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INDUSTRIAL ENGINEERING

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Chapter 07 – Manufacturing Technologies

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Chapter 07

MANUFACTURING TECHNOLOGIES

OUTLINE

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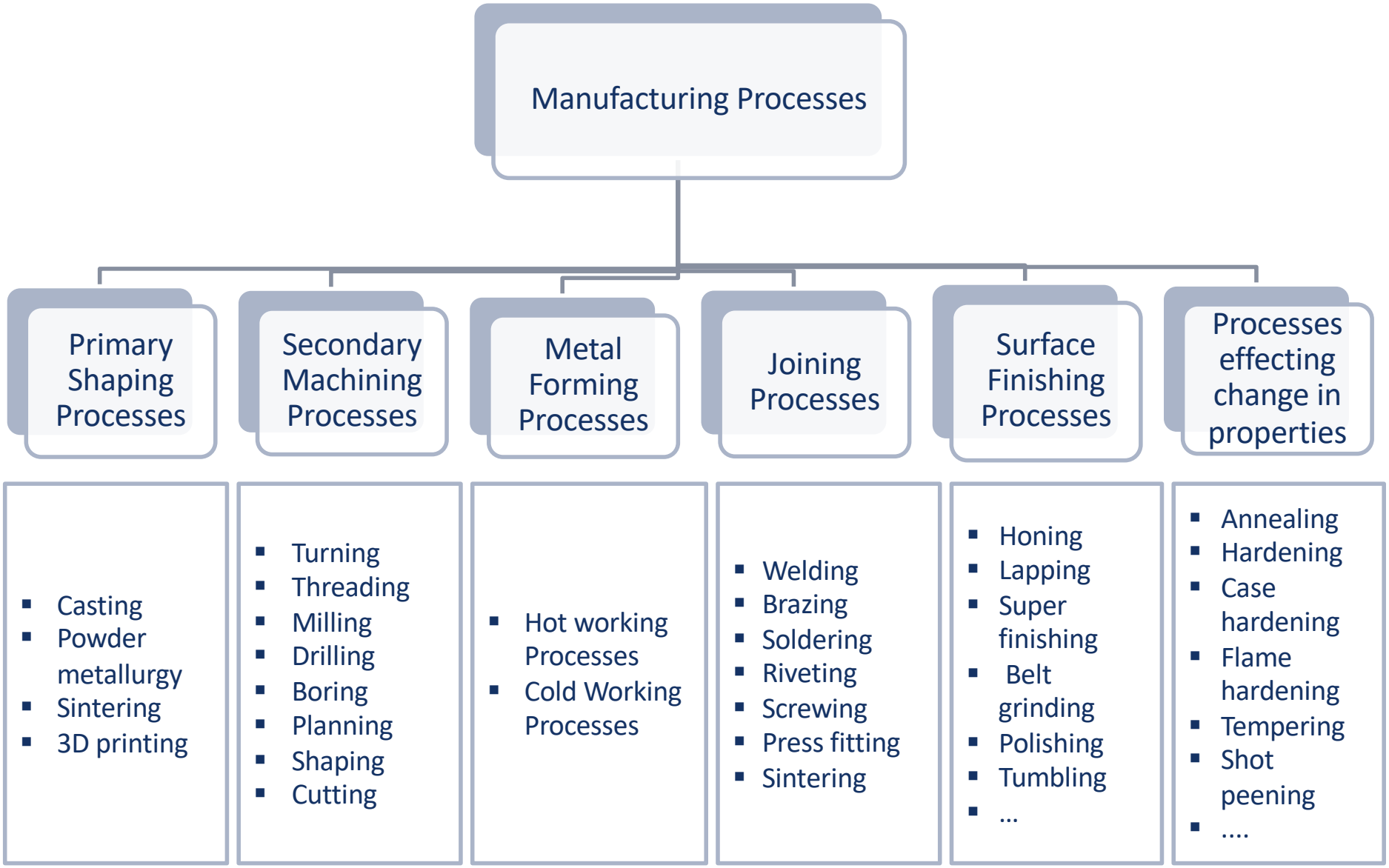
INTRODUCTION

DETAILED CLASSIFICATION OF MANUFACTURING PROCESSES



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PRIMARY SHAPING PROCESSES

PRIMARY SHAPING PROCESSES

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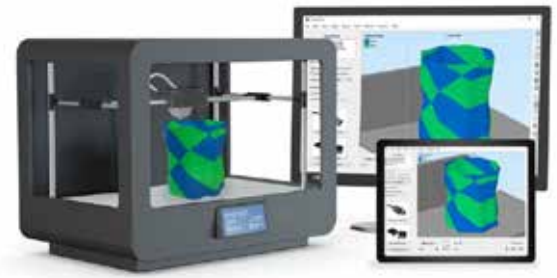
Manufacturing of a product from an amorphous (raw) material

Casting	Powder metallurgy	3D Printing
		
a solid is dissolved into a liquid, heated to appropriate temperature, and is then added into a mold or cavity.	materials are made from metal powders reducing the need to use metal removal processes	joining materials to make objects from 3D)model data, layer by layer

The parts produced through these processes may or may not require to undergo further operations.

