University of BRISTOL

Department of Mechanical Engineering

VIRTUAL PRODUCT DEVELOPMENT (MENGM6049) – Lecture 7
Process Planning for Machining
2017-2018

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The Purpose of the Lecture

Integrated CAD/CAM & CAPP

- What is Process Planning?
  - Route operations sheet
  - Example of route (operations) sheet, pinion shaft
  - Tasks/steps required (1-14) & determination of cutting conditions data
  - Machinability data systems & characteristics of machining operations
  - Computer Aided Process Planning (CAPP)

Intended Learning Outcomes

After taking the unit the students would be able to:

1. Draw, manipulate and analyse advanced engineering curves including splines and Bezier curves on a Computer Aided Design system.

2. Create a machining process plan for a part and perform virtual machining of the product based on this process plan on a Computer Aided Manufacturing system.

3. Design and optimise a mechanical product from concept to full digital prototype in an integrated Product Lifecycle Management environment.

Å To complement the unit, 9 lectures with a series of laboratories (24 hours) are provided to support the unit.

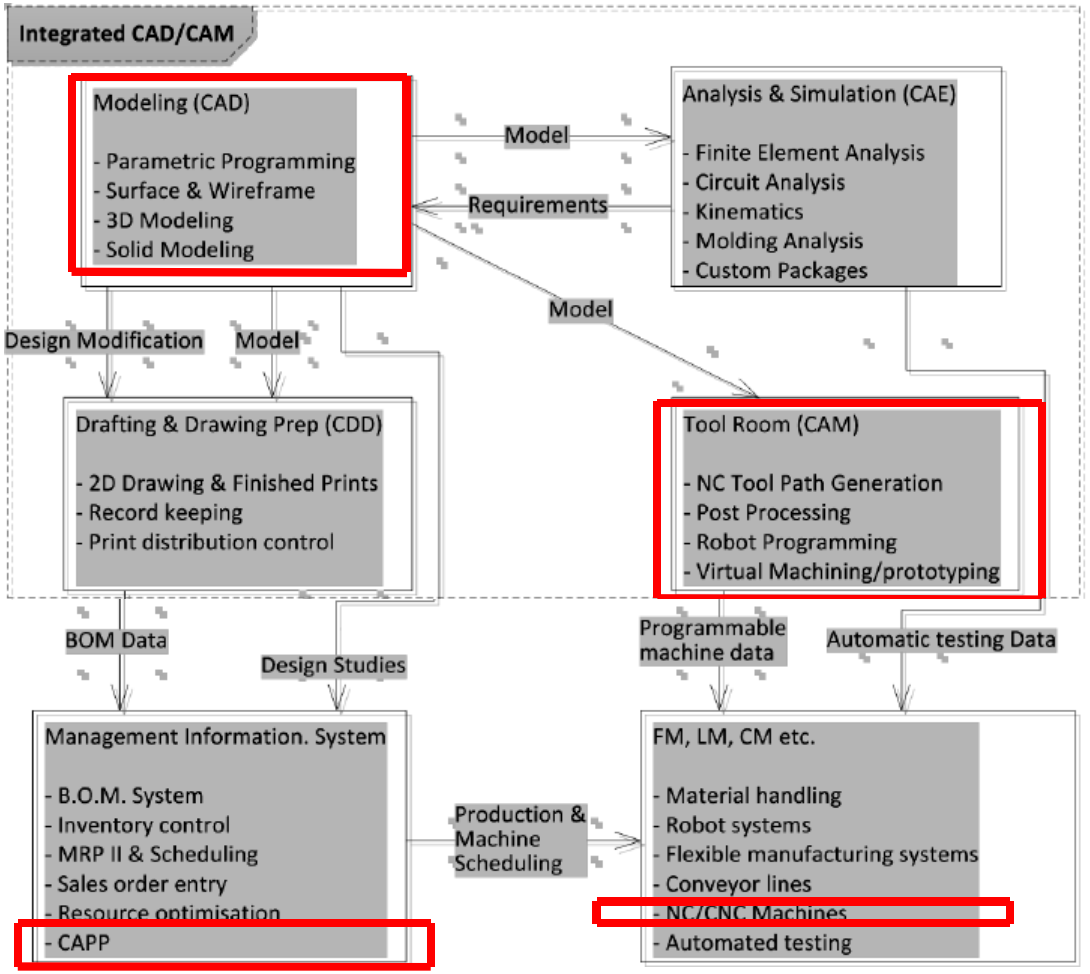
Unit – Supporting Lectures

- Lecture 0 Introduction to coursework/assignment;
- Lecture 1 Introduction to VPD and PLM.
- Lecture 2 CAD Overview & Intro. to Engineering Curve.
- Lecture 3 Reverse Engineering.
- Lecture 4 Curve Analysis.
- Lecture 5 Interrogation of Solids.
- Lecture 6 Design for Machining & CNC Machining.
- Lecture 7 Process Planning for Machining.
- Lecture 8 Virtual Machining.
- Lecture 9 Iterative design, analysis and Optimisation in PLM.

Integrated CAD/CAM & CAPP

- Integrated CAD/CAM allows the CAM to automatically generate tool-paths, cutter location data (CLDATA) files and NC programs for CNC machine tools from CAD directly based on **the Process Planning.**

- This integration is the key to successful exchange of information more efficiently, and simultaneously, for accelerating new product development.



Process Planning

- Process Planning is an important part of machining. It is concerned with determining the sequence of individual operations needed to produce a given part or product.

Process planning is also associated with determining:

- cutting conditions for the machining operations.
- setting the time standards for the operations.

The factors which will affect the planning decisions include:

- Part geometry, Required accuracy, Surface finish, Material, Number to be produced.

