special tools, process oriented preparation and manufacturing.

Continuous: The machine tool layout (organization) is based on the manufacturing sequence. (mass production)
Workshop based: The machine tool needed by one operation are grouped in one workshop. (single production)

Production and Manufacturing

Production: manufacturing + administration

Manufacturing: Process + storing and transportation

Process : metal forming (removing) process

Raw material	Production	Product
Bulk Sheet Wire Power	Pre-production Part-production Assembling	One type material, one or some pieces Several type of material, hundred thousand parts

PRE-PRODUCTION	**PART PRODUCTION**	**ASSEMBLING**
CASTING	**METAL CUTTING**	**JOINING**
WELDING	**GRINDING**	**SETTING, BALANCING**
DIEING	**SPARKING**	**SURFACE TREATMENT**
STAMPING	**COATING**	**CONSERVATION**
CUT-OFF	**HEAT TREATMENT**	**PACKAGING**
PRE_-PRODUCT	**PART**	**PRODUCT**

The hierarchy of manufacturing process

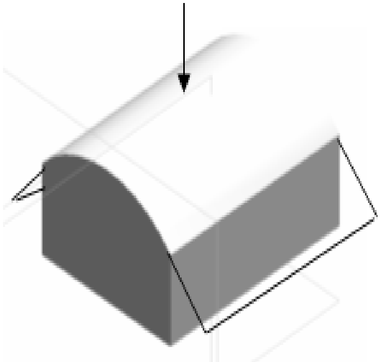
ETAP:	That period of production by which product parts reach the same state condition. Different types of operation. (pre-production, part-production , assembling)
GROUP OF OPERATION:	The same type of operations. (turning operations)
OPERATION:	Sum of activities which is realized in the same workpiece clamping on the same machine. An other definition: part of activity which is completed..
GROUP OF OPERATION ELEMENTS:	The same type of operation elements. (drilling operation elements)
OPERATION ELEMENT:	Metal forming or removing process realized on the same workpiece surface with the same tool, with the same cutting conditions. Sum of motions
MOTION:	People or machine made activities which has separated functions regarding the operation . (clamping, entry, clear. E.t.g.)
MOTION ELEMENT:	Activity which has not got separate function regarding the operation (start, switch, ..)

Surface generation methods

According motion geometry (Theory of the surface production):

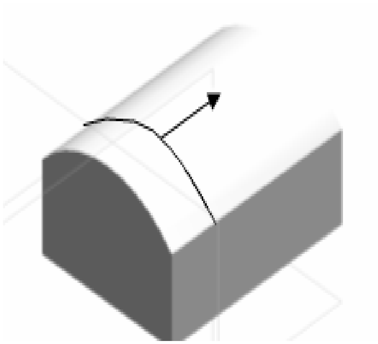
a. Casting, Forming

- The tool is the negative replica of the workpiece
- Simple tool motion
- Machining time is small
- Expensive, complicated tooling
- Even surface no furrows on it
- Typical mass production



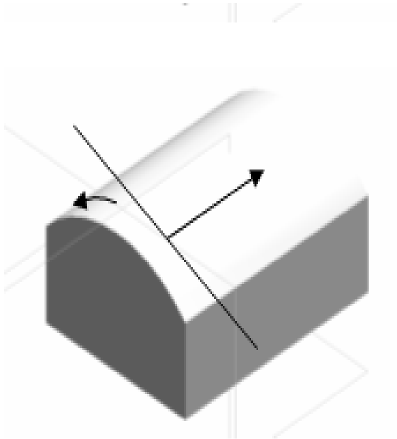
b. Profiling, copying

- Cutting edge is generated according a surface curve
- Tool-motion along a directrix.
- Machining program is delivered by the tool
- Fine surface, furrows are one direction
- Typical mass production



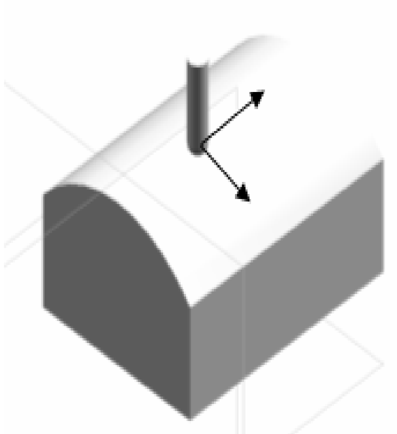
c. Generation

- The machined surface is generated by the tool
- workpiece rolling on the common rolling elements.
- Complicated tool and tool- motion
- Once or two times furrowed surface
- Small and large series production
- Turning, milling, grinding



d. Shaping

- Motion of a universal tool along surface curves (generatrix and directrix)
- Complicated tool motion 2-3-4-5 D axis tool path control
- Two times furrowed surface
- Long cutting time (high speed cutting)
- Typically single production



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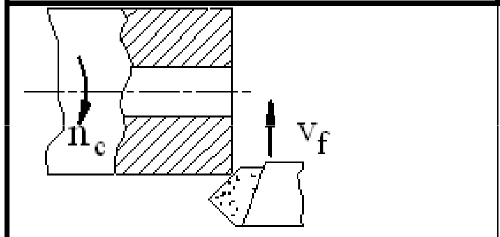
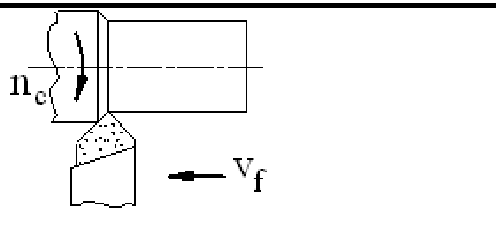
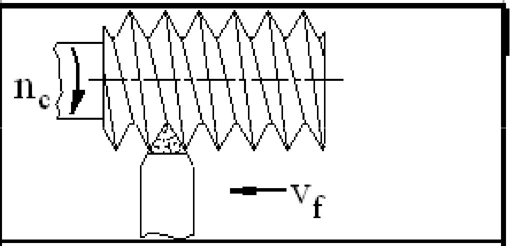
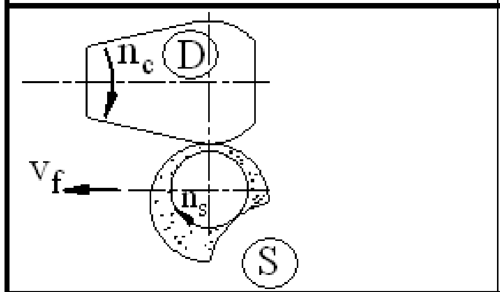
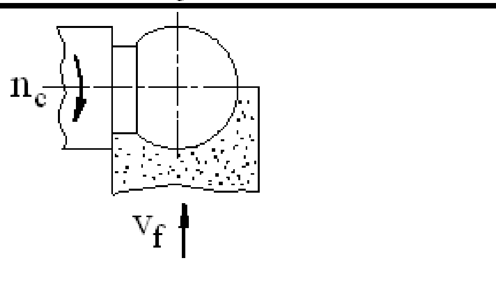
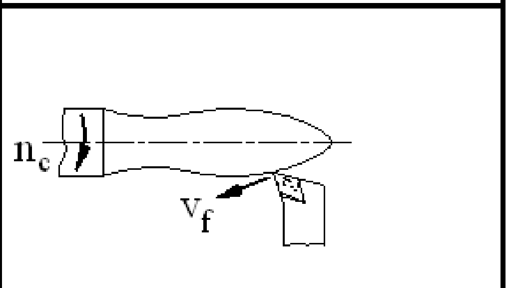
Classification of the manufacturing processes

According metal removing process :
Main group - Group – Subgroup – Codes

1. Casting, Forming	4. Joining
2. Forging, Dieing	5. Coating
3. Separation	6. Heat-treatment

An example of the subgroup

3.2.1. Turning		
		
3.2.1.1. Plane	3.2.1.2. Cylindrical	3.2.1.3. Thread
		
3.2.1.4. Generative	3.2.1.5. Profiling	3.2.1.6. Shape

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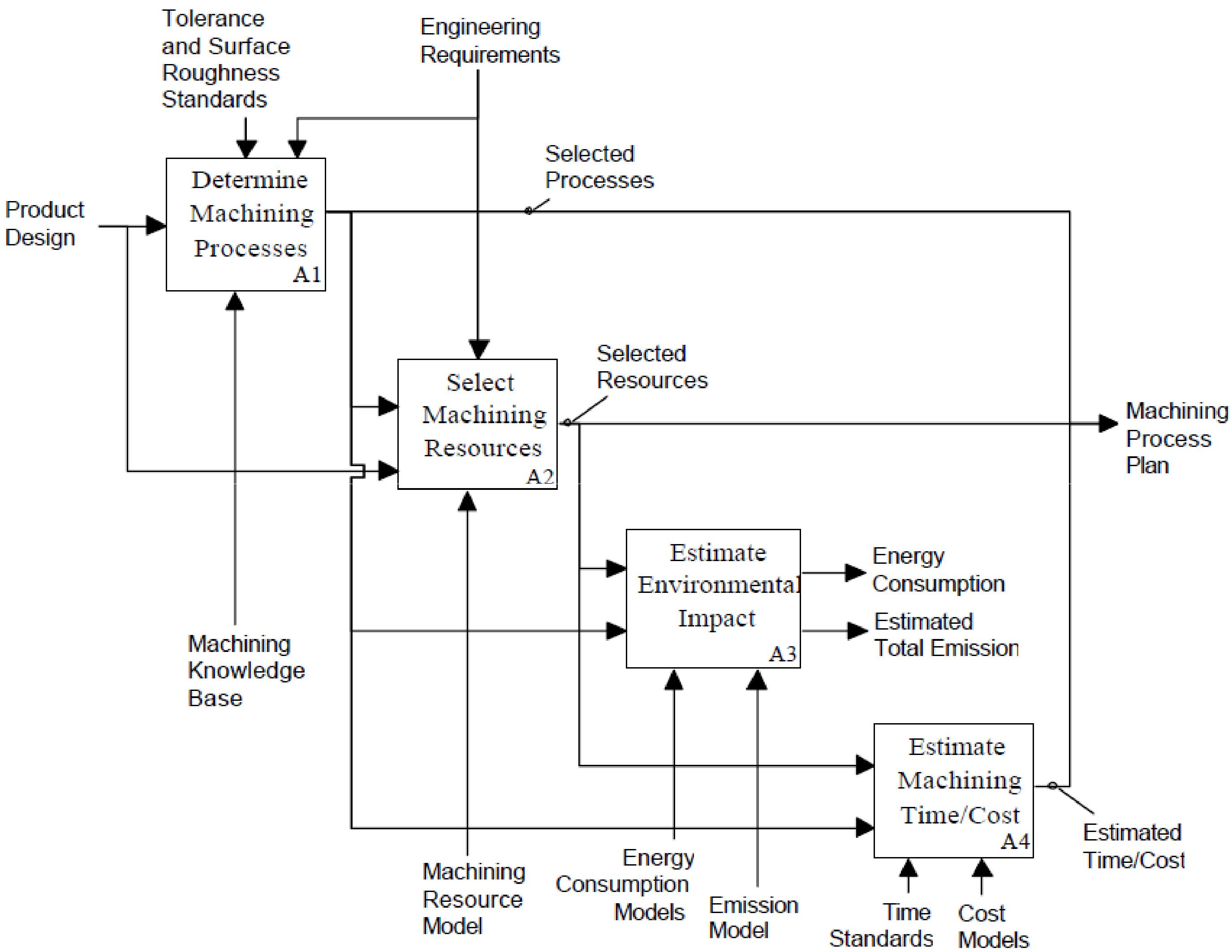
Process planning activity plan