TYPES OF CASTING

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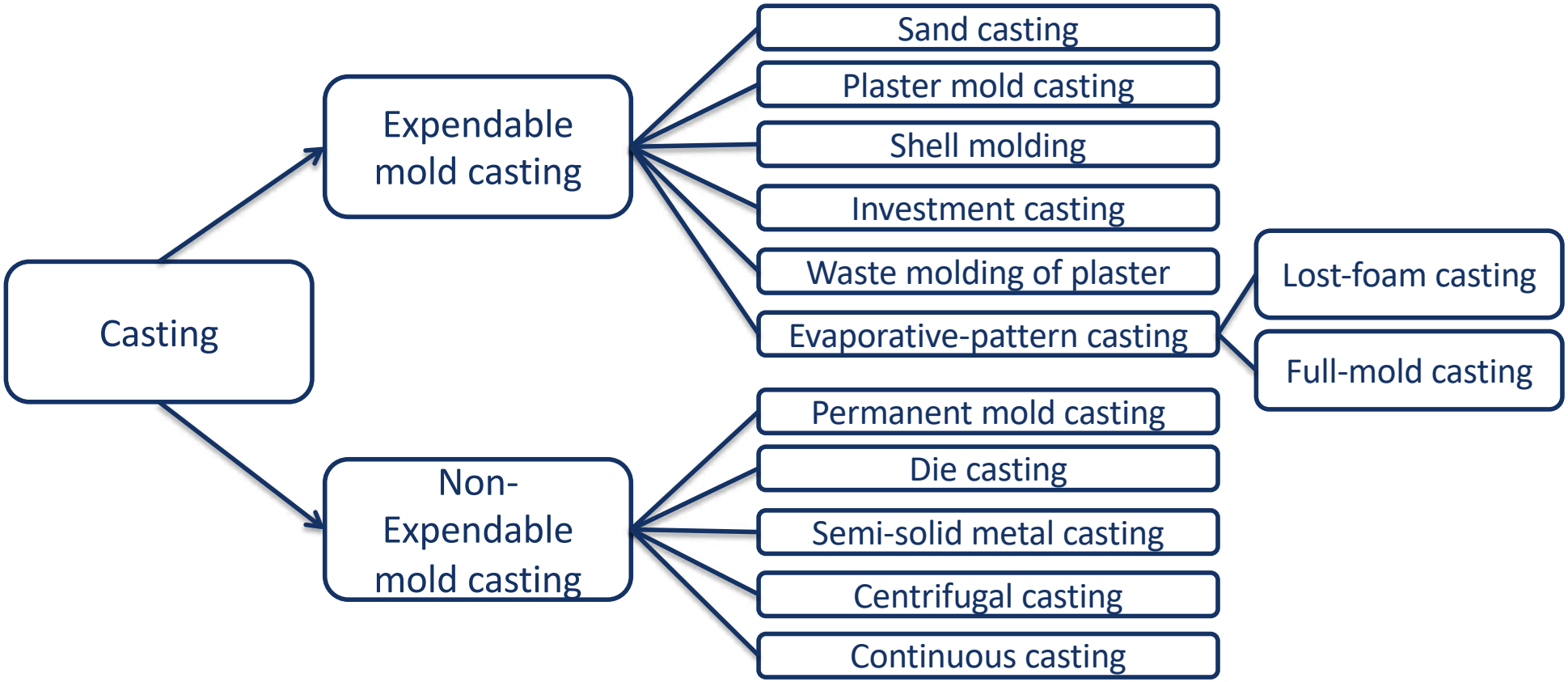
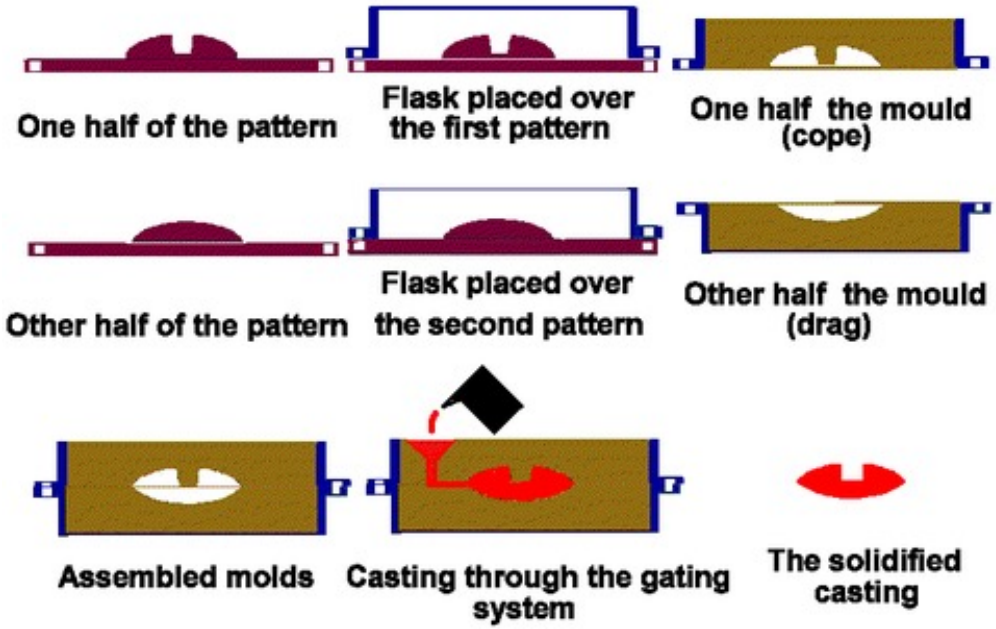
A process, in which liquid metal is poured into a mold, that contains a hollow cavity of the desired shape, and is then allowed to cool and solidify

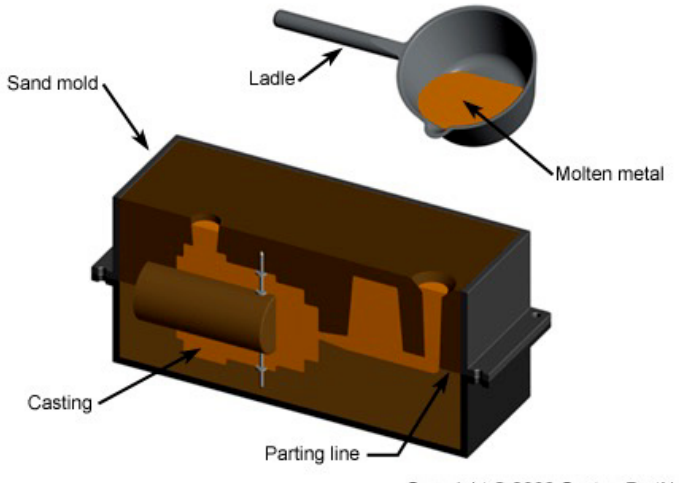


Most often used for making rather complex shapes in large numbers that would be difficult or infeasible to make by other methods

SAND CASTING

Is a metal casting process characterized by using sand as the mold material





Cope & drag (top and bottom halves of a sand mold), with cores in place on the drag

Sand casting allows for smaller batches than permanent mold casting and at a very reasonable cost

SAND CASTING PROCESS

SAND CASTING EXAMPLE:
BMW ENGINE BLOCK CASTING

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POSSIBLE PRODUCT OF SAND CASTING