Process Planning

The operation sequence is documented on a form called:

Route sheet, *which contains:*

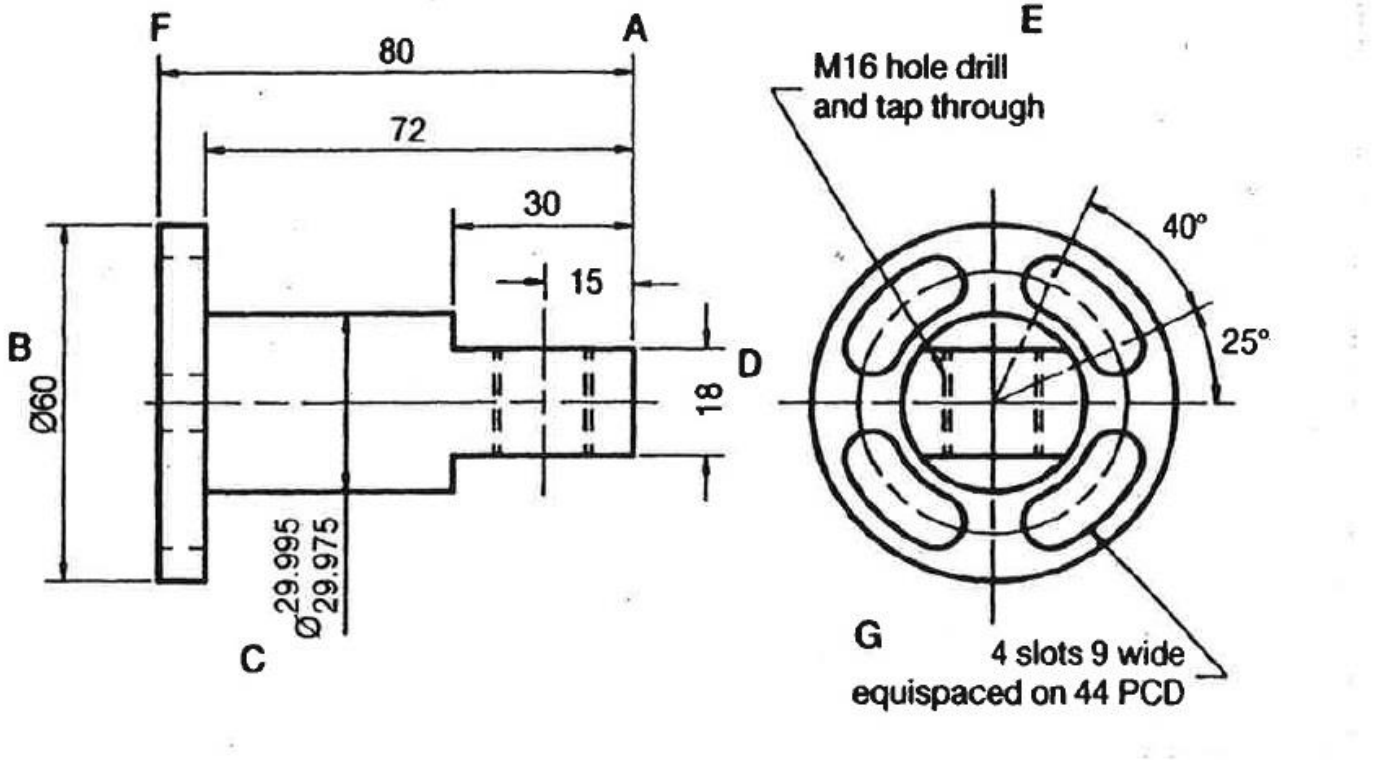
- machine tools
- tools and fixtures
- individual operations
- process drawings

The ***Route (operations) sheet*** is one of the most important documents next to the *product description*, or the *engineering print* in manufacturing.

Example of Process Planning

The part shown below is produced by a combination of turning and milling of a billet, sawn to length from a bar stock.

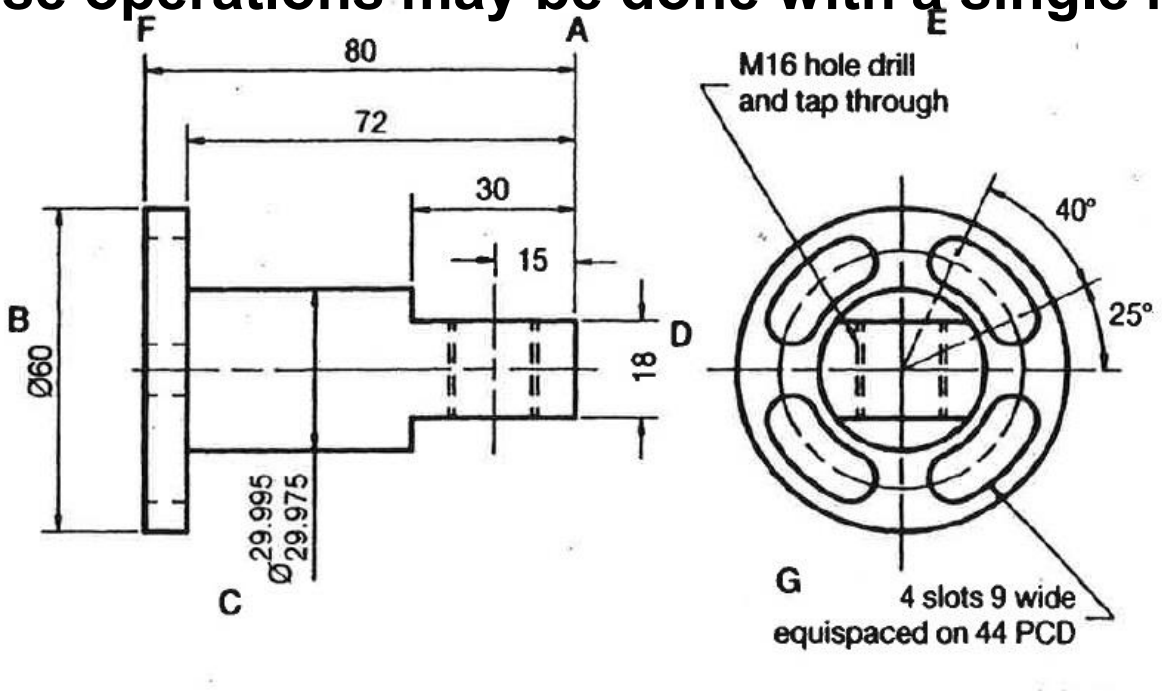
The sequence of machining operations using a CNC mill/turn centre (a lathe with a milling head which is capable of carrying out both turning and milling operations) is shown below:



Example of Process Planning – Single Machine

- Face the part (A)
- Turn the 60 mm outside diameter (B)
- Turn the 30 mm nominal diameter with two finish cuts to achieve the correct tolerance (C)
- Mill the two flats (D)
- Drill and tap the M16 hole (E)
- Part off (F)
- Reverse part in chuck; mill the radial slots (G)

All of these operations may be done with a single machine.