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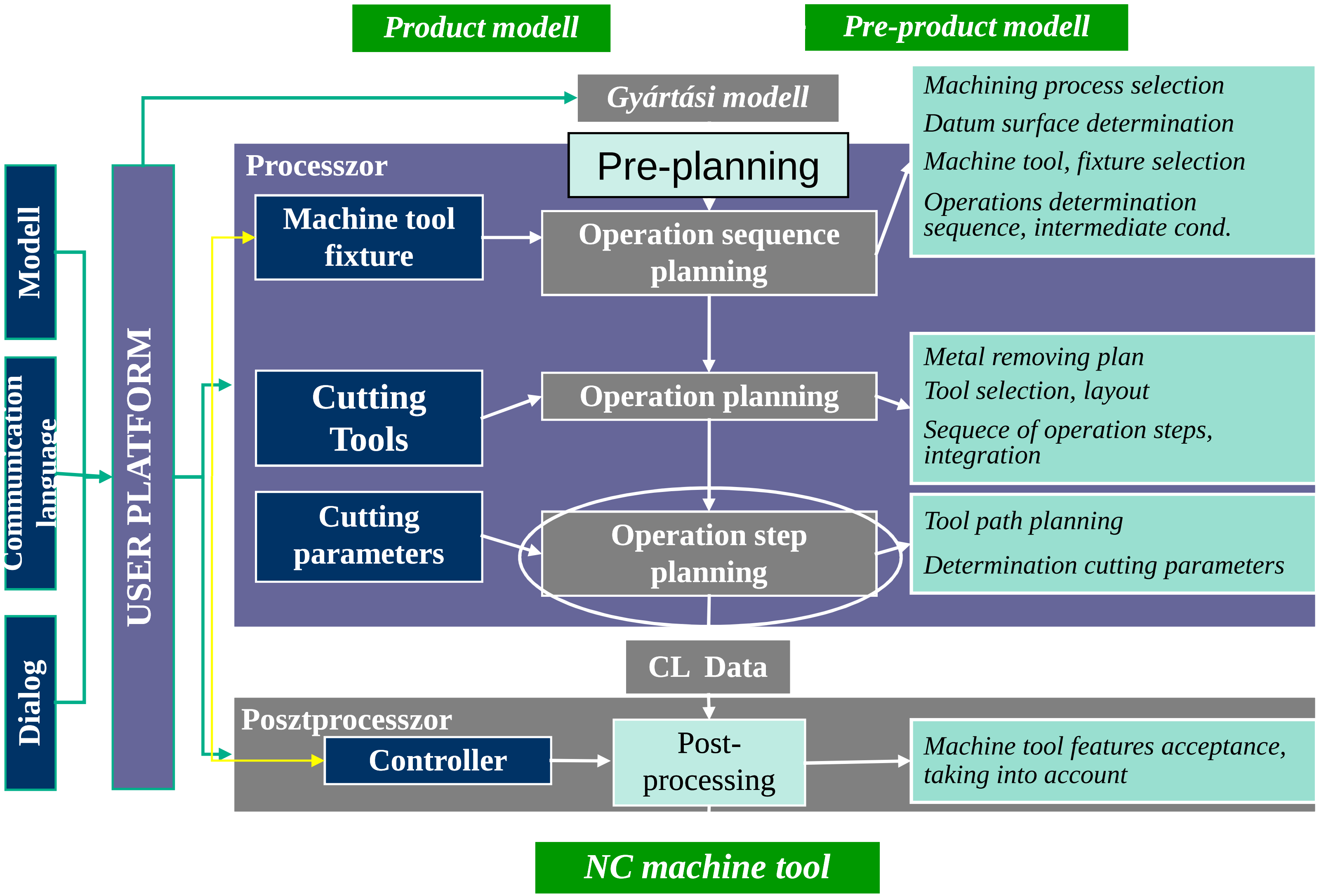
Levels and steps of the process planning



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Place of the pre-planning in the process hierarchy

Knowledge about the designing function and ideas

Information about the part geometry

Knowledge about the operations and they sequence

Knowledge about the operation steps

Knowledge about cutting parameters

Tool path

Shortage of information

Accuracy

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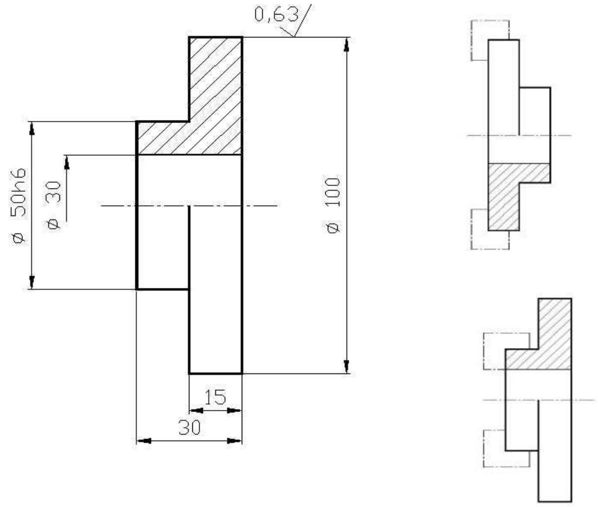
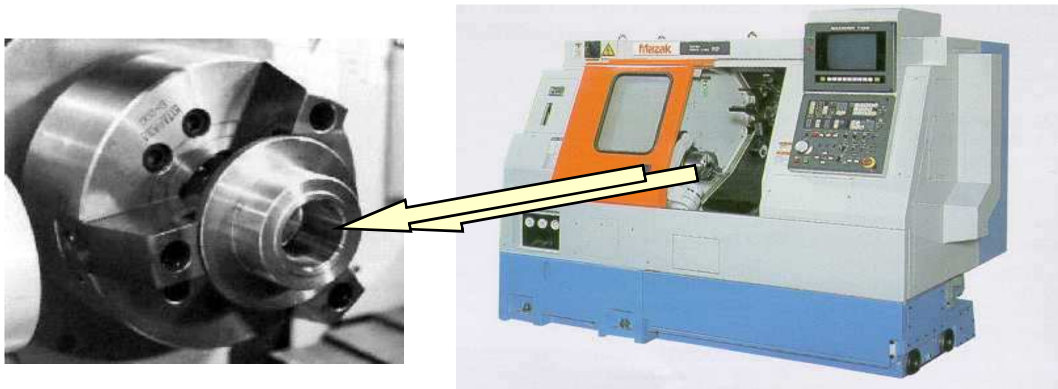
Operation sequence planning

- Determination of the machining needs
- Define machining modes
- Datum plate (surfaces) selection
- Machine-tool selection
- Clamping fixture selection
- Define operation boundaries
- Define of the operation sequence
- Determination of the intermediate contours



Operation: part of the manufacturing process realized on one machine and in one clamping.