SAND CASTING - CAPABILITIES

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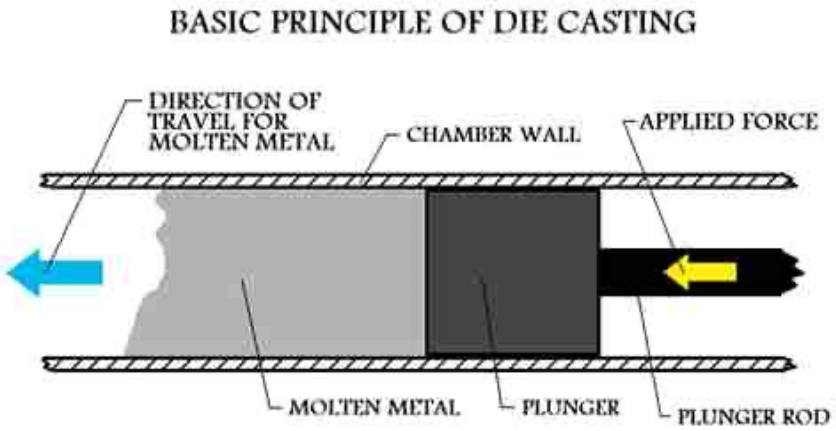
	Typical	Feasible
Shapes:	Thin-walled: Complex Solid: Cylindrical Solid: Cubic Solid: Complex	Flat Thin-walled: Cylindrical Thin-walled: Cubic
Part size:	Weight: 28 g – 450 t	
Materials:	Metals Alloy Steel Carbon Steel Cast Iron Stainless Steel Aluminum Copper Magnesium Nickel	Lead Tin Titanium Zinc
Surface finish - Ra:	8 -15 µm	3 – 50 µm
Tolerance:	± 0.8 mm	± 0.38 mm
Max wall thickness:	3.2 – 127 mm	2.3 mm – 1m
Quantity:	1 – 1,000	1 – 1,000,000
Lead time:	Days	Hours
Applications:	Engine blocks and manifolds, machine bases, gears, pulleys	

DIE CASTING

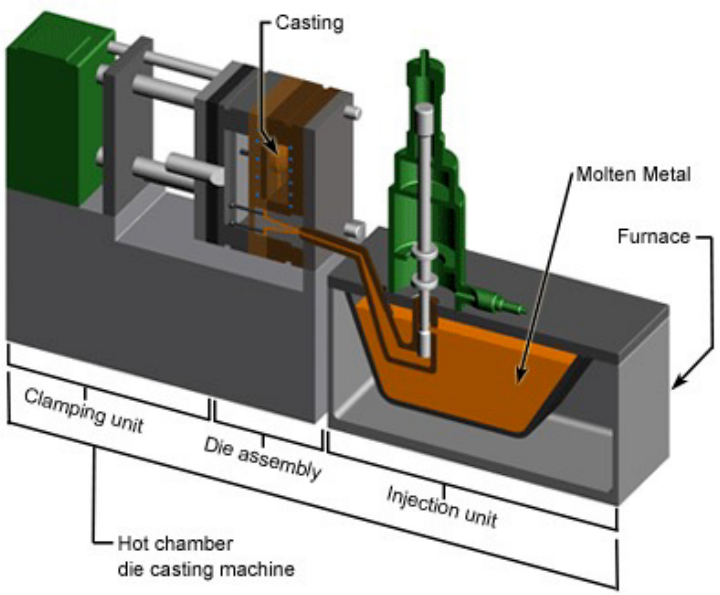
A metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity.



An engine block with aluminium and magnesium die castings

Depending on the type of metal being cast, a hot- or cold-chamber machine is used.

DIE CASTING PROCESS



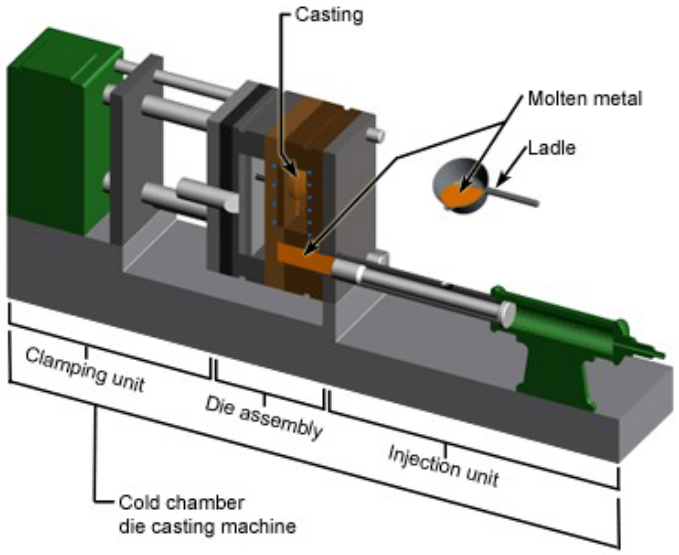
1 - Clamping

2 - Injection
(up to 1,500 bar/ 150 Mpa)

3 - Cooling

4 - Ejection

5 - Trimming



Schematic of a hot-chamber machine

Schematic of a cold-chamber die casting machine

DIE CASTING

EXAMPLES OF DIE CASTING

DIE CASTING

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	Typical	**Feasible**
Shapes:	Thin-walled: Complex Solid: Cylindrical Solid: Cubic Solid: Complex	Flat Thin-walled: Cylindrical Thin-walled: Cubic
Part size:	Weight: 14 g – 230 kg	
Materials:	Metals Aluminum Lead Magnesium Tin Zinc	Copper
Surface finish - Ra:	0.8 – 1 µm	0.4 – 3 µm
Tolerance:	± 0.38 mm	± 0.013 mm
Max wall thickness:	0.05 - 0.5 in. (1.3 – 13 mm)	0.38 – 38 mm
Quantity:	10,000 – 1,000,000	1,000 – 1,000,000
Lead time:	Months	Weeks
Applications:	Engine components, pump components, appliance housing	