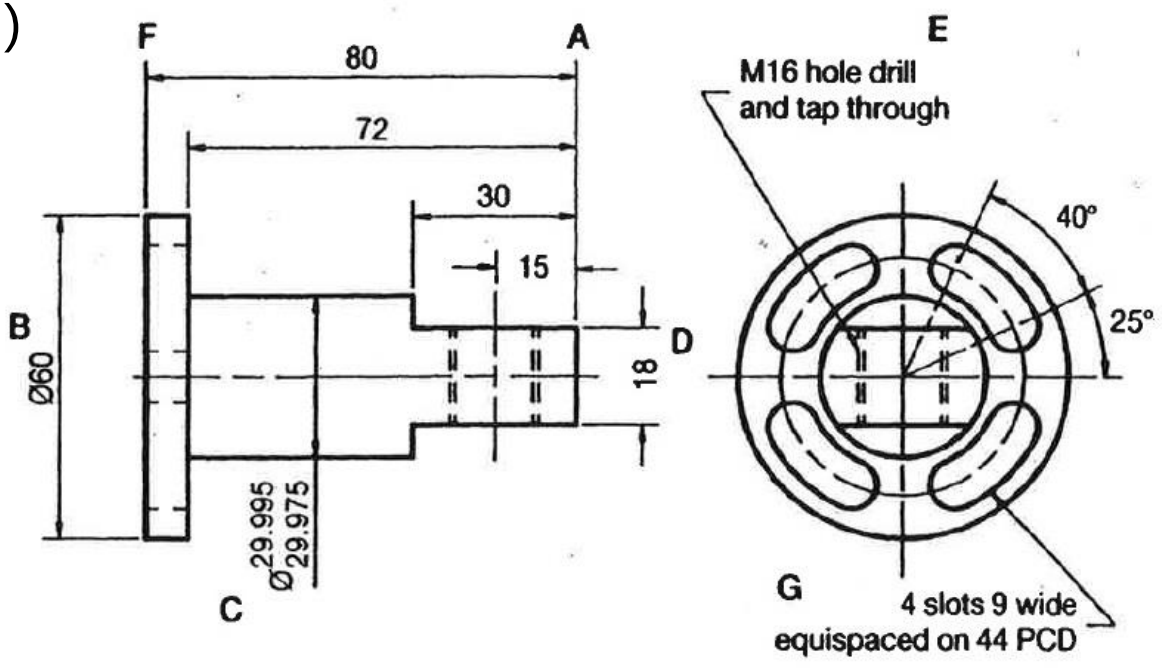
Example of Process Planning – Two Machines

- Face the part (A)
- Turn the 60 mm outside diameter (B)
- Turn the 30 mm nominal diameter with two finish cuts to achieve the correct tolerance (C)
- Part off (F)

  Transfer to milling machines (*)
- Mill the two flats (D)

  Transfer to drilling machines (*)
- Drill and tap the M16 hole (E)

  Transfer to milling machines (*)
- Mill the radial slots (G)



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Example of Route (operations) sheet – Pinion Shaft

Example of Pinion shafts

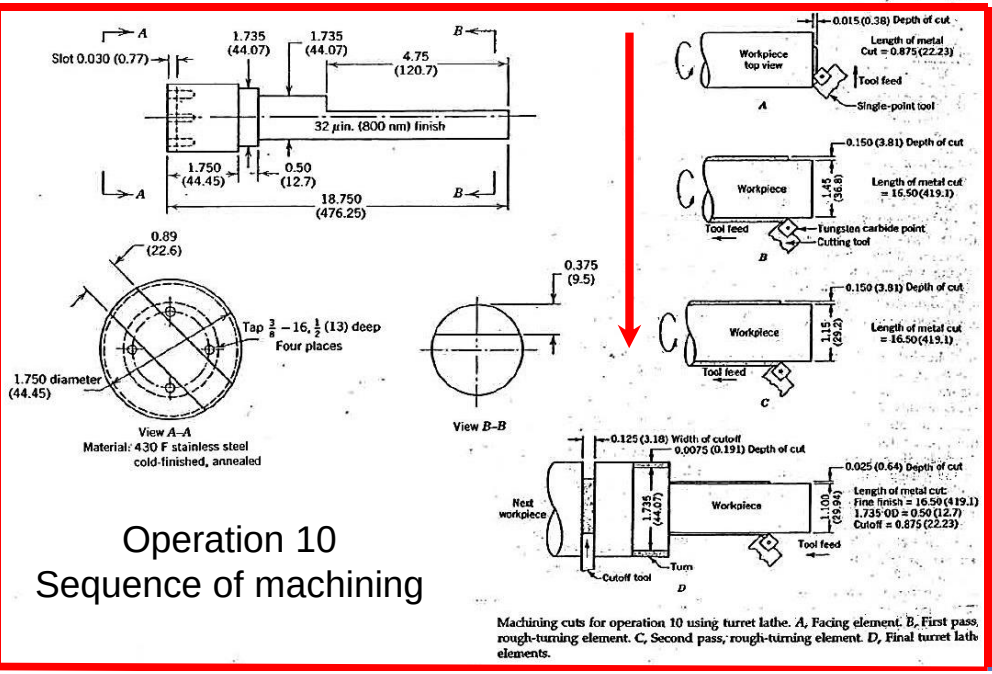
https://dir.indiamart.com/ahmedabad/pinion-shafts.html

https://www.youtube.com/watch?v=7g1QIdfSRCo

Pinion Route (Operations) Sheet

Part No: 4943806	Ordering quantity 1000	Material 430° F
Part name	Lot requirement 200	Stainless 1.750 ± 0.003
Operation planner Ed		Cold finished 12 ft long

Workstation	Op. No.	Description	Special or Standard tools
CNC Turret Lathe	10	Position for length Face 0.015 off end Turn rough to 1.45 OD Turn rough to 1.15 OD Turn finish to 1.110 OD Cut off to length 18.750	Carbide tools standard Use collet
Vertical Mill	20	End mill 0.89 slot with ¾ carbide end mill	Collet vertical hold
Horizontal Mill	30	Slab mill 4.75 x $\frac{3}{8}$	Nesting vice Carbide milling Cutter tool Collet fixture
NC Turret Lathe	40	Drill $\frac{5}{8}$ holes for $\frac{3}{8}$-16 tap	Drill Tap
Deburring Bench	50	Deburr Sharp edges	File