Source: Miko

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Operation sequencing rules

- **Rule 1: avoid qualifying and requalifying operations where possible**
- **Rule 2: requalifying operations are necessary after heat treatment**
- **Rule 3: perform process critical operations as early as possible**
- **Rule 4: perform product critical operations, identified by close tolerances, as early as possible**
- **Rule 5: perform product critical operations, identified by surface finish, as late as possible**

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Operation sequencing rules

- Rule 6: operations producing datum or location surfaces must be performed before the operations using those surfaces as datums or for location
- Rule 7: the sequence should minimize the number of setups and machine changes
  - match sequence to manufacturing cell layout
- Rule 8: datum changes should be minimized within a setup
- Rule 9: the sequence should minimize manufacturing tolerance stackups
  - finishing sub-tree should match design dimension graph
  - manufacturing datum sequence should match GD&T datum sequence
- Rule 10: for rotational parts, do not use tapered or shaped surfaces or their end points as datums or for location (exception is between center location)
- Rule 11: if a known sequence exists between two operations (see stock removal sequencing) then the first operation should be closer to the datum-hierarchy tree center or else in a separate branch

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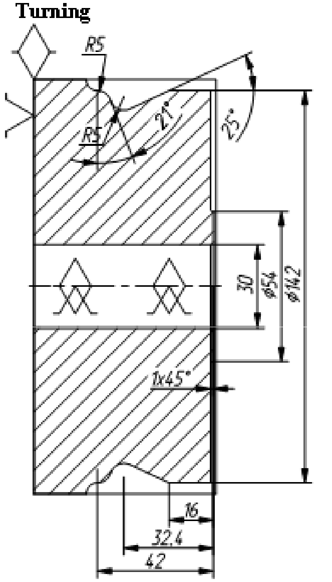
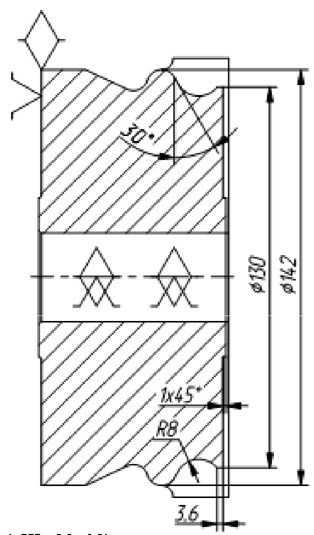
Sequence of operations

BME Manufacturing Engineering Department	OPERATION PLAN Part's name: Body of milling cutter		Material: Steel C45 Raw dimension: ø150, L=66	Number of Op. plan: Page Number: 1
Number of Op.	Description of the operation	Machine:	Measuring equip:	Cutting Tool:
1	**1. Turning**  1.1 Workholding; 1.2 Center spot drilling ø5; 1.3 Center drilling ø28 mm; 1.4 Facing; 1.5 Finish bore ø30 mm, bevel 1x45°; 1.6 Rough turning OD; 1.7 Finish turning OD; Workpiece release.	Mori Seiki CL 200A CNC Lathe	Measuring equipment	Cutting tool

BME Manufacturing Engineering Department	OPERATION PLAN			Page Number: 2
Number of Op.	Description of the operation	Machine:	Measuring equip:	Cutting Tool:
2	**2. Turning**  2.1 Workholding 2.2 Facing; 2.3 Bevel 1x45°; 2.4 Rough turning OD; 2.5 Finish turning OD; 2.6 Workpiece release.	Mori Seiki CL 200A CNC Lathe	Measuring equipment	Cutting tool

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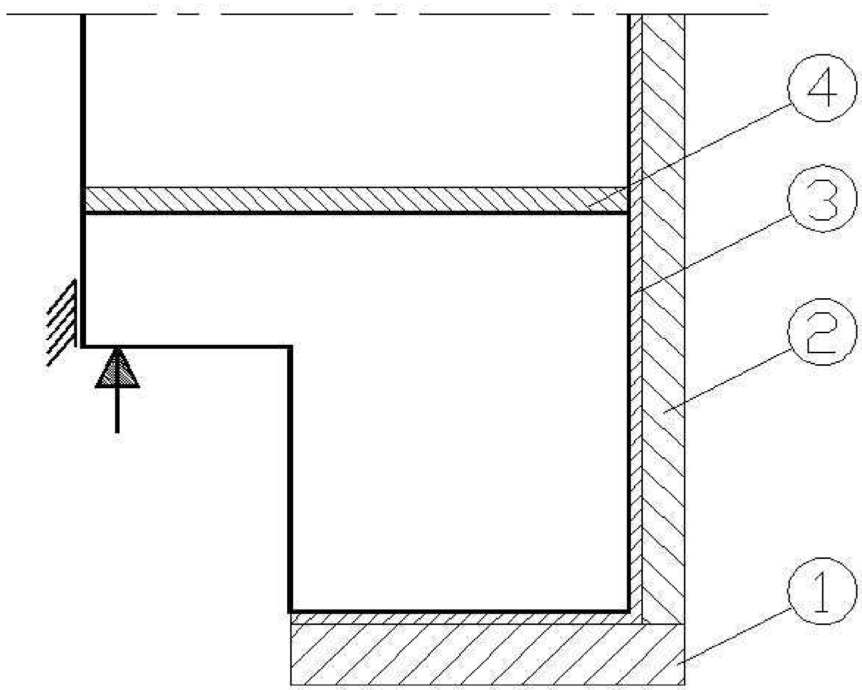
Operation planning

- Metal removing plan
  (Generation of operation steps)
- Cutting tool selection
- Integration of operation steps
- Determination of the sequence of the operation steps
- Cutting tool layout preparation

<u>Operation step</u>: part of the manufacturing process where the machining allowance is removed by a given tool.



Source: Miko

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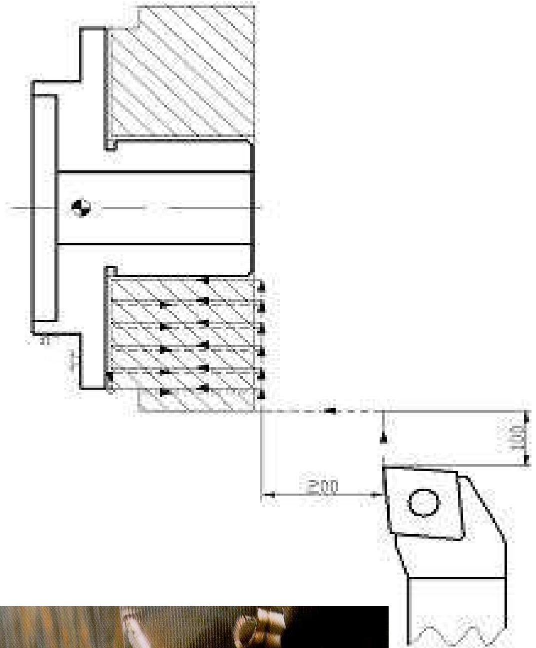
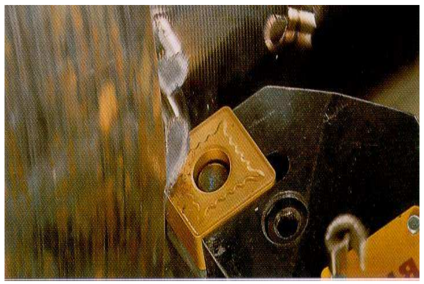
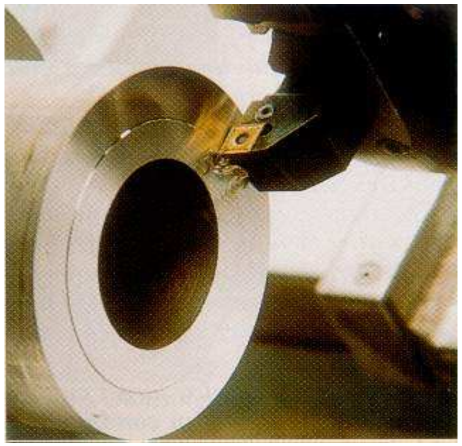
Planning operation steps

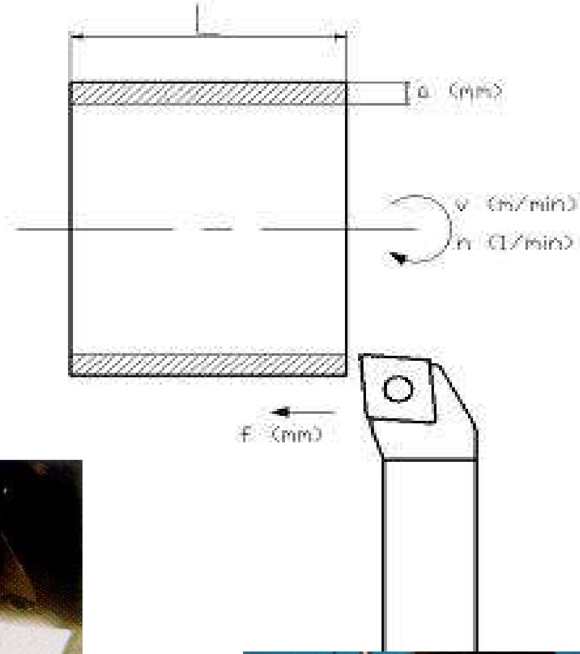
- Tool path planning

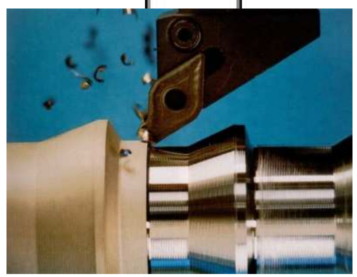




- Determination cutting parameters







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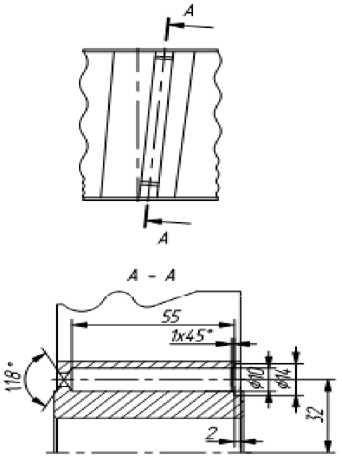
Description of the operation steps (elements)

BME Manufacturing Engineering Department	OPERATION ELEMENT			Number of Op. Elem.: 2	Page number:
Gyártásijel:	Drawing number:	Part's name: Ball oldalbetét		Identification of part:	
Material:	Raw dimension: 42x47,5x8 3	Mat. condition:	Name of the operation: Nagyolás-menetkészítés	Identification of Operation:	Number of Op. Plan:

Sketch:

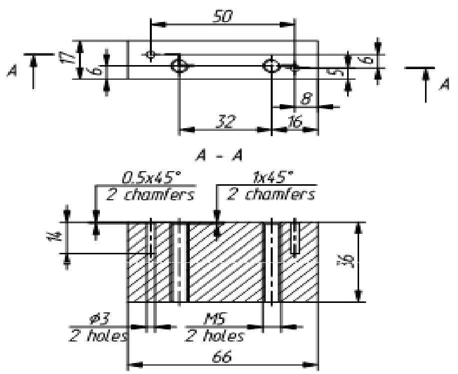


No.	Operation element	No. of surface	Cutting tool	v [m/min]	n [1/min]	f [mm/rev]	a [mm]
1	Spotfacing		⌀14 mm, L = 2 mm	200	7100	0,07	4
2	Drilling		⌀10 mm, L = 55 mm	100	3180	0,25	2
3	Countersinking		⌀11 mm	100	3000	0,25	0,5
4	Repeat for 6 teeth						