3D PRINTING – ADDITIVE MANUFACTURING

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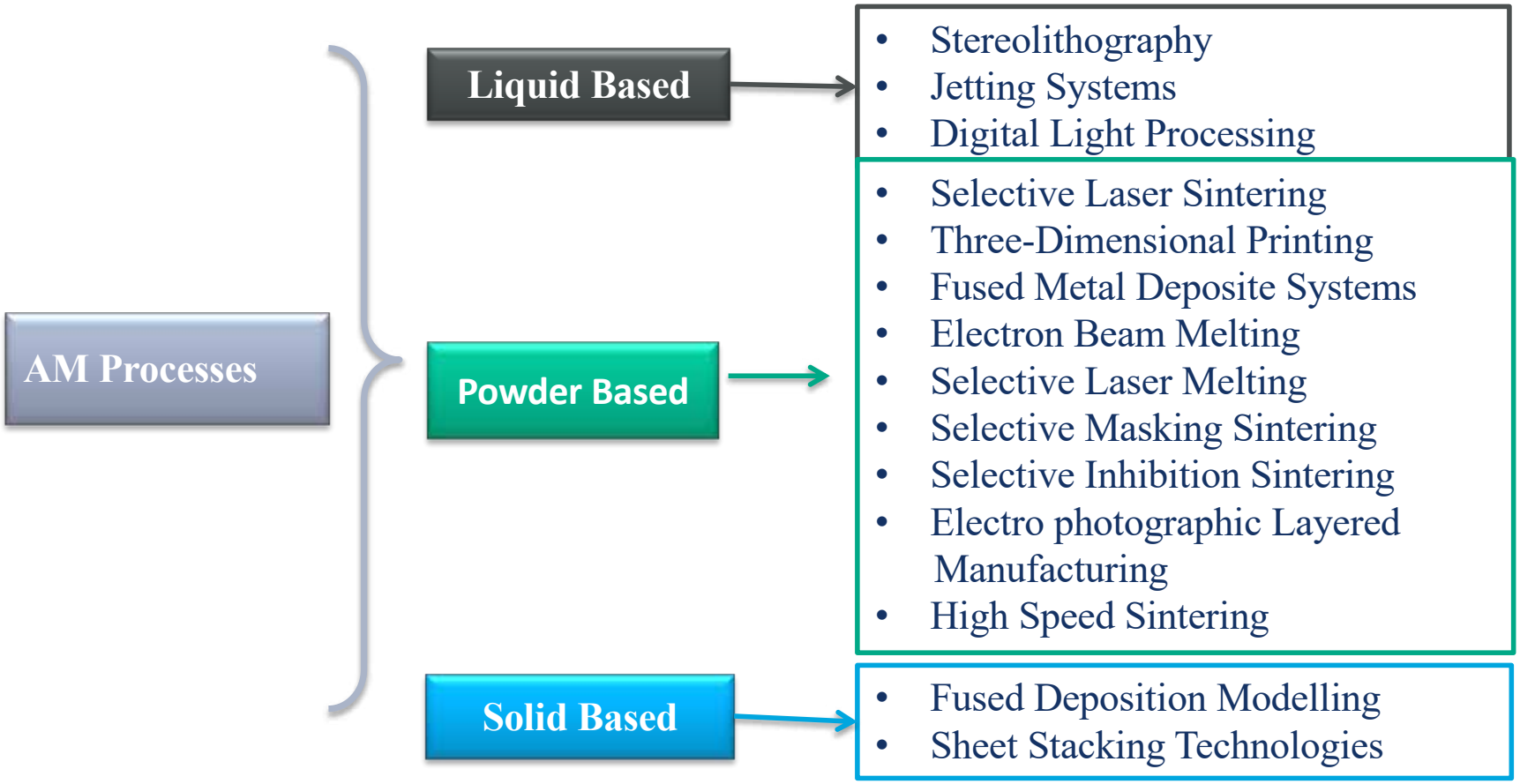
The process of joining materials to make objects from three-dimensional (3D) model data, usually layer by layer



Manufacturing components with virtually no geometric limitations or tools

FUSED DEPOSITION FDM & FREEFORM FABRICATION

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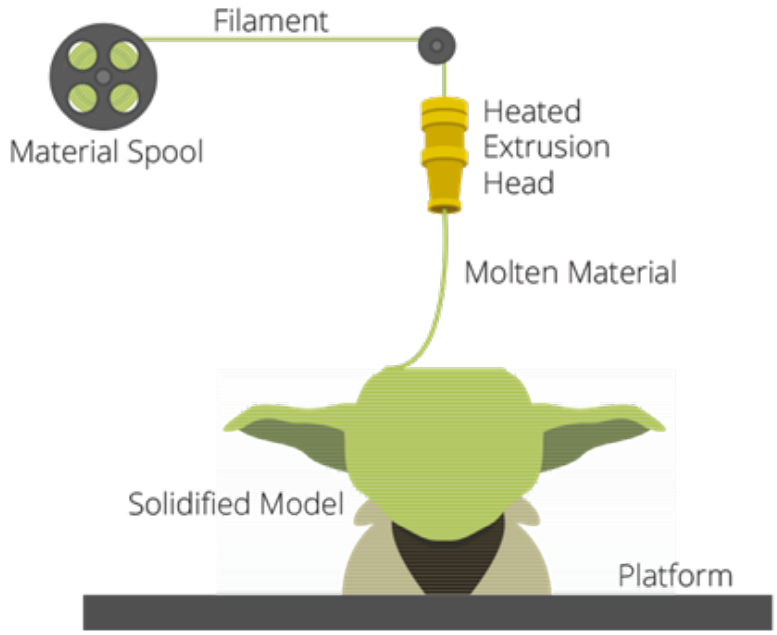
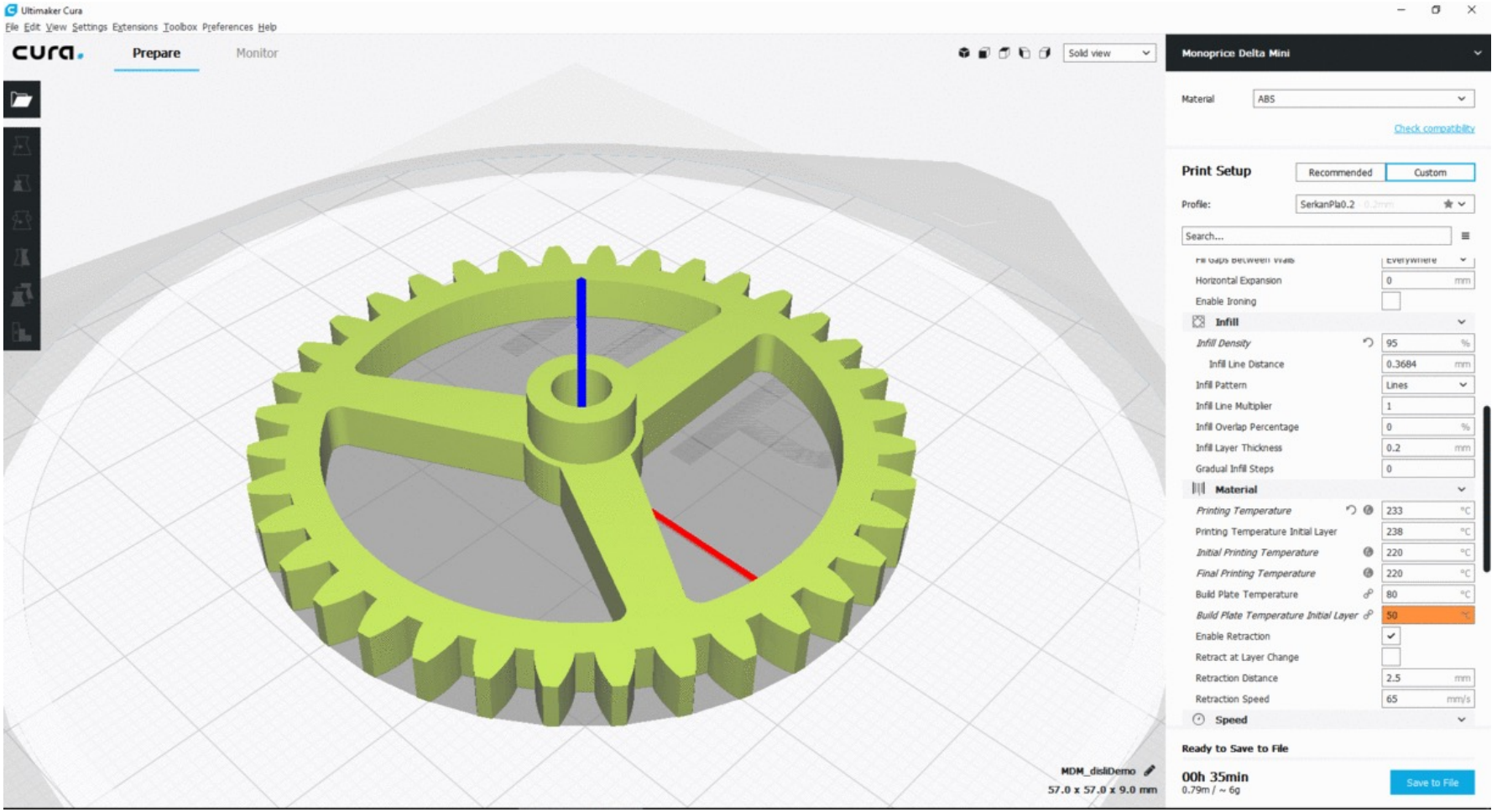
The process works by melting plastic filament that is deposited, via a heated extruder, a layer at a time, onto a build platform according to the 3D data supplied to the printer.