Operation 10
Sequence of machining

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Pinion Route (Operations) Sheet

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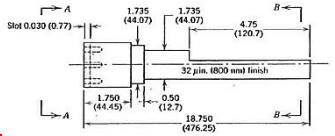
Operation planner Ed



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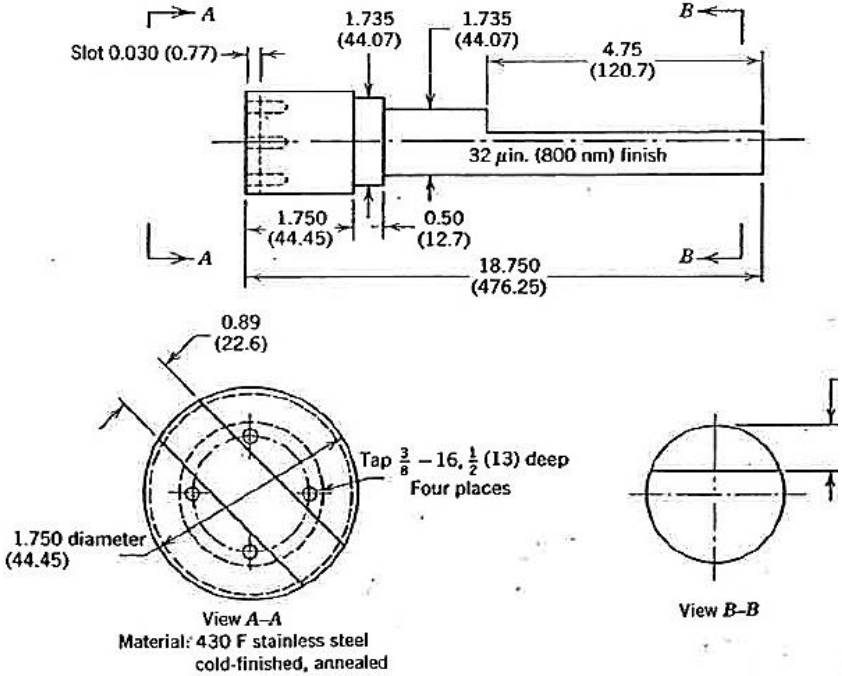

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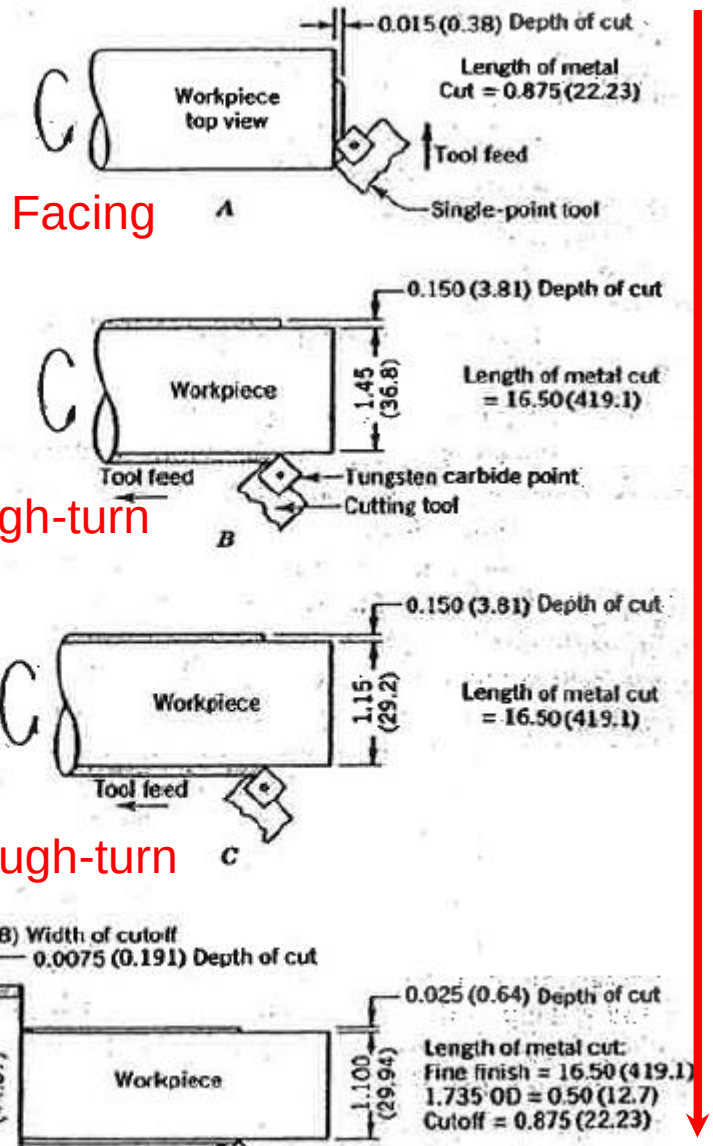

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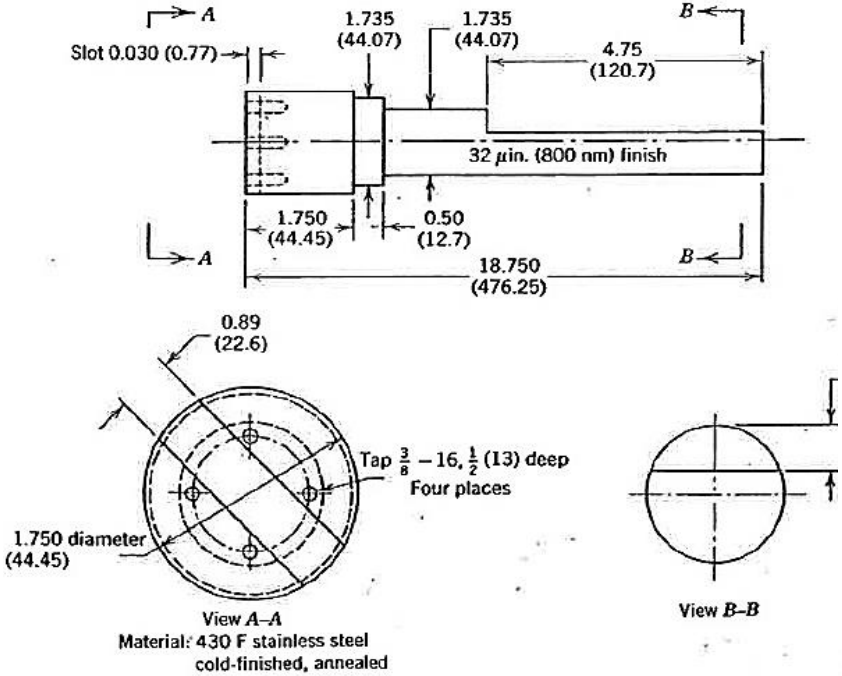