Name: Vo Ngoc Em	Preparation time		Part time		Number of the produced part:		
Date: 2002. 05. 04	Norma time	Added time	Norm time	Added time			
					Types of machine		
			Shop	Group of machines		a	
					Variation	b	
						c	
						d	

BME Manufacturing Engineering Department	OPERATION ELEMENT			Number of Op. Elem.: 2	Page number:
Gyártásijel:	Drawing number:	Part's name: Ball oldalbetét		Identification of part:	
Material:	Raw dimension: 42x47,5x8 3	Mat. condition:	Name of the operation: Nagyolás-menetkészítés	Identification of Operation:	Number of Op. Plan:

Sketch:



No.	Operation element	No. of surface	Cutting tool	v [m/min]	n [1/min]	f [mm/fog, mm/rev]]	a [mm]
1	Face milling bottom surface;			305	6472	0,11	1
2	Spot drilling 2 manufacturing holes		⌀2 mm;	90	5700	0,08	1
3	Spot drilling 2 holes in bottom surface		⌀2 mm;	90	5700	0,08	1
4	Drilling 2 manufacturing holes		⌀3 mm, L = 14 mm;	90	8500	0,08	1,5
5	Drilling 2 holes in bottom surface		⌀4 mm;	90	8500	0,1	2
6	Countersinking 2 manufacturing holes		⌀4 mm;	90	8500	0,1	0,5
7	Countersinking 2 through holes		⌀6 mm;	90	8500	0,1	0,5
8	Tapping two through holes M6;			10		1	

Name: Vo Ngoc Em	Preparation time	Part time	Number of the produced part:

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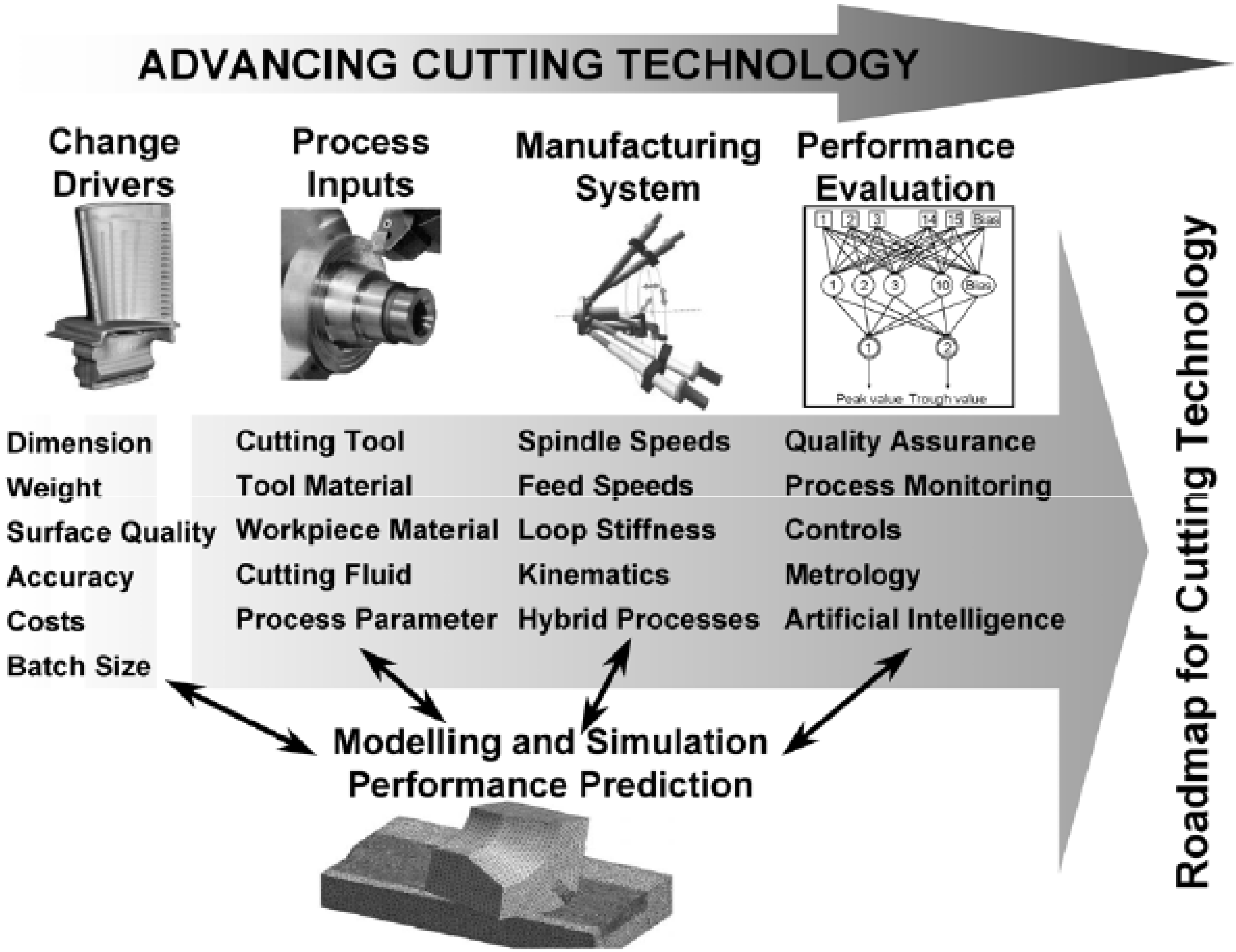
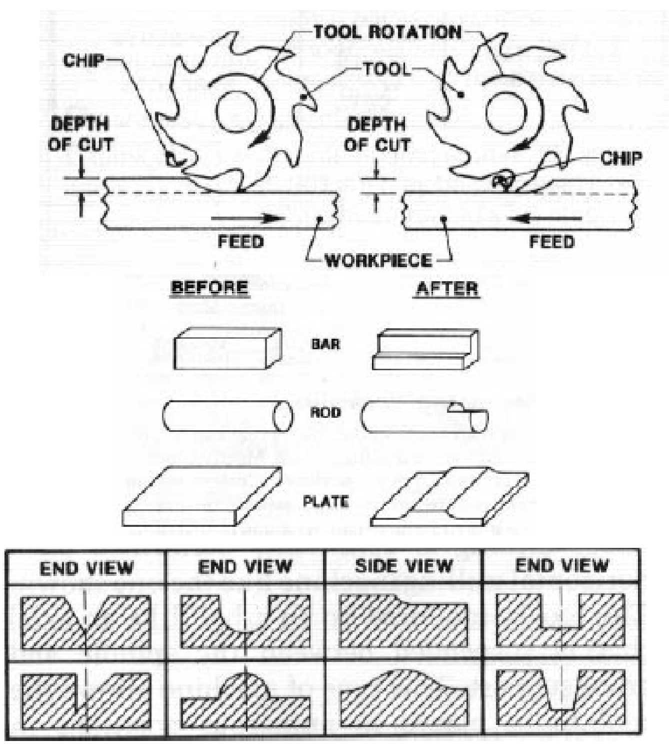
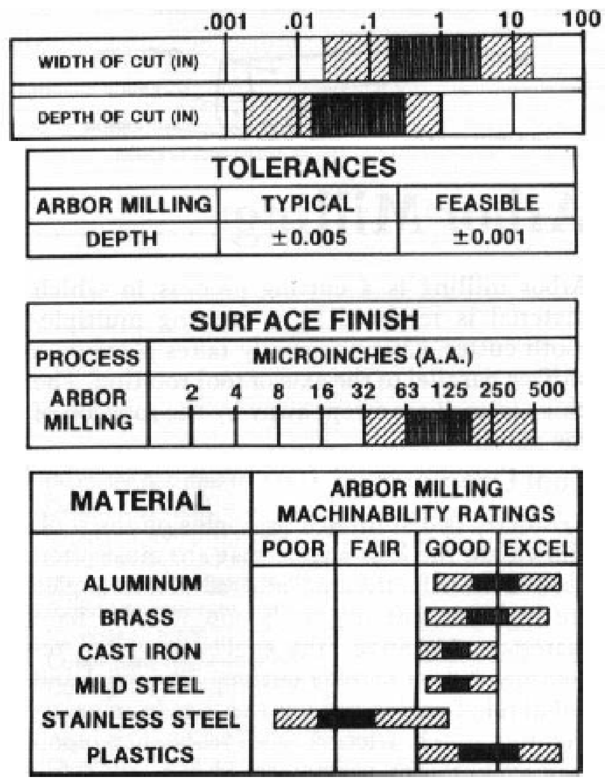
Manufacturing/Cutting technology



Description of the machining process

Function – Sub function	Shape Material → Reduce Material → Mechanical
Reference	Alting,Leo. "Manufacturing Processes Reference Guide." 1994
Date	April 2003
Author	Joaquín Aca