Each layer hardens as it is deposited and bonds to the previous layer

FUSED DEPOSITION MODELING – LIVE DEMO



EXAMPLE: GIANT 3D PRINTER OF LOGISTICS ENGINEERING & TECHNOLOGIES GROUP @ JU

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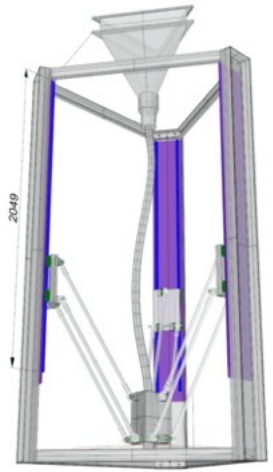

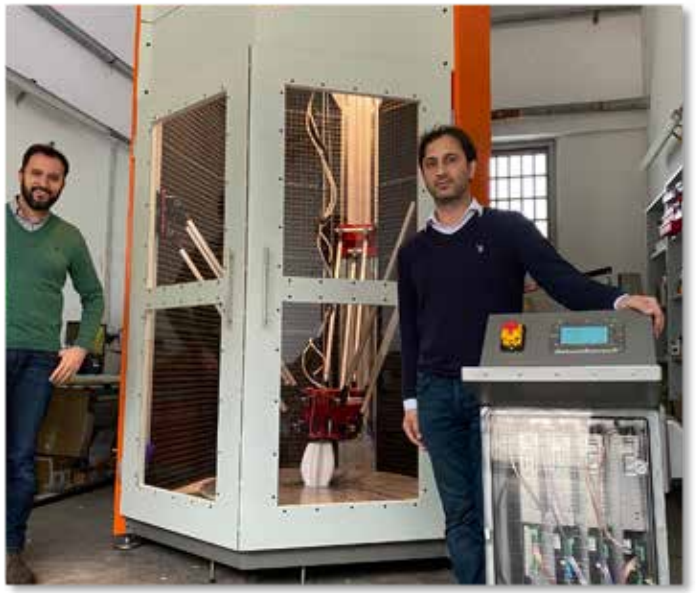

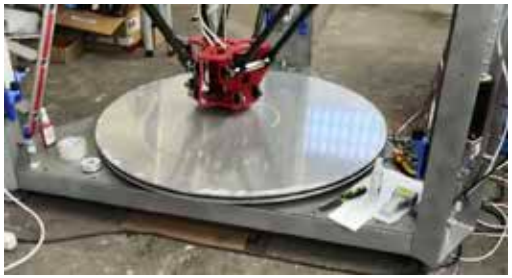

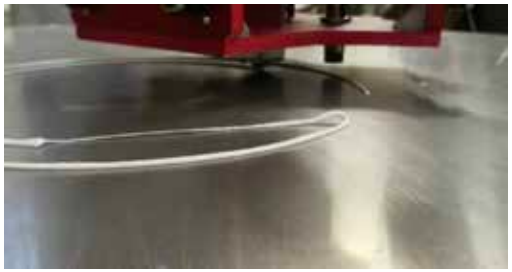

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SECONDARY SHAPING PROCESSES

SECONDARY SHAPING PROCESSES

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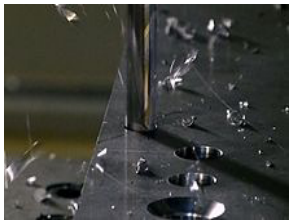
Where raw material or a component is taken for further working, usually involving material removal, and is carried out after a primary forming process.

Turning	Grinding	Drilling	Pressing	Boring	Milling

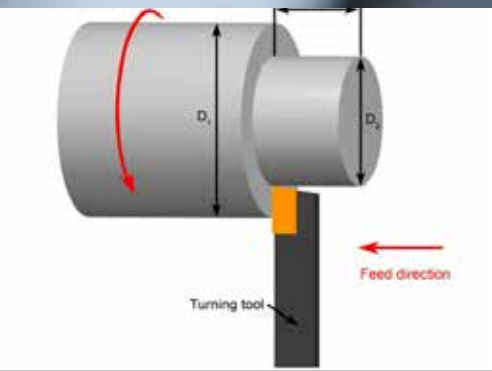


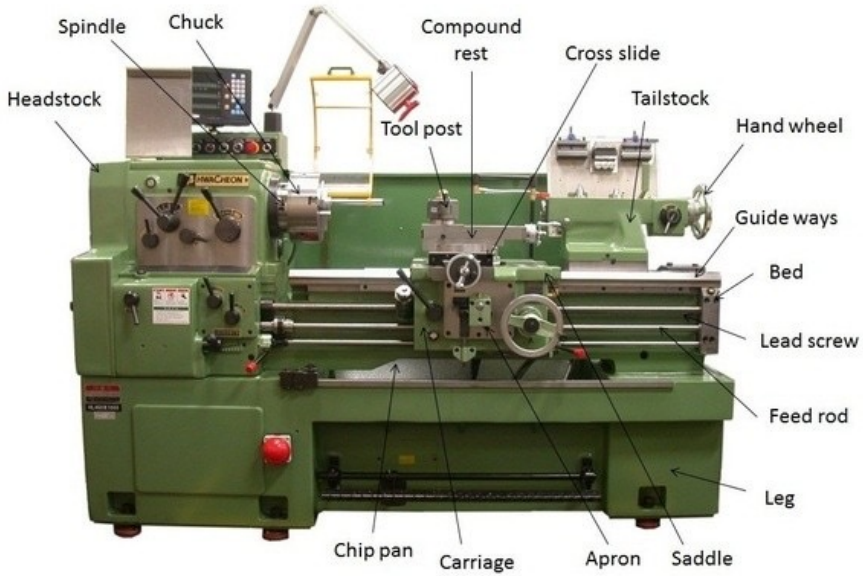



Provides the final shape with tighter controls over size, shape and surface finish