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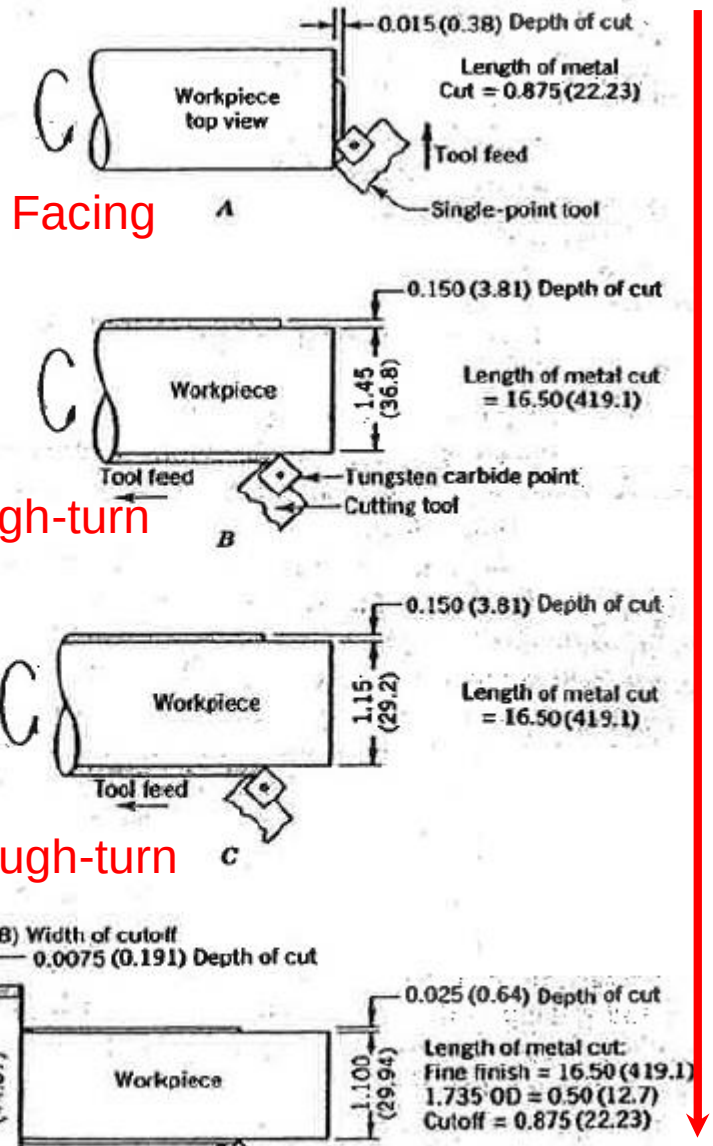

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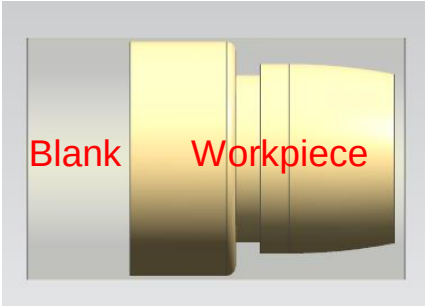
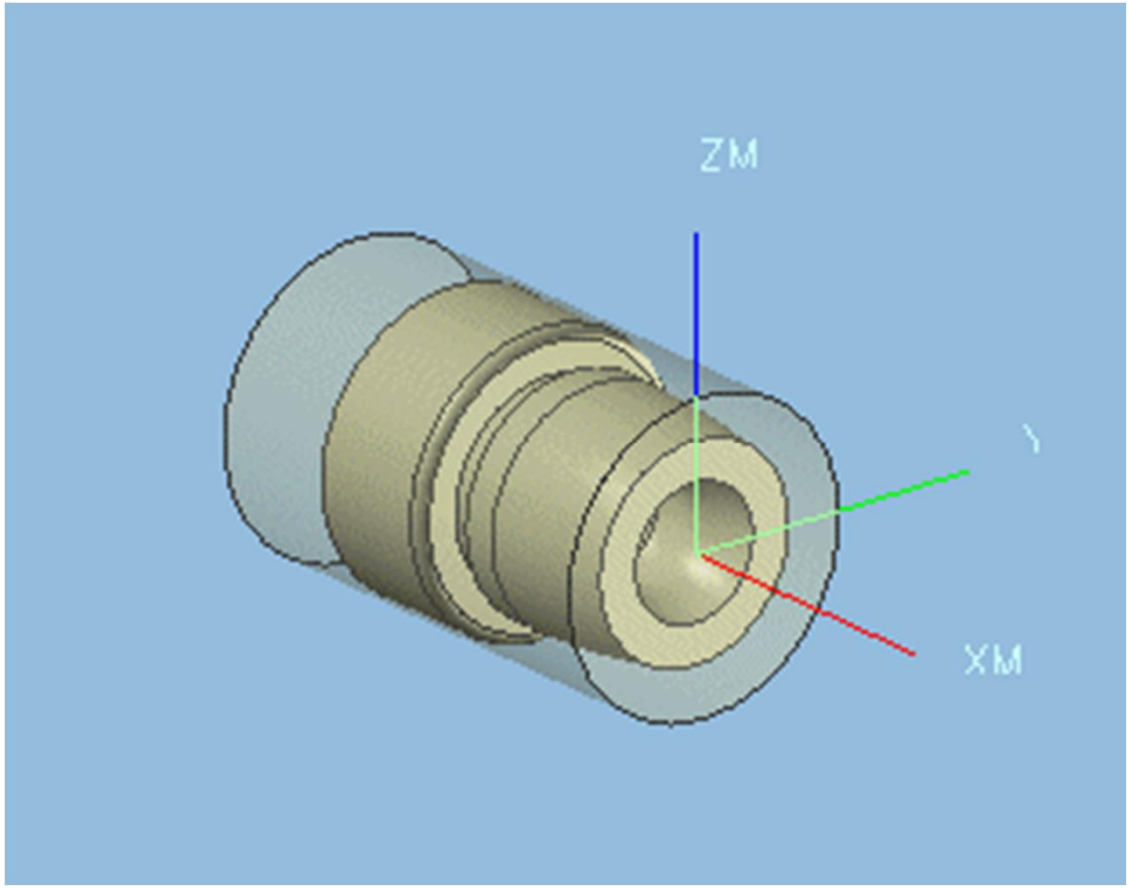
NX CAM Tutorial