Description: Arbor Milling	Capabilities
	

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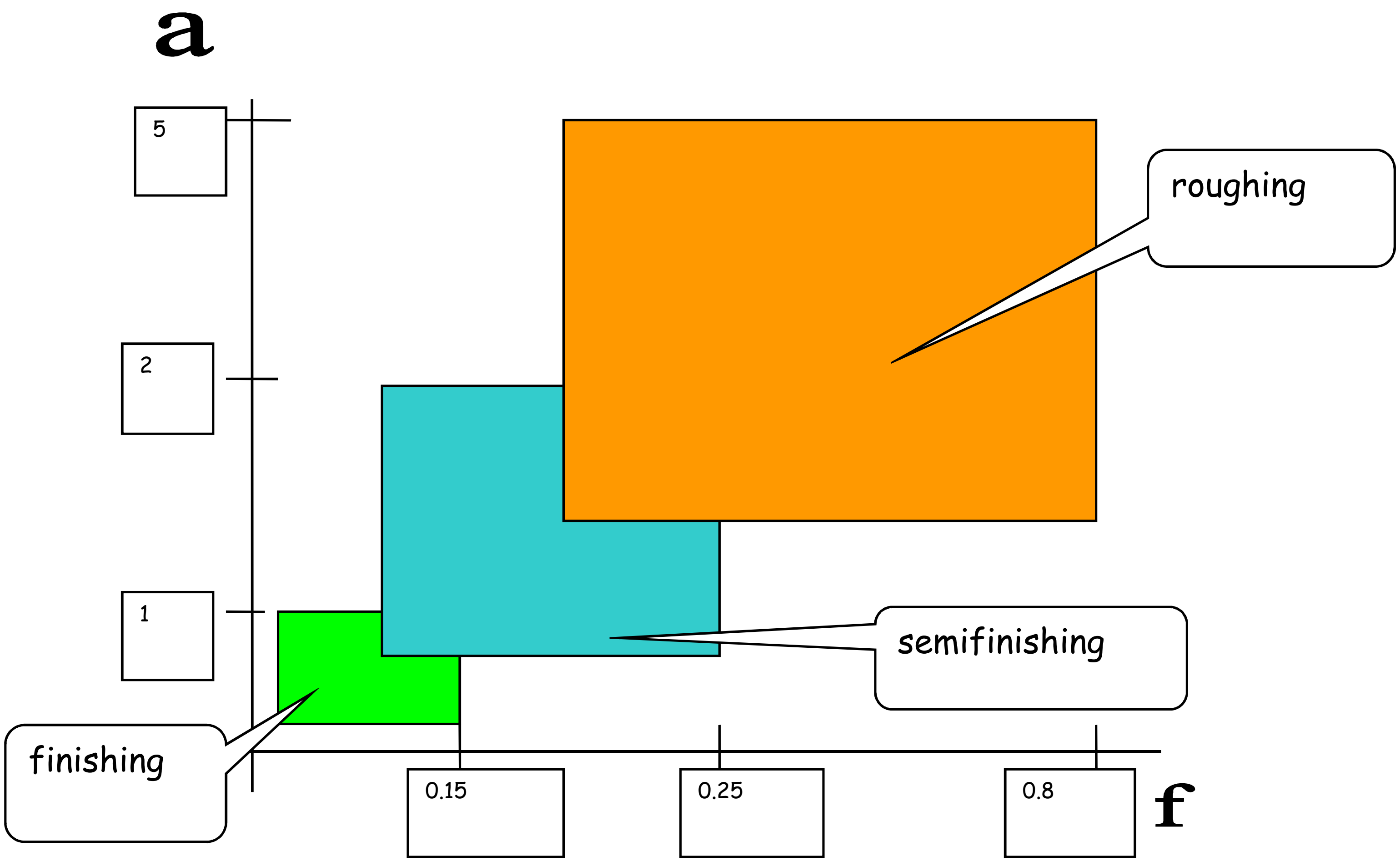
Process parameters for turning



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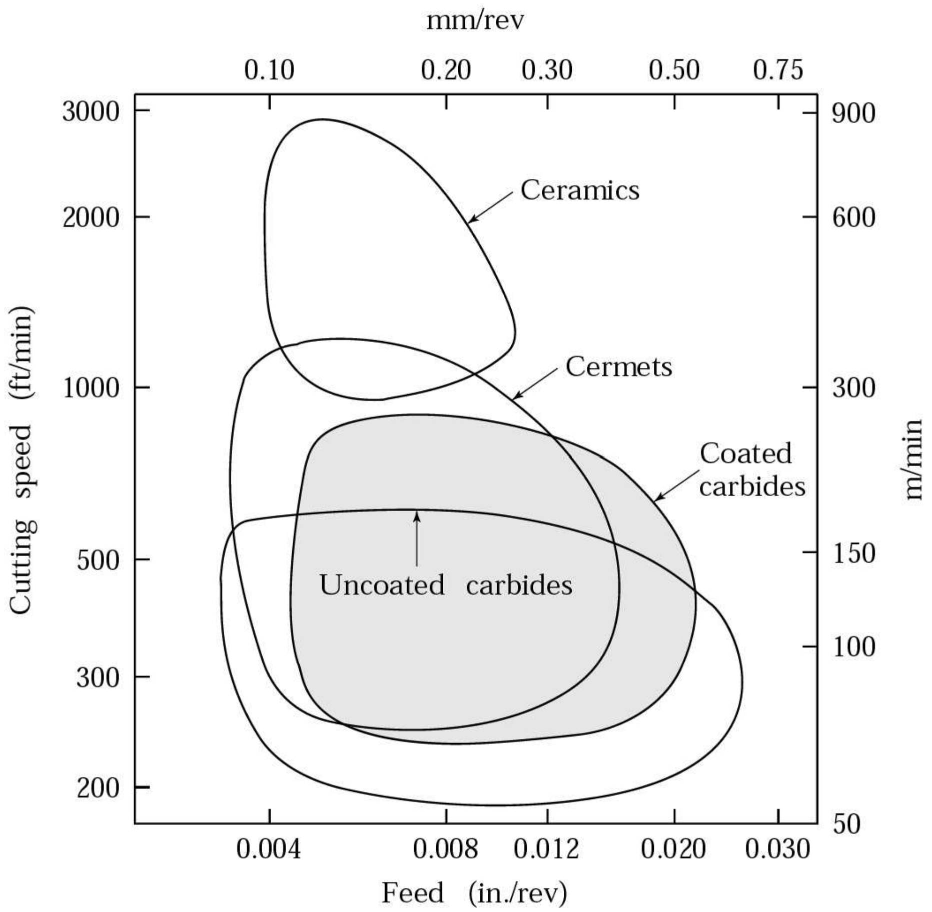
Turning

TABLE 22.5 Representative Machining Conditions for Various Work and Tool–Material Combinations

Work Material	Tool	Rake Angles (degrees) Back	Side	Cutting Speed m/min	fpm
B1112 steel	HSS	16	22	69	225
	WC	0	3	168	550
	Ceramic	− 5	− 5	427	1400
4140 steel	HSS	12	14	40	130
	WC	0	3	91	300
	Ceramic	− 5	− 5	274	900
8620 steel	HSS	uncoated			100
	WC	uncoated			400
	WC	coated with TiC			600
	WC	coated with AL_2O_3			1100
	WC, AL_2O_3 with LFG				1300
18–8 steel (stainless)	HSS	8	14	27	90
	WC	4	8	84	275
	Ceramic	− 5	− 5	152	500
Gray cast iron (medium)	HSS	5	12	34	110
	WC	0–4	2–4	69	225
	Ceramic	− 5	− 5	244	800
Brass (free-machining)	HSS	0	0	76	250
	WC	0	4	221	725
Aluminum alloys	HSS	35	15	91	300 plus
	WC	10–20	10–20	122	400 plus
Magnesium alloys	HSS	0	10	91	300 plus
	WC	10	10	213	700 plus
Titanium (turning)	WC	0	5	46	150

Table Valve Typical for
Lathe turning operation
Single-point tool

Feed: 0.38 mm/rev (0.015 ipr)
Depth: 3.18 mm (0.125 in.)



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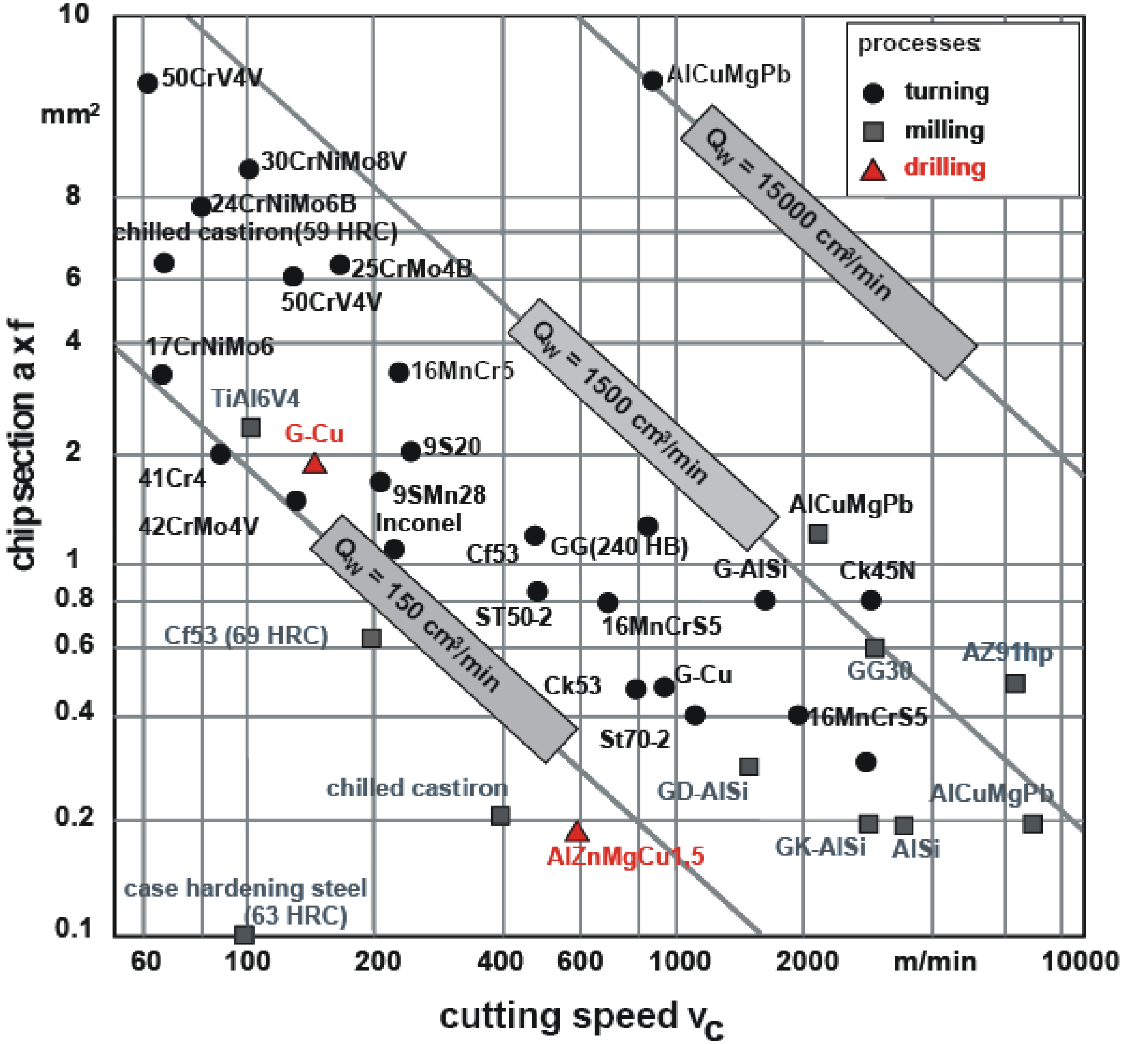
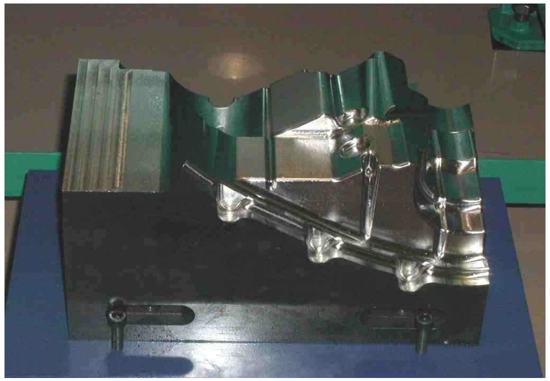
Machinability of different workpiece materials