TURNING

Turning involves rotation of the workpiece while the cutting tool moves in a linear motion. This results in a cylindrical shape. A lathe is the machine of choice for all turning operations.





Turning is either done manually or automatically.

EXAMPLES OF TURNED PARTS

TURNING

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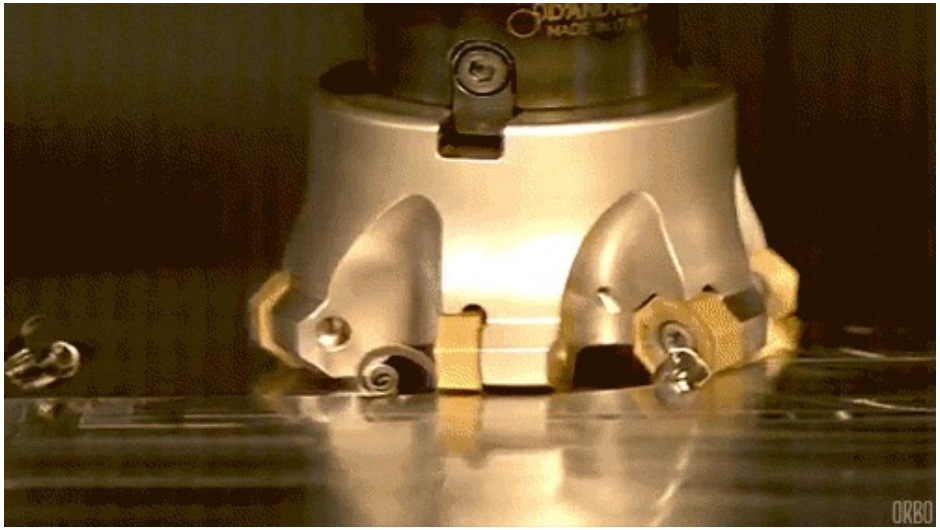
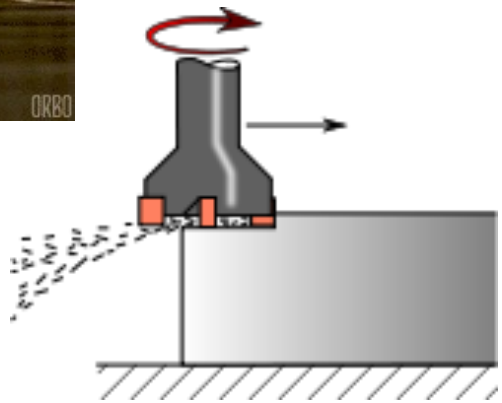
	Typical	**Feasible**
Shapes:	Thin-walled: Cylindrical Solid: Cylindrical	
Part size:	Diameter: 0.5mm – 2 m	
Materials:	Metals Alloy Steel Carbon Steel Cast Iron Stainless Steel Aluminum Copper Magnesium Zinc	Ceramics Composites Lead Nickel Tin Titanium Elastomer Thermoplastics Thermosets
Surface finish - Ra:	0.4 – 3 µm	0.05 – 6 µm
Tolerance:	± 0.025 mm	± 5 µm
Max wall thickness:	0.5 – 63 mm	0.5 mm – 2m
Quantity:	1 – 1,000	1 – 1,000,000
Lead time:	Days	Hours
Applications:	Machine components, shafts, engine components	

MILLING

Milling operations involve using multi-point rotary cutters to remove material from a workpiece (face vs. peripheral)





Most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

EXAMPLES OF MILLED PARTS

MILLING

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	Typical	Feasible
Shapes:	Solid: Cubic Solid: Complex	Flat Thin-walled: Cylindrical Thin-walled: Cubic Thin-walled: Complex Solid: Cylindrical
Part size:	Length: 1 mm - 1.8 m Width: 1 mm - 1.8 m	
Materials:	Metals Alloy Steel Carbon Steel Cast Iron Stainless Steel Aluminum Copper Magnesium Zinc	Ceramics Composites Lead Nickel Tin Titanium Elastomer Thermoplastics Thermosets
Surface finish - Ra:	0.8 – 3 µm	0.2 - 12 µm
Tolerance:	± 0.025 mm	± 0.013 mm
Max wall thickness:	1 mm – 1 m	1 mm – 1.8 m
Quantity:	1 – 1,000	1 – 1,000,000
Lead time:	Days	Hours
Applications:	Machine components, engine components	

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JOINING PROCESSES

JOINING PROCESSES

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The joining processes are carried out by fusing, pressing, rubbing, riveting, screwing or any other means of assembling.

Joining processes are widely used in fabrication and assembly work

WELDING

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A fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing fusion, which is distinct from lower temperature metal-joining techniques

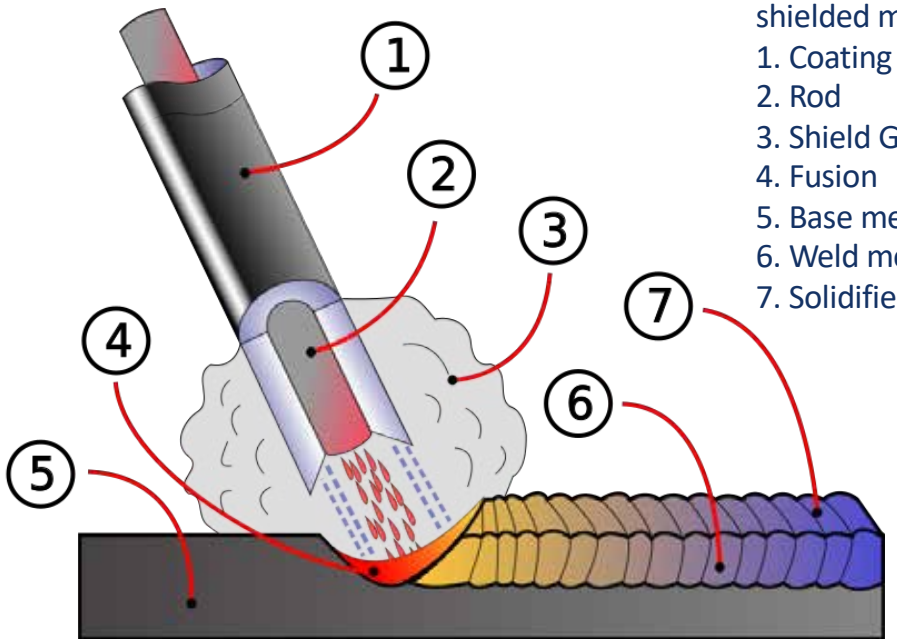

Diagram of arc and weld area, in shielded metal arc welding.
1. Coating Flow
2. Rod
3. Shield Gas
4. Fusion
5. Base metal
6. Weld metal
7. Solidified Slag