- Animation below shows the machining sequence.



1. Face the part
2. Spot drill
3. Drill
4. Rough the OD
5. Groove the OD
6. Finish the OD
7. Rough bore the ID
8. Finish the ID
9. Groove the ID
10. Finish bore the remaining ID
11. Thread the ID
12. Cut the part off



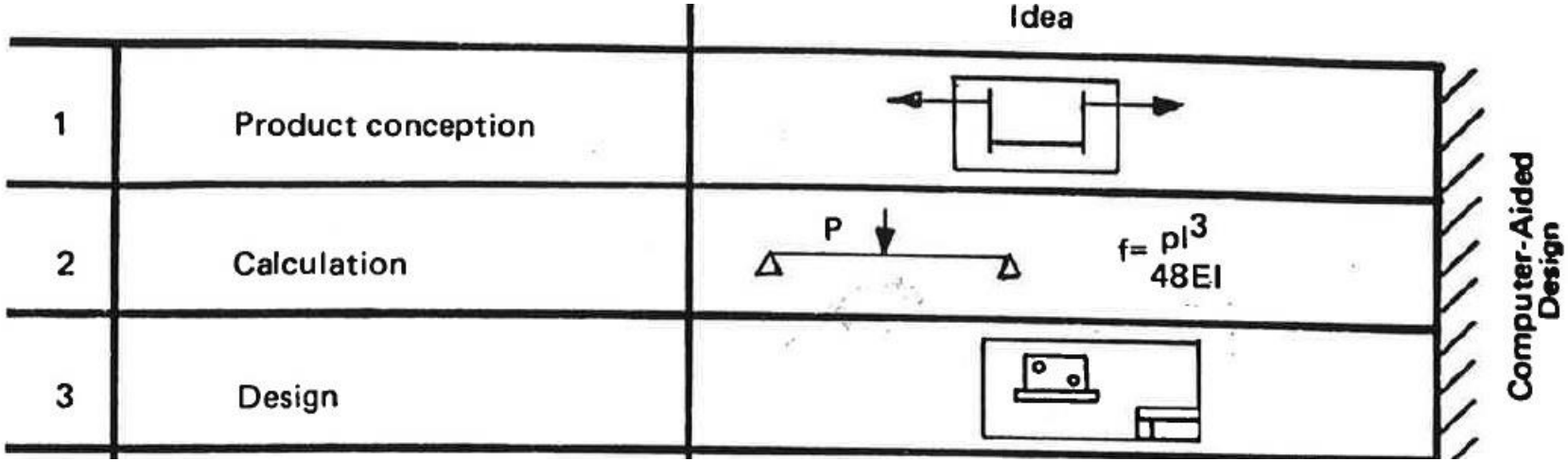
Process Planning Tasks - 14 Steps

- Process planning requires detailed knowledge of both the manufacturing processes available (e.g. machining, forming) and the production capabilities of the specific plant/machines in which the parts are to be manufactured.

- There are 14 steps in the design and planning for manufacture of a product and its component parts.

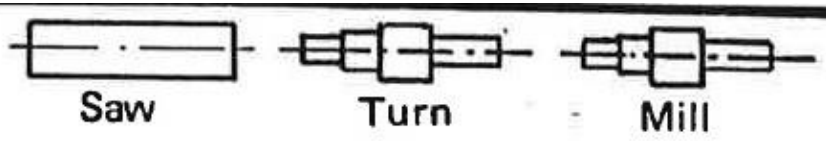
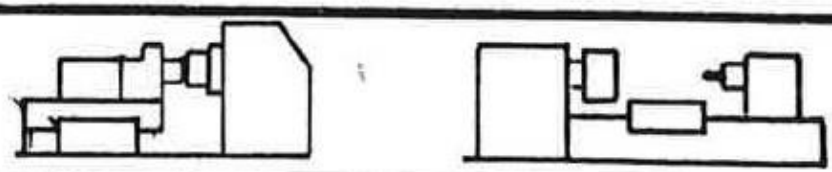
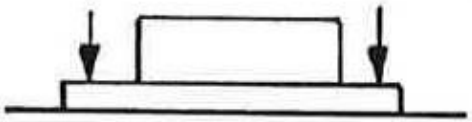
Process Planning Tasks – Steps 1-3

- Steps 1-3 are concerned with the design of the items to be produced - CAD systems are aimed at increasing the efficiency of these tasks.