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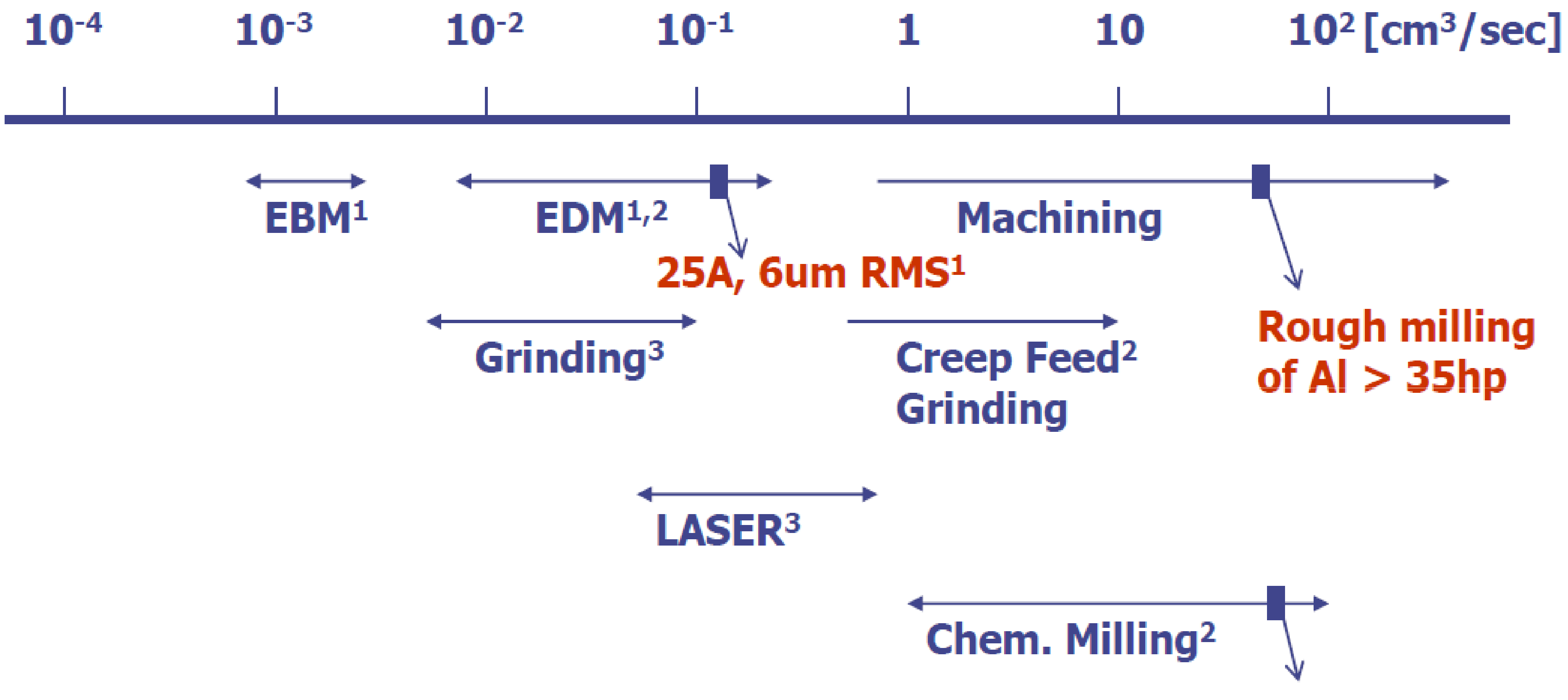
Typical material removal rate



Note: $1 cm^3/sec = 3.67 in^3/min$

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Metal removal rate (mm3/min)

Material	Melting temperature Tm	Roughing (30 A) mm3/min	Finishing (5 A) mm3/min
Zink	420	1000	120
Magnesium	600	800	100
Aluminum	660	500	80
Brass	900	320	50
Copper	1080	220	30
Steel	1350	160	25
Nickel	1450	150	20
Hardmetal	3000	60	10
Tungsten	3400	40	6

$$MRR=40*I/Tm^{1.23}$$

Copper electrode material, max. 7A/ mm2

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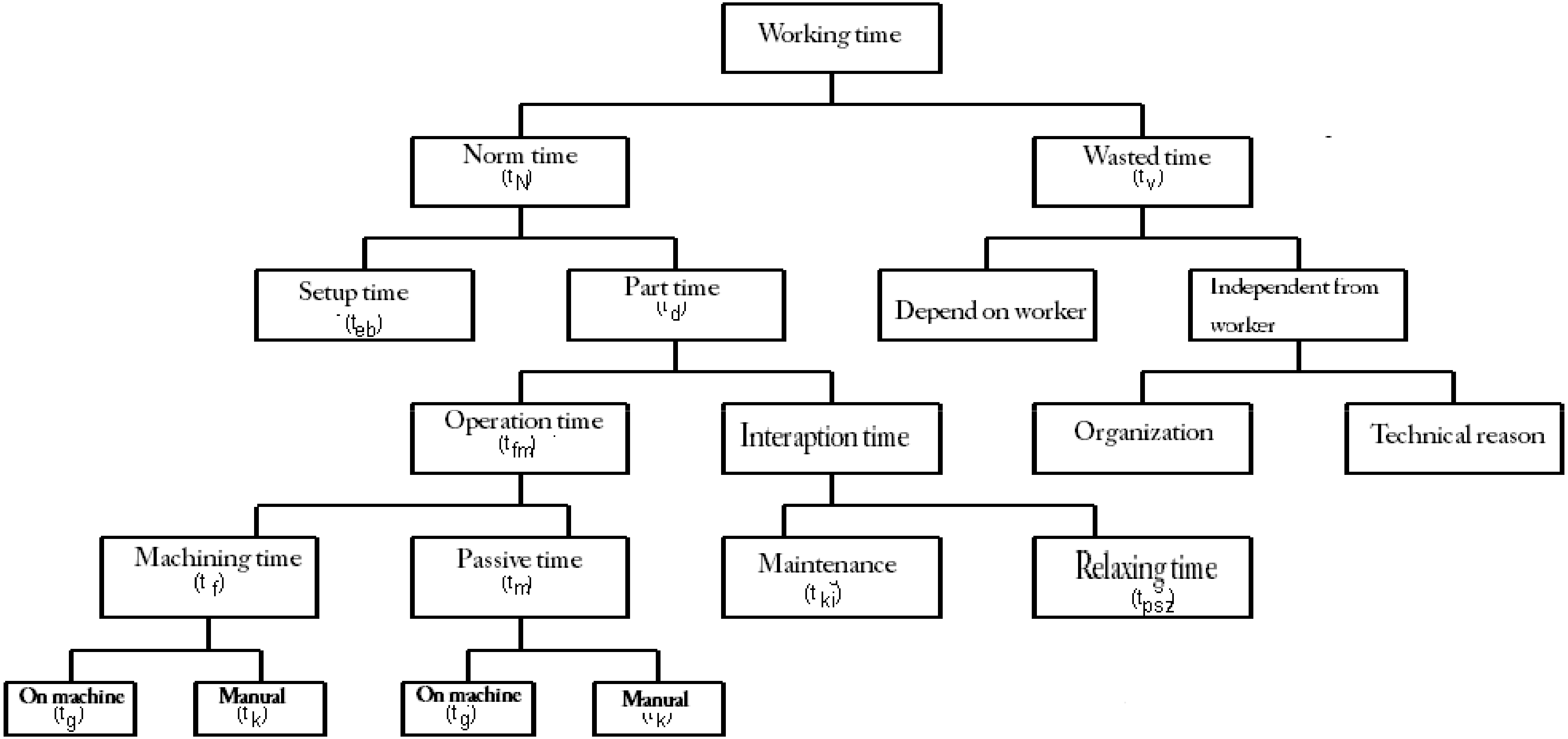
Components of the machining time