In melting the base metal, a filler material is typically added to the joint to form a pool of molten material that cools to form a joint that is usually stronger than the base material

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PROCESSES EFFECTING CHANGE IN PROPERTIES

PROCESSES EFFECTING CHANGE IN PROPERTIES

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Generally employed to provide certain specific properties to the metal work pieces for making them suitable for particular operations or use.

- Annealing
- Hardening
- Case hardening
- Flame hardening
- Tempering
- Shot peening
- Grain refining

Heat treatments affect the physical properties and also make a marked change in the internal structure of the metal

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CALCULATION OF REQUIRED NUMBER OF MACHINES

CALCULATION OF NUMBER OF MACHINES

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1 Required Machine Utilization Time
$T_{Ri} = \sum_{j=1}^{n} t_{uij} = \sum_{j=1}^{n} (t_{sij} * lj) + (q_{ij} * t_{eij})$
T_{Ri} = Required machine utilization time of machine *i* [min/year]
t_{uij} = Machine utilization time for product *j* on machine *i* [min/year]
t_{sij} = Machine setup time for product *j* on machine *i* [min/year]
l_j = Number of lots of product *j* per year [annual output of product *j* / lot size of product *j*]
q_{ij} = Demanded quantity of product *j* on machine *i* [unit/year]
t_{eij} = Execution time per unit for product *j* on machine *i* [min/unit]

CALCULATION OF NUMBER OF MACHINES

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2 Available Machine Utilization Time

$$T_{Ai} = D_i * h_i * \mu_{zmax} \quad [\text{min/year}]$$

T_{Ai}	=	Available machine utilization time [min/year]
D_i	=	Number of working days for machine *i* [days/year]
h_i	=	Available utilization time for machine *i* per day and shift
μ_{zmax}	=	Performance level of machine *i*, e.g.: 0.7 (manuf. & assembly within one-off production) 0.8 (manufacturing within series production) 0.9 (assembly within series production)

3 Number of Required Machines

$$M_i = T_{Ri} / T_{Ai}$$

EXAMPLE

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Planning Data

- Annual Output
  120.000 pcs/a
- Execution Time
  2 min/pc
- Labor Hours
  - 1 shift
  - 8 h/d
  - 5 d/week
  - 20 d/month
  - 12 months / a
- Daily Capacity
  8 h/d
- max. performance level
  0.8

Required # of machine calculation

- **Required Machine Utilization Time**
  120.000 pcs/a · 2 min/pc = 240.000 min/a
  = 4.000 h/a
- **Available Machine Utilization Time**
  240 d/a · 8 h/d · 0.8 = 1.536 h/a
- **Number of required machines:**

$$\frac{\text{Req. Mach. Ut. Time}}{\text{Available Mach. Ut. Time}} = \frac{4.000 \text{ h/a}}{1.536 \text{ h/a}} = \rightarrow 2{,}604 \rightarrow 3 \text{ BM}$$

Assumption

- No Setup

CONSECUTIVE EXERCISE 7.1

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- Calculate the required number of machines by using the corresponding spreadsheet (S22 – 24) under following assumptions:
  - Machines producing only one product do not need to be set up
  - Machines producing more than one product pick the corresponding lots of those products alternately, i.e. the respective machine needs to be set up for the second product´s lot after finishing the first product´s lot, and once finished with the first product´s lot, it needs to be set up again for the second product´s lot again, and so on.
  - The lot sizes are for each item 200 except for I-074 which is 50
  - Work Stations 43 and 44 are the inbound and outbound warehouse respectively
  - The number of business days are 250 per year
  - The available utilization time per day and shift is 8 hours (=labor hours)
  - The maximum performance level of all machines is 0.8

CONSECUTIVE EXERCISE 7.1
EXPLANATION: ALTERNATING SETUP

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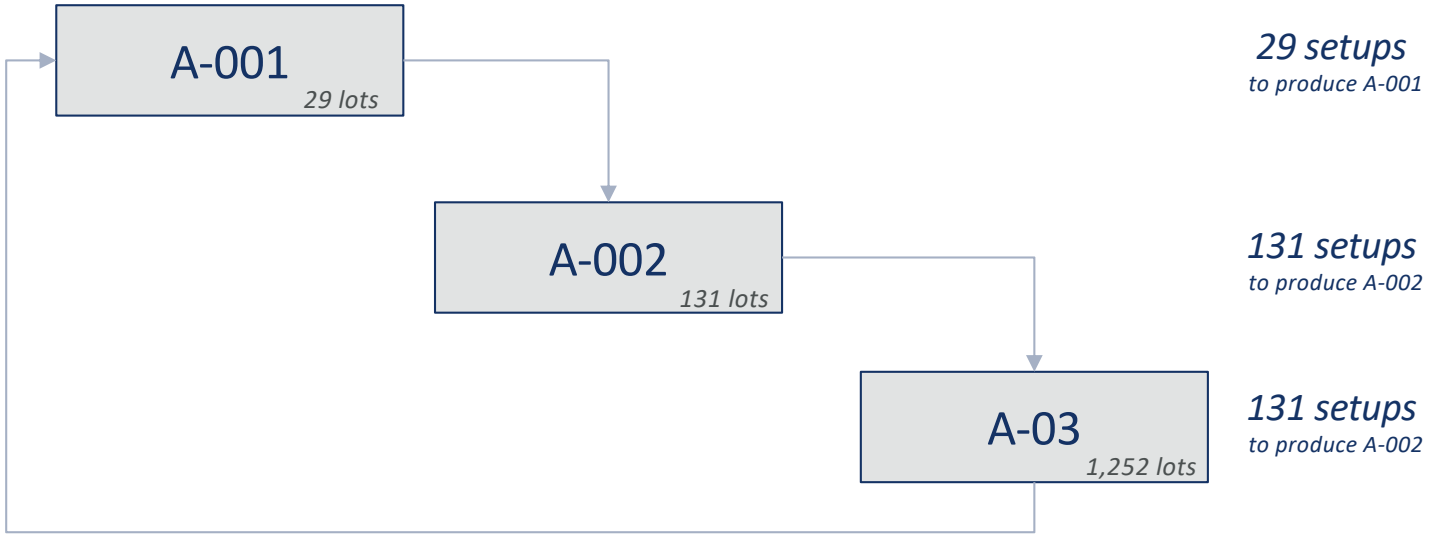
On WS-99

after 1 lot the next product´s lot will be produced



CONSECUTIVE EXERCISE 7.1
EXPLANATION: GETTING UNIQUE DISTINCT VALUES

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Q2: =INDEX($A$2:$A$118, MATCH(0, COUNTIF($Q$1:Q1, $A$2:$A$118), 0))

