2006-02 CAD/CAM

# CAM (Computer-Aided Manufacturing)

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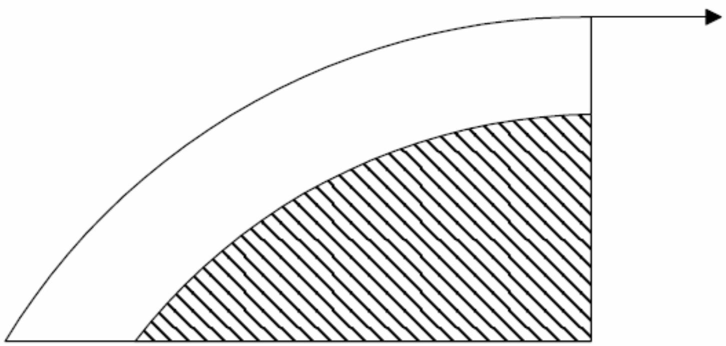
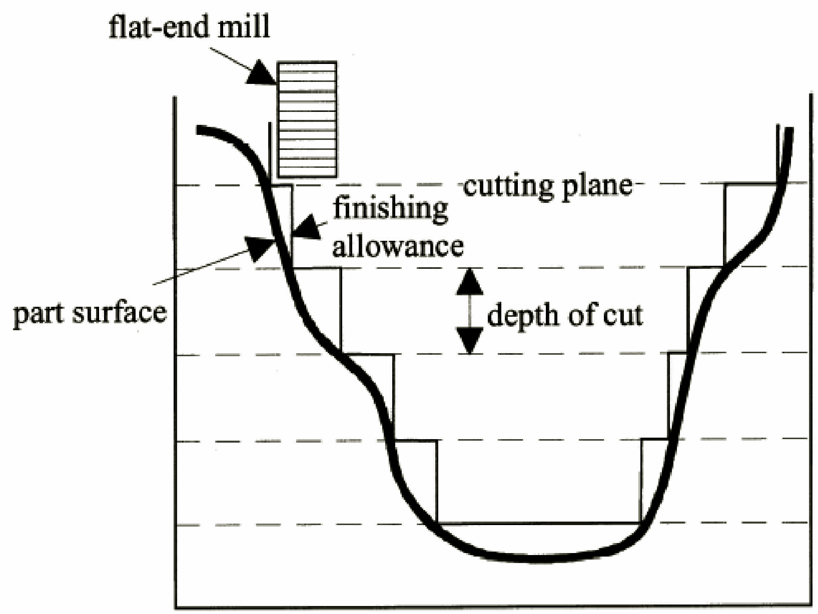
2006-10-30

# Tool Path Generation

- Rough Cutting
  - Remove bulk material
  - One type: the raw material has a shape close to the final shape
  - Second type: the raw material is provided in the form of block