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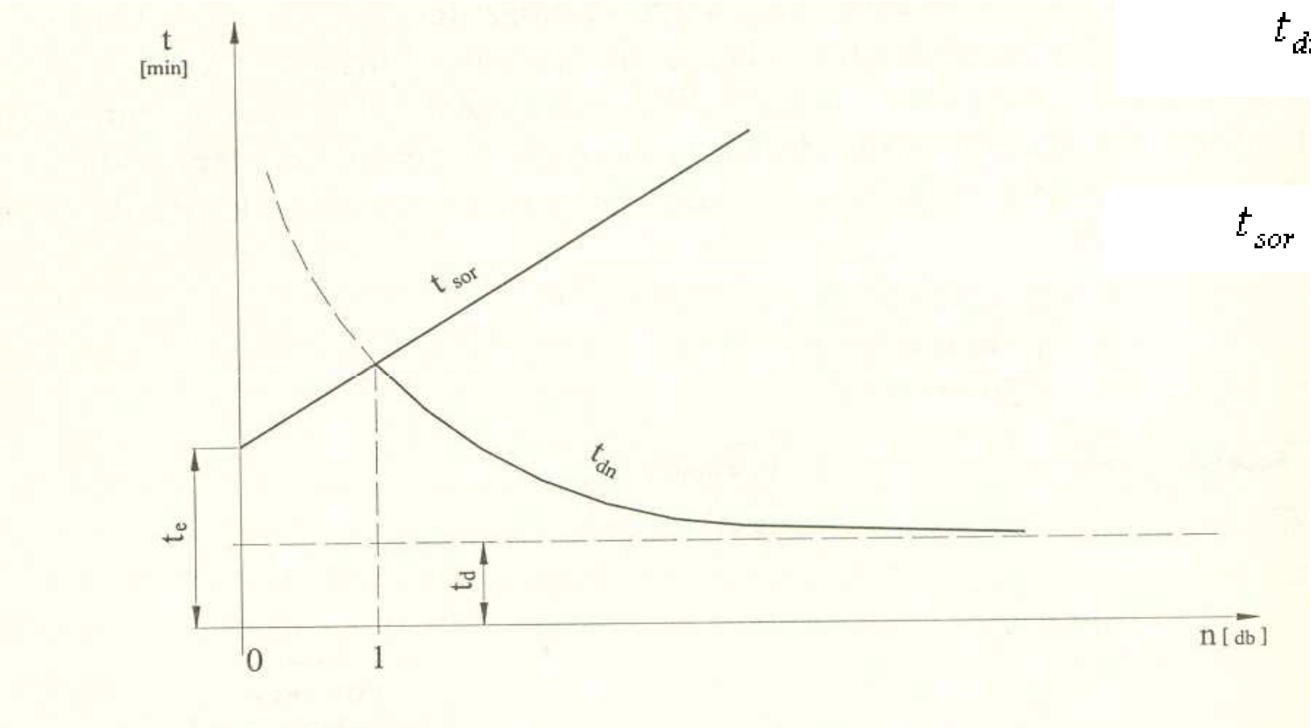
Changing of the setup time depend on the part numbers

Effect of the Setup time to the norm time:



$$t_{dn} = \frac{t_e}{n} + t_d$$

$$t_{sor} = t_e + n \cdot t_d$$

A norm time for a given part is:

$$t_d \equiv t_{f,m} \left(1 + \frac{t_{ki} + t_{psz}}{100}\right)$$

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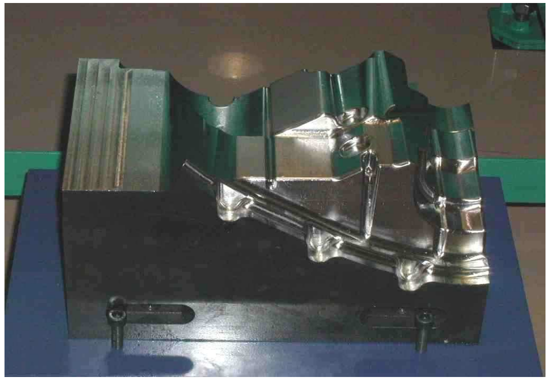
Components of the setup time

Preparation

- Program loading
- Tools to the tools magazine
- Tool pre-setting
- Fixture positioning, alignment
- Workpiece clamping, positioning fixing
- Zero-point determination
- Program writing, program inspection
- Soft jaw machining

Finishing

- Workpiece unclamping
- Cleaning, deburring
- Measuring and inspection



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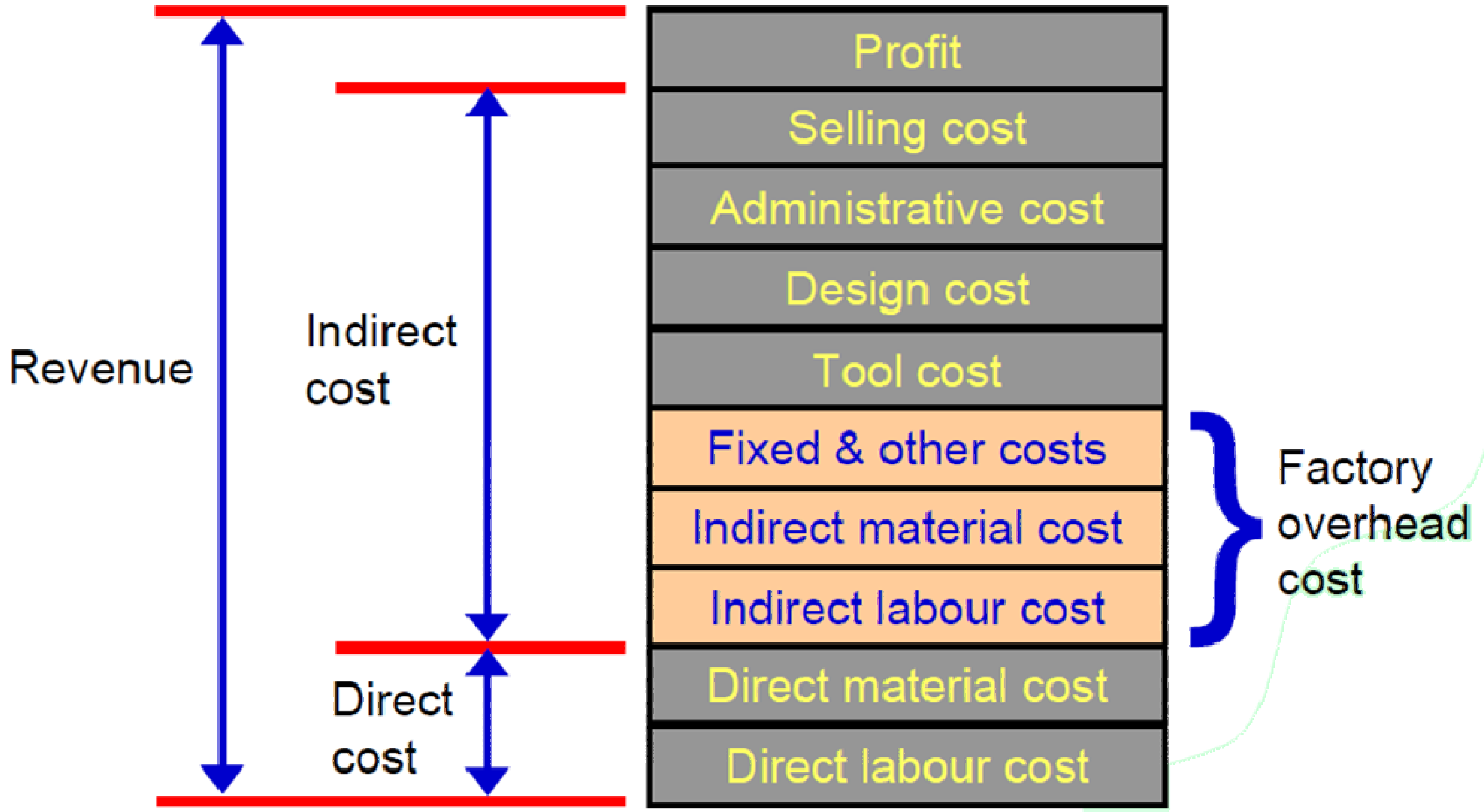
Reduction of the machining time

- The cutting time mainly depend on the cutting speed and the feedrate (cutting parameters).
- Alternative solutions to reduce the cutting time:
  - Improved cutting tool quality
  - Improved cooling and lubrication
  - Contraction of the operation elements,
  - Multi-tool tool holders,
  - Multi-spindle machining
- All the solutions cause the increasing of the production cost.

Classification of product costs



Direct costs can be traced to a specific product.
Indirect costs cannot be traced to a specific product.