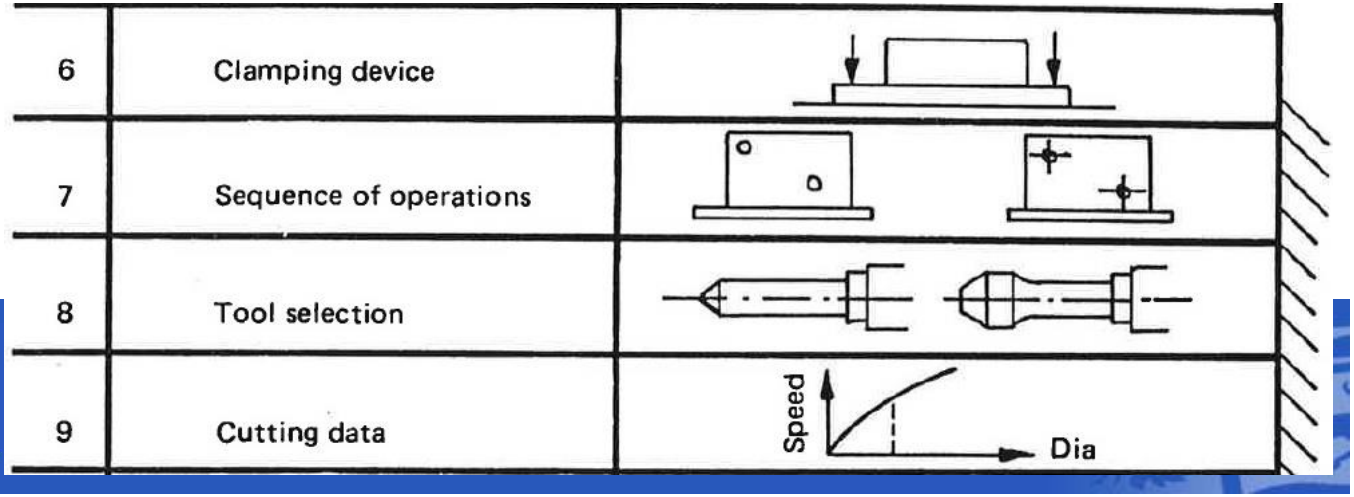
Process Planning Tasks - Steps 4-6

- Steps 4-6 describe the main steps required in process planning. The process planner converts the geometric information (drawings) about the items to be manufactured into appropriate sequences of manufacturing operations and determines the processing parameters (e.g. feeds and speeds) for each operation, taking into consideration the part geometry, material, and quantities required.

4	Machining sequence	
5	Sequence of machines	
6	Clamping device	

Process Planning Tasks - Steps 6 - 9

- Steps 6-8 are concerned with the detailed planning of each operation on each machine and includes the selection of work-holding methods, sequences of operations and tools
- Finally step 9 is the determination of cutting data, such as feeds and speeds, together with estimates of the cycle time.
- At this stage the machinability of the material and economics of the process must be considered in determining the most appropriate cutting parameters.



Process Planning Tasks - Step 9

The determination of cutting conditions data such as speed, feed & depth of cut is predetermined by the workpiece geometry & operation sequence using machinability data system.

Machinability data systems provide the characteristics of a machining operation as below:

1. Type of machining operation
2. Machine tool parameters
3. Cutting tool parameters
4. Workpart/workpiece characteristics
5. Operating parameters other than feed and speed

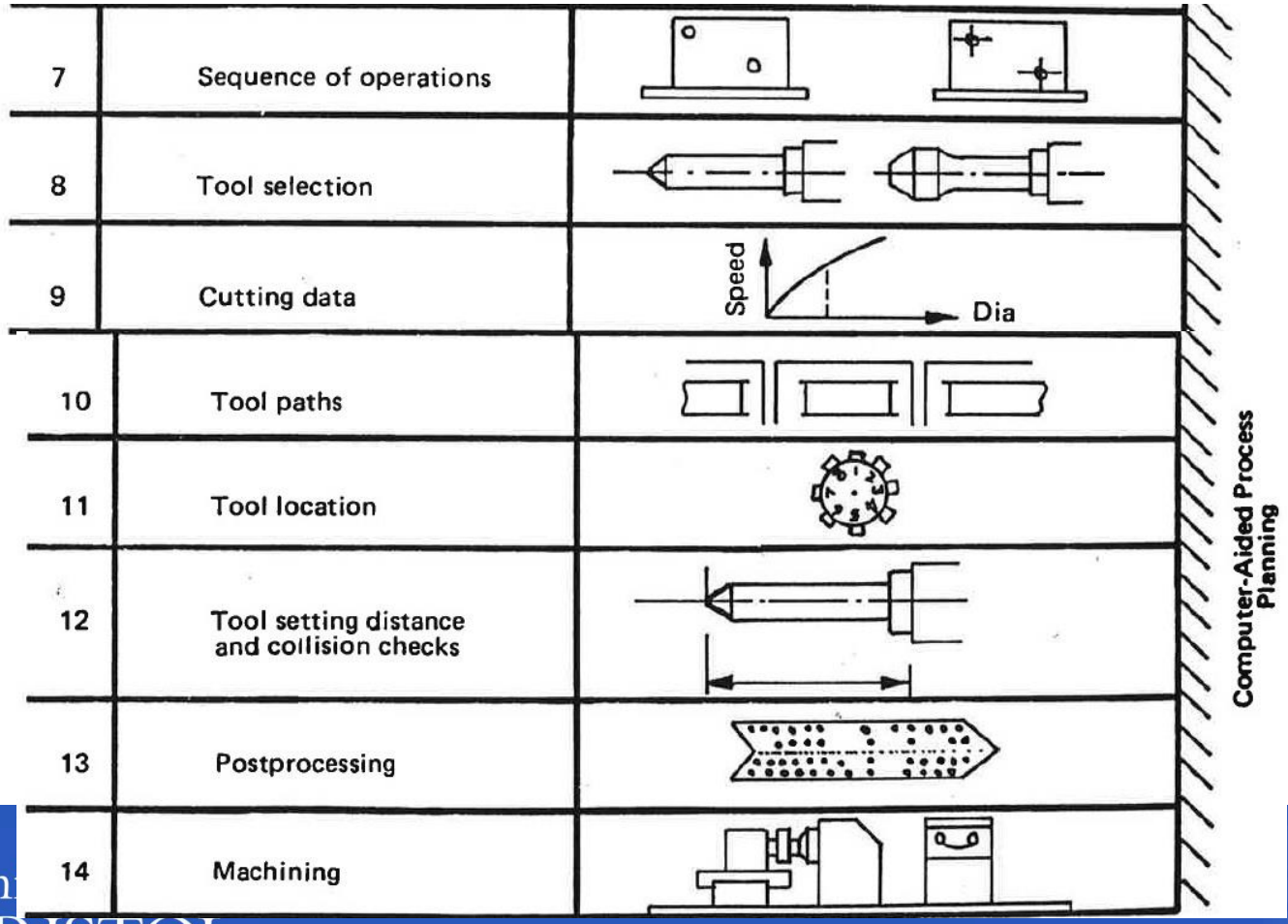
Process Planning Tasks - Step 9

The characteristics of a machining operation:

1	**Type of Machining Operation**	
	a	Process type-turning, facing, drilling, tapping, milling, boring, grinding, etc
	b	Roughing operation versus finishing operation.
2	**Machine Tool Parameters**	
	a	Size and rigidity
	b	Horsepower
	c	Spindle speed and feed rate levels
	d	Conventional or NC
	e	Accuracy and precision capabilities
	f	Operating time data
3	**Cutting Tool Parameters**	
	a	Tool material type (high-speed steel, cemented carbide, ceramic, etc.)
	b	Tool material chemistry or composition
	c	Physical and mechanical properties (hardness, wear resistance, etc.)
	d	Type of tool (single point, drill, milling cutter, etc.)
	e	Geometry (nose radius, rake angles, relief angles, number of teeth, etc.)
	f	Tool cost data
4	**Workpart Characteristics**	
	a	Material-basic type and specific grade
	b	Hardness and strength of work material
	c	Geometric size and shape
	d	Tolerances
	e	Surface finish
	f	Initial surface condition of workpiece
5	**Operating Parameters Other Than Feed and Speed**	
	a	Depth of cut
	b	Cutting fluid, if any
	c	Workpiece rigidity
	d	Fixtures and jigs used

Process Planning Tasks - Steps 7 - 14

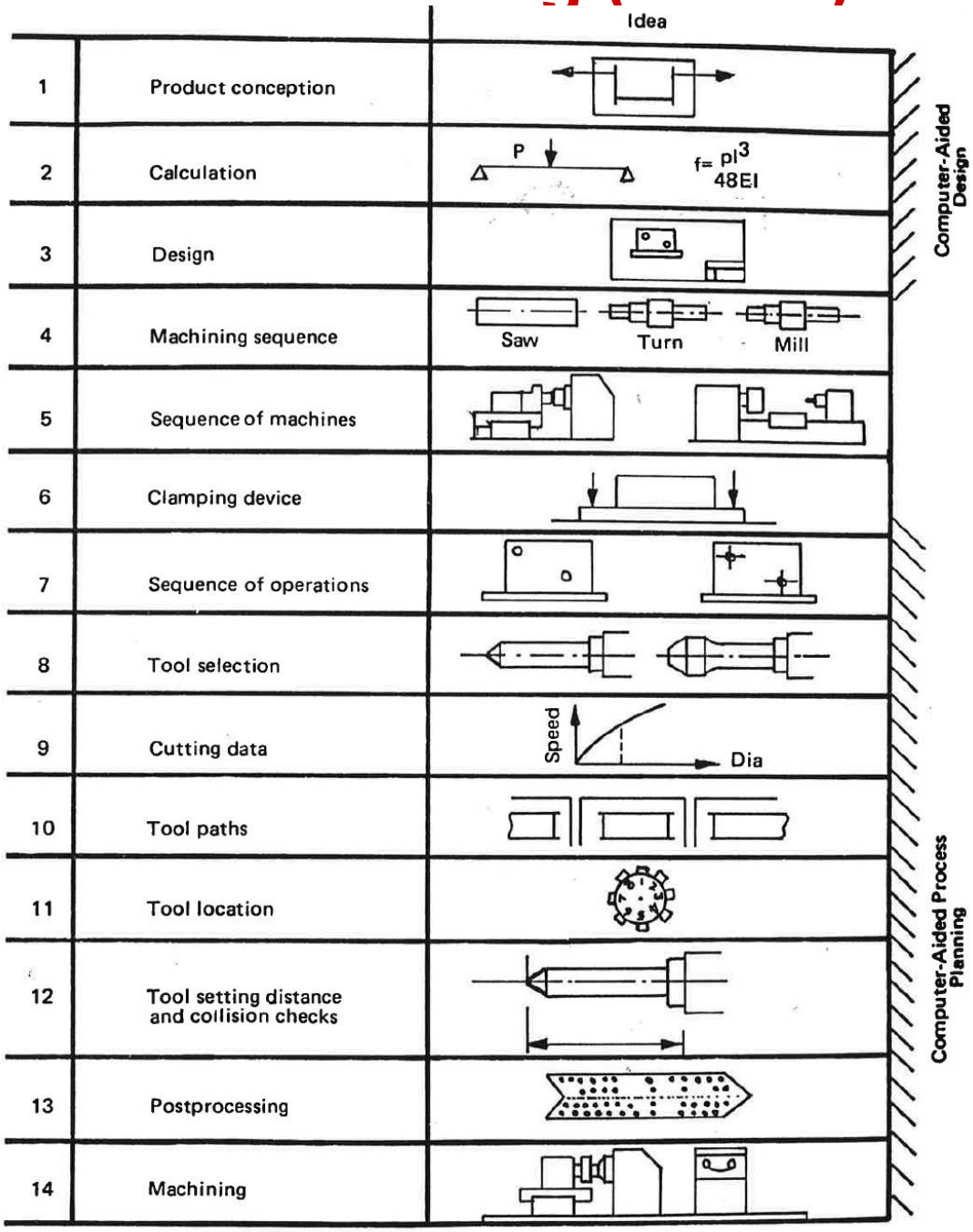
- In CAM, steps 7-9 are the selection of tools and cutting conditions that are done automatically with further automation of steps 10-13 (this is called computer-aided part programming and will be covered next).



Computer Aided Process Planning (CAPP)

- CAPP incorporates logic, judgement and experience into a computer program to deal with the steps 4-9.

- Integrated CAD/CAM allows CAPP and CNC machines to exchange information more efficiently and simultaneously for accelerating new product development.



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Learning Outcomes from Machining

- **In general, you will learn and practice the following important principles:**
- Set up the job where the workpiece, stock and machines, with their machine coordinate system (MCS), are defined.
- Identify the operational sequences required to produce a spinning topôs features.
- Identify cutting tools and order of use, corresponding to the sequence of operations.
- Analyse the machining operations and relationship between the part geometry, cutting tool and machining strategy, to highlight inherent design problems with your spinning top design and possible solutions using dynamic visualization of virtual machining.
- Create the tool-path coordinates and CL DATA file.
- Create a CNC program using a post-processor.
- Shop-floor machining.

CAPP Presentation

Any questions?