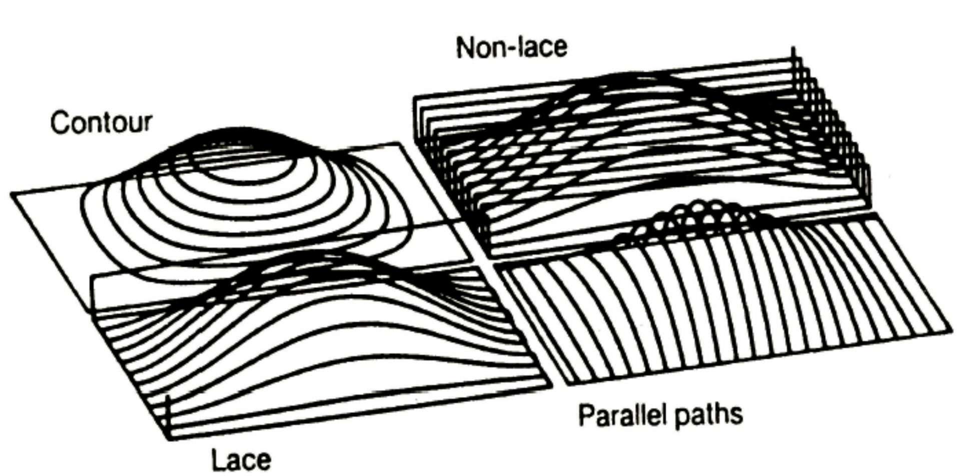
< One type of rough cutting >




< Second type of rough cutting >

# Tool Path Generation (cont.)

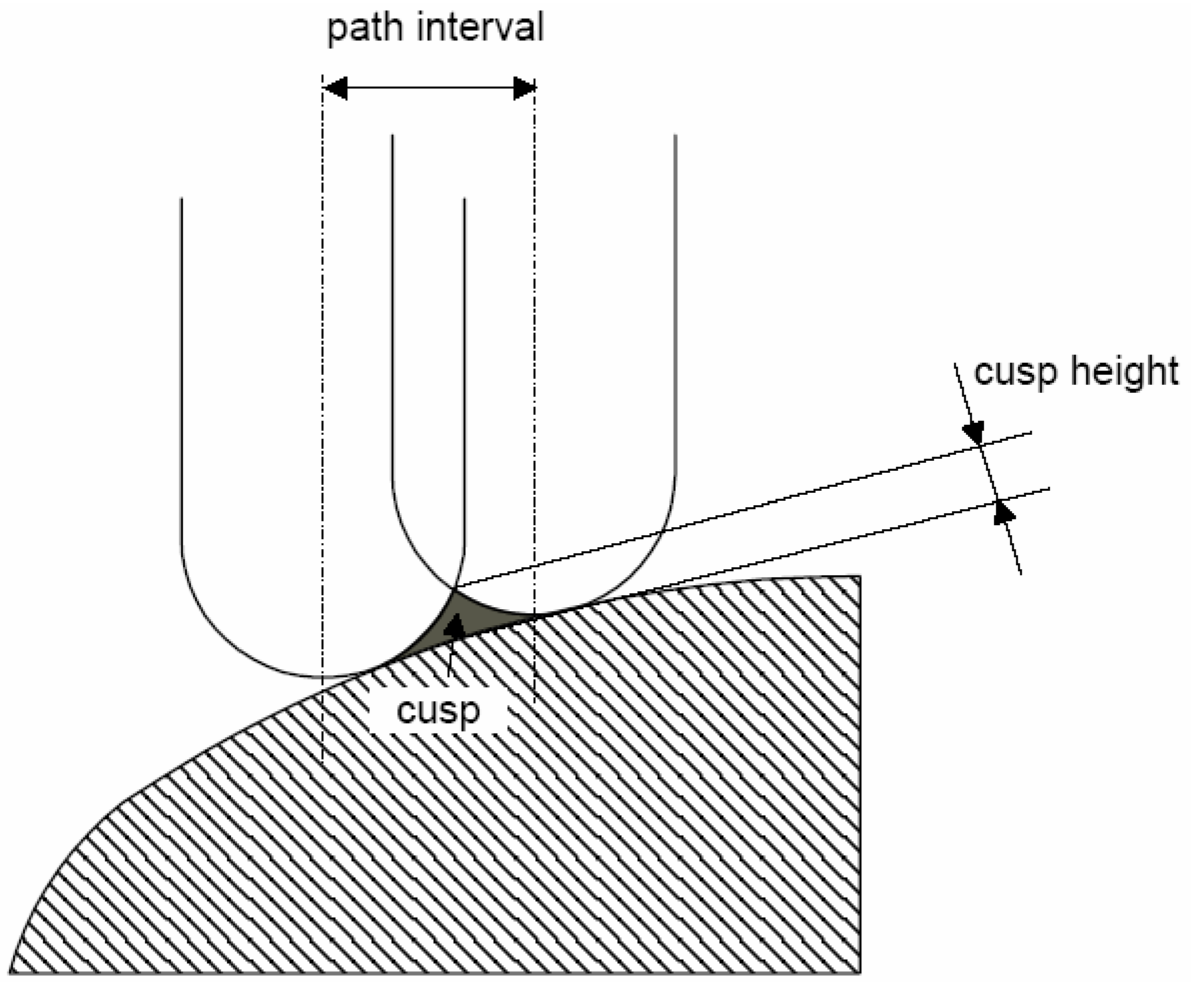
- Finish cutting
  - For the machining accuracy, below relationships should be considered
    - Path interval and cups height
    - Step length and deviation
    - Generation of CC points by subdivision
    - CC point and CL point