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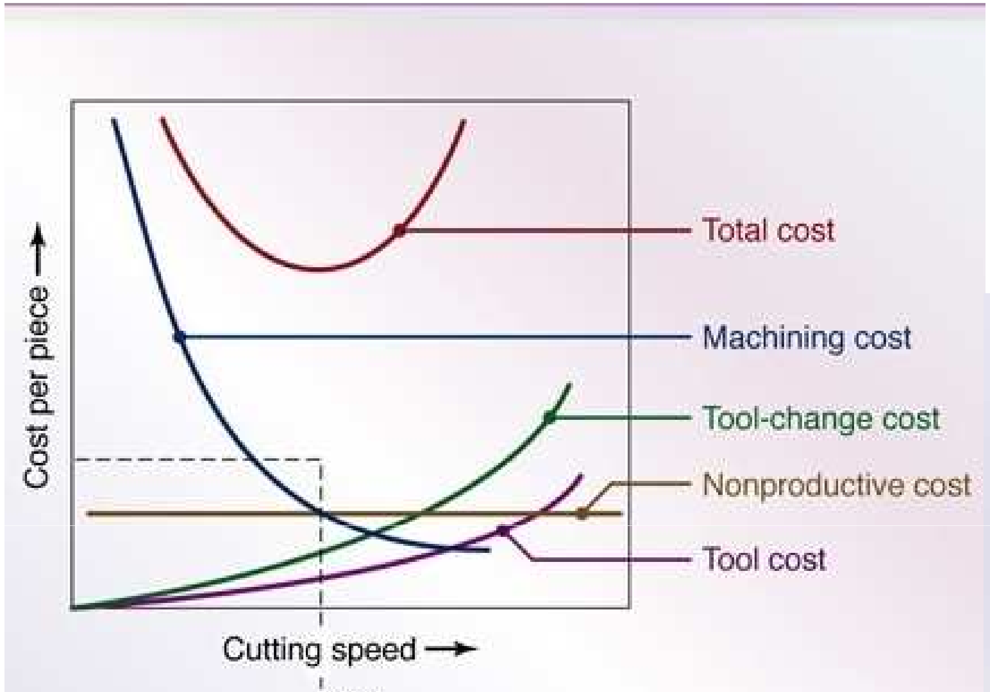
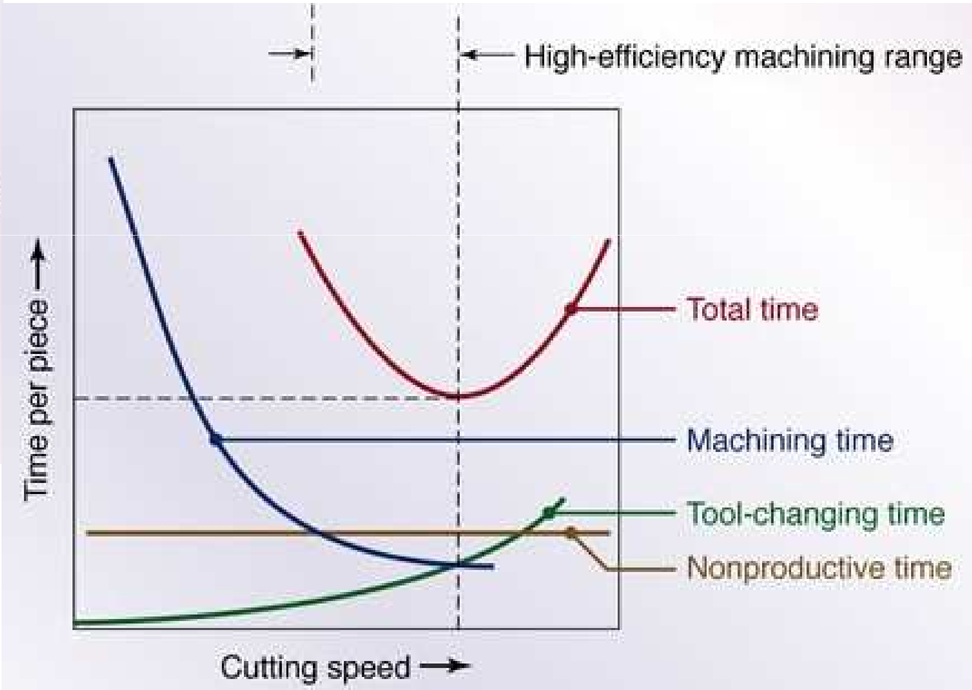
Changing of the cost components



(a)



(b)

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Cost components

$$K_e = \frac{K_{esz}}{n} + K_{egy} + K_{ea}\,; \quad \mathrm{K}_{\mathrm{egy}} = \sum_{i=1}^{m} C_{Mi} \cdot t_{Ni}$$

$$K_a = \frac{K_{asz}}{n} + \mathrm{K}_{\mathrm{agy}} - \mathrm{K}_{\mathrm{f}}\,; \quad \mathrm{K}_{\mathrm{agy}} = \mathrm{ua}$$

$$\mathrm{K}_{\mathrm{s}} = \frac{K_{ssz}}{n} + K_{sgy}\,; \qquad \mathrm{K}_{\mathrm{sgy}} = ua$$

$$K_{gy} = K_e + K_a + K_s$$

where:

K_{gy} - product direct manufacturing costs

K_e - cost of the pre-production

K_s - assembling cost

K_a - cost of the part manufacturing

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Details of the notification

K_{esz} - tool and fixture cost of the pre-production

K_{asz} - tool and fixture of the part manufacturing

K_{ssz} - tool and fixturing cost of the assembly

n - number of the produced parts

K_{egy} - production cost of the pre-product

K_{agy} - Cost of the part production

K_{sgy} - cost of the assembling process

K_{ea} - Material cost of the pre-product

K_{f} - Cost (price) of the chip, garbage price
(it can increase the cost, for instance: dangerous waste)

C_{M} - Cost of the machine tool, or workspace (Ft/min)
(machine tool, equipment, assembling workspace etc.)

t_{N} - time of the observed operation m – operation number

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Cost calculation

$$C_M = \left(1 + \frac{R}{100}\right)b + \frac{Ag\left(\frac{1}{a} + \frac{Rg}{100}\right)}{60\,H_{év}}$$

b	**Labour cost, Ft/min;**
R	**labour cost overhead %;**
Ag	**Price of the machine tool, Ft;**
a	**Amortization time, year;**
Rg	**Cost connected to the usage of the machine tool**
	(maintenance, energy, emulsion, overhead, %.)
Hév	**machine tool operation time, hours.**

Cost of the part manufacturing, machining

Direct cost (Kd):

- Material
- Operation, machining
  1. setup
  2. clamping, unclamping
  3. machining
  4. tool
  5. fixture
- Measuring, inspection
- Repearing, refuse replacement
- Transportation

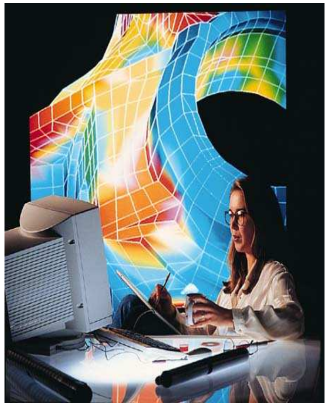
Indirect costs (Kov):

Kov Ft/piece = Kd*overhead/100

(Kd = direct part costs)

Typical overhead tasks:

- process planning
- NC programming
- scheduling



Cost components

Ka /piece = part mess * specific (unit) cost (Ft/kg)

= part volume * specific(unit) cost (Ft/cm3)

Ke/piece = setup time*workplace cost/batch number

Kb/piece = (clamping +unclamping time) * workplace (machine tool) cost (CM Ft/min)

alternative

Kb/piece = (clamping +unclamping time (into fixture)) * labour cost (CL Ft/min) +

= (clamping +unclamping time (into machine tool)) * Workplace (machine tool) cost (CM)

Km/piece = (Σ cutting time+ Σ time of the rapid motion+ Σ tool changing time)*CM

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Cost components

Ksz/piece = Σ Cutting time*CT (Ft/min)

(CT = depreciation + re-sharpening + insert + pre-setting)

alternative

Ksz/piece = Σ (tooling cost * cutting time/tool life)

alternative

Ksz/piece = Σ tooling cost /batch number

Kk/piece = (fixture cost + Maintenance cost)/yearly (planned) batch number

Kme/piece = Σ measuring, inspection time * sampling rate*batch number * Workplace cost (CI Ft/min)

Kjs/piece = refuse percentage* Km/piece

Ksz/piece = Σ transportation, storing cost/batch number

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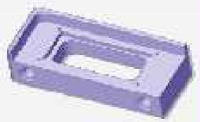
Cost estimation based on feature recognition

Feature Recognition Applications

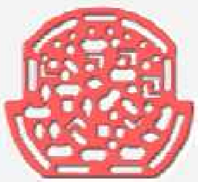
Part Name	Mold Base
Size	9" x 12" x 1.75"
Material Grade	Steel SAE 4140
CAD File Type	3D Model .step file
Equipment	Mazak VCN
Operations	2 Axes Machining
Manufacturing Time	310 Minutes
Time to Estimate	**7 Minutes**
Cost	$573.12

Part Name	Housing Blank
Size	2.25" Dia. x 3.375"
Material Grade	Steel SAE 12L14
CAD File Type	SolidWorks .sdlprt
Equipment	Hardinge T42
Operations	2 Axes Machining
Manufacturing Time	4.39 Minutes
Time to Estimate	**3 Minutes**
Cost	$21.30

Part Name	Lock Plate
Size	8" x 5" x 1.25"
Material Grade	Steel SAE 1018
CAD File Type	SolidWorks
Equipment	HAAS HMC
Operations	2 Axes Machining
Manufacturing Time	98 Minutes
Time to Estimate	**4 Minutes**
Cost	$167.10



Part Name	Mounting Block
Size	4.2" x 1.62" x 1.25"
Material Grade	Alum. SAE 6061-T6
CAD File Type	Parasolid .x_t
Equipment	Mori Seiki MV 55
Operations	2 Axes Machining
Manufacturing Time	41 Minutes
Time to Estimate	**4 Minutes**
Cost	$73.42



Part Name	Top Plate
Size	24" x 21.5" x .062"
Material Grade	Steel SAE 1018
File Type	AUTOCAD 2D.dxf
Equipment	Amada Laser
Operations	2 Axes Cutting
Manufacturing Time	11.53 Minutes
Time to Estimate	**5 Minutes**
Cost	$31.03

3D Estimating Incorporates SolidWorks™ – **2D Estimating** incorporates an intelligent CAD system and smart digitizing. Standard CAD and graphic **file formats** are supported.

Control questions

- Geometrical modeling solution. Data (geometrical model) exchange between CAD systems, interface possibilities. Rework requirements, and application.
- Surface creation methods. Meaning of the forming, profiling, generation, shaping.
- Connection between tool path planning and the surface generation.
- Definition of the Machinability. Machinability of different workpiece materials. Machinability parameters: metal removal rate, specific cutting force...
- Definition of the machining operation. Operation planning. Operation sequencing rules.
- Levels and steps of the operation planning. Process planning hierarchy.
- Components of the machining time. Machining time and cost estimation.
- Tool path generation process steps in CAM system. CAM strategies, solutions.

Thank you for your attention !

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