Cell Q2

COUNTIF($Q$1:Q1, $A$2:$A$118)

COUNTIF("Unique Distinct Values of WS", {"WS-02";"WS-02";"WS-02";"WS-03";…;"WS-44"})

⇩ returns

{0;0;0;0;…;0}

MATCH(0, COUNTIF($Q$1:Q1, $A$2:$A$118), 0)

MATCH(0, {**0**;0;0;0;…;0}, 0)

⇩ returns

1

INDEX({"**WS-02**";"WS-02";"WS-02";"WS-03";…;"WS-44"}, 1)

⇩ returns

"WS-02"

Cell Q3

COUNTIF($Q$1:Q2, $A$2:$A$118)

COUNTIF({"Unique Distinct Values of WS";"WS-02"}, {"WS-02";"WS-02";"WS-02";"WS-03";…;"WS-44"})

⇩ returns

{1;1;1;0;…;0}

MATCH(0, COUNTIF($Q$1:Q2, $A$2:$A$118), 0)

MATCH(0, {1;1;1;**0**;…;0}, 0)

⇩ returns

4

INDEX({"WS-02";"WS-02";"WS-02";"**WS-03**";…;"WS-44"}, 4)

⇩ returns

"WS-03"

CONSECUTIVE EXERCISE 7.1
EXPLANATION: EXTRACTING VALUES

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S3: =INDEX($E$2:$E$118, SMALL(IF($A$2:$A$118=S$2, ROW($E$2:$E$118) - ROW($E$2)+1), ROWS($S$3:S3)))

Cell S3

IF($A$2:$A$118=S$2, ROW($E$2:$E$118) - ROW($E$2)+1)

IF("{TRUE;TRUE;TRUE;FALSE;…;FALSE}, {2;3;4;5;6;7;…;118} – (2)+1)

⇩

{**1;2;3**;4;5;6;…;117}

⇩ returns

{1;2;3;FALSE;…;FALSE}

SMALL({**1**;2;3;FALSE;…;FALSE}, ROWS($S$3:S3))

⇩

1

⇩ returns

1

INDEX($E$2:$E$118, 1)

INDEX({**1252**;129;129;433;…}, 1)

⇩ returns

"1252"

Cell S4

IF($A$2:$A$118=S$2, ROW($E$2:$E$118) - ROW($E$2)+1)

IF("{TRUE;TRUE;TRUE;FALSE;…;FALSE}, {2;3;4;5;6;7;…;118} – (2)+1)

⇩

{**1;2;3**;4;5;6;…;117}

⇩ returns

{1;2;3;FALSE;…;FALSE}

SMALL({1;**2**;3;FALSE;…;FALSE}, ROWS($S$3:S4))

⇩

2

⇩ returns

2

INDEX($E$2:$E$118, 2)

INDEX({1252;**129**;129;433;…} , 2)

⇩ returns

"129"

ADVANCED: VBA CODE FOR PASTING THE PROPER WORK STATIONS IN SPREADSHEET S22

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```
Sub Sheet22_WS_Item()
Application.DisplayAlerts = False
Application.ScreenUpdating = False
   Dim cur_cell As String
   Dim cur_sheet As String
   Dim lookval As String

   cur_cell = ActiveCell.Address
   cur_sheet = ActiveSheet.Name

   Sheets("S08 ABC Output").Select
   Range("A3").Select

   Do While ActiveCell.Value <> ""
      If ActiveCell.Interior.ThemeColor = 9 Then
         lookval = ActiveCell.Value
         Sheets("S12 Operations").Select
         Range("C1").Select
         Selection.AutoFilter

         Selection.AutoFilter Field:=3, Criteria1:=lookval
         Range("E2").Select
         Range(Selection, Selection.End(xlDown)).Select
         Selection.SpecialCells(xlCellTypeVisible).Copy

         Sheets(cur_sheet).Select
         Range("A99999").End(xlUp).Offset(1, 0).Select
         Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
            :=False, Transpose:=False
         Sheets("S12 Operations").ShowAllData
         Sheets("S08 ABC Output").Select
      End If
      If ActiveCell.Interior.ThemeColor = 9 Then
         lookval = ActiveCell.Value
         Sheets("S12 Operations").Select
         Range("C1").Select
         Selection.AutoFilter
         Selection.AutoFilter Field:=3, Criteria1:=lookval
         Range("C2").Select
         Range(Selection, Selection.End(xlDown)).Select
         Selection.SpecialCells(xlCellTypeVisible).Copy

         Sheets(cur_sheet).Select
         Range("B99999").End(xlUp).Offset(1, 0).Select
         Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
            :=False, Transpose:=False
         Sheets("S12 Operations").ShowAllData
         Sheets("S08 ABC Output").Select
      End If
      ActiveCell.Offset(1, 0).Select

   Loop
   Sheets(cur_sheet).Select
   Range(cur_cell).Select

   Sheets("S22 Required Machine Hours").Select
   ActiveWorkbook.Worksheets("S22 Required Machine Hours").AutoFilter.Sort. _
      SortFields.Clear
   ActiveWorkbook.Worksheets("S22 Required Machine Hours").AutoFilter.Sort. _
      SortFields.Add2 Key:=Range("A1:A149"), SortOn:=xlSortOnValues, Order:= _
      xlAscending, DataOption:=xlSortNormal
   With ActiveWorkbook.Worksheets("S22 Required Machine Hours").AutoFilter.Sort
      .Header = xlYes
      .MatchCase = False
      .Orientation = xlTopToBottom
      .SortMethod = xlPinYin
      .Apply
   End With

   Application.DisplayAlerts = True
   Application.ScreenUpdating = True
End Sub
```

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THANK YOU!