< Various cutter paths on a surface >

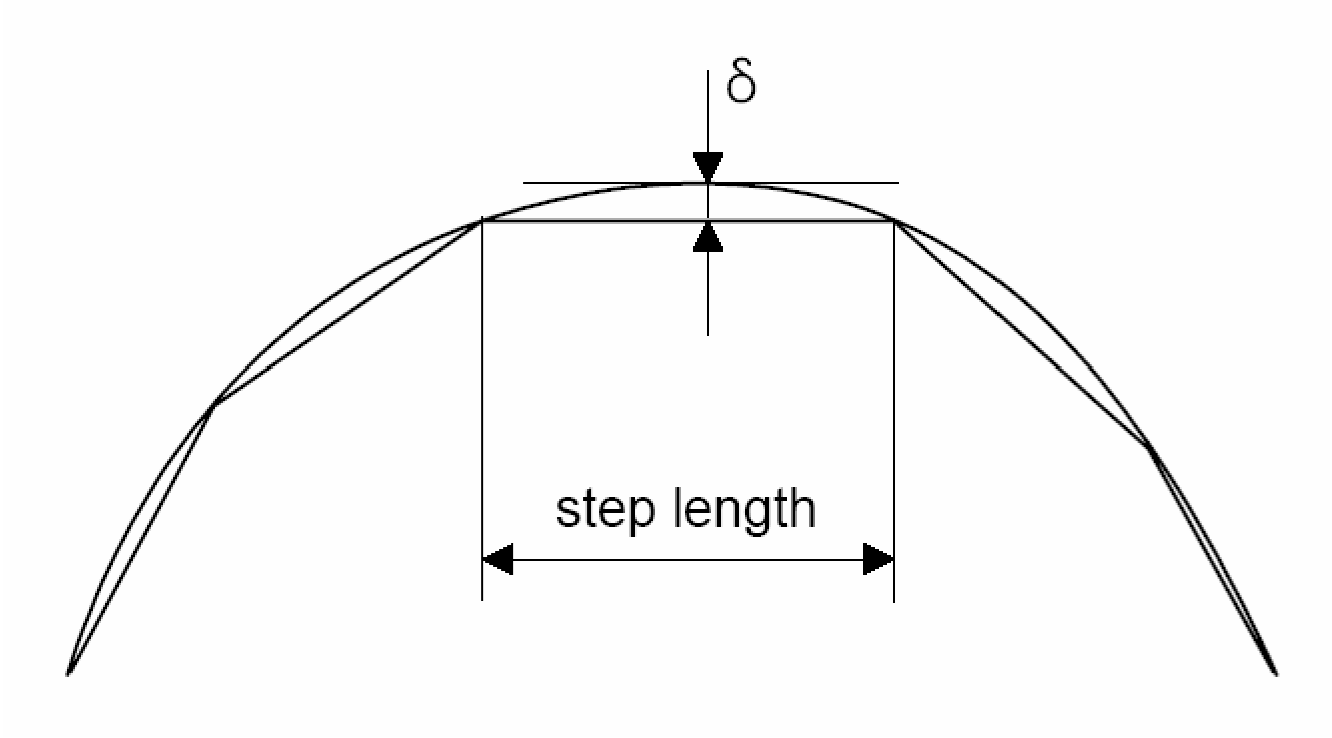
# Tool Path Generation (cont.)

- Relationship between path interval and cusp height



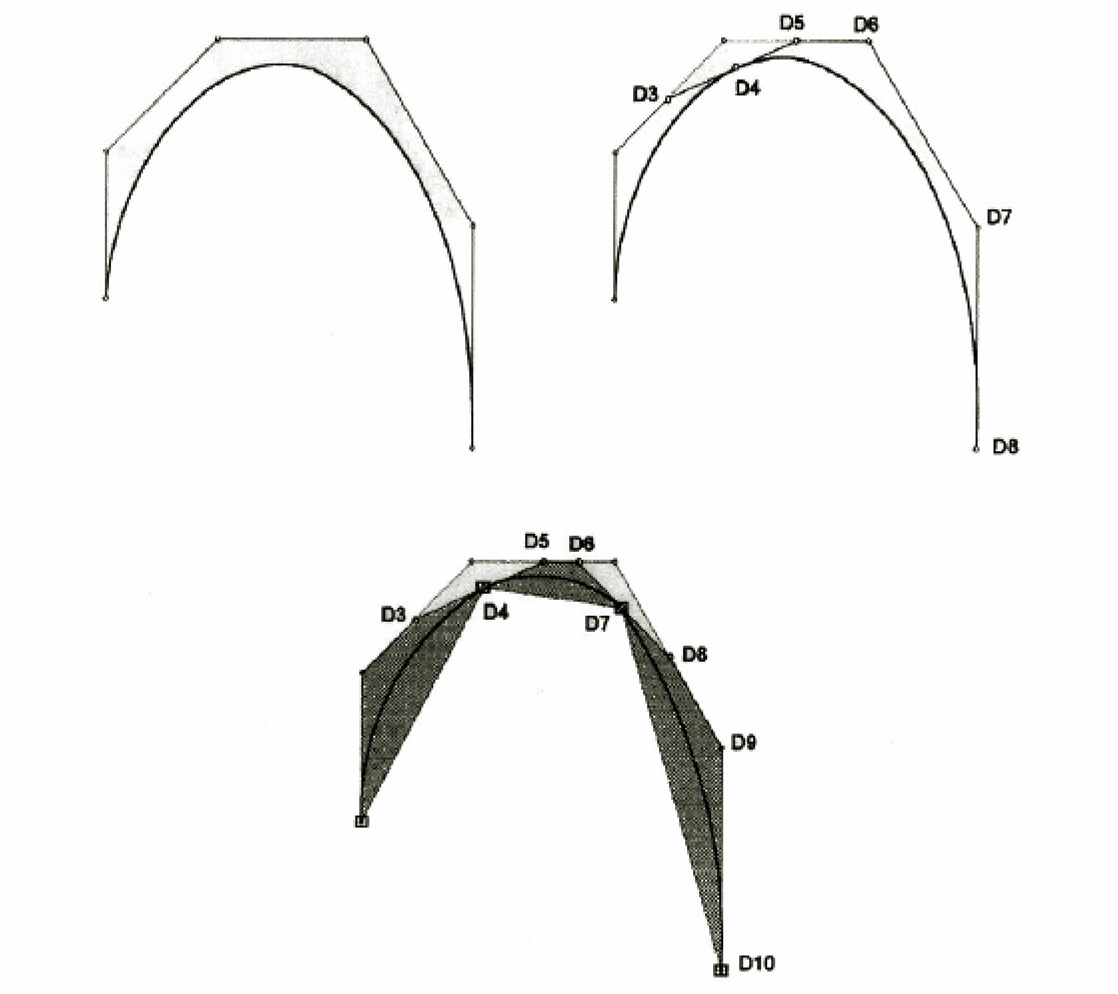
# Tool Path Generation (cont.)

- Relationship between step length and deviation



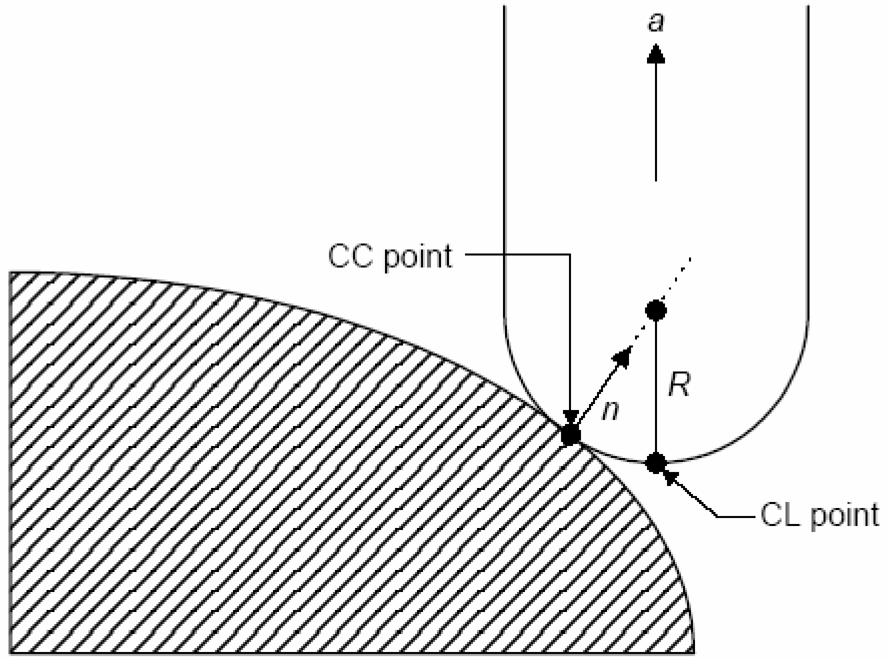
# Tool Path Generation (cont.)

- Generation of CC point by subdivision



# Tool Path Generation (cont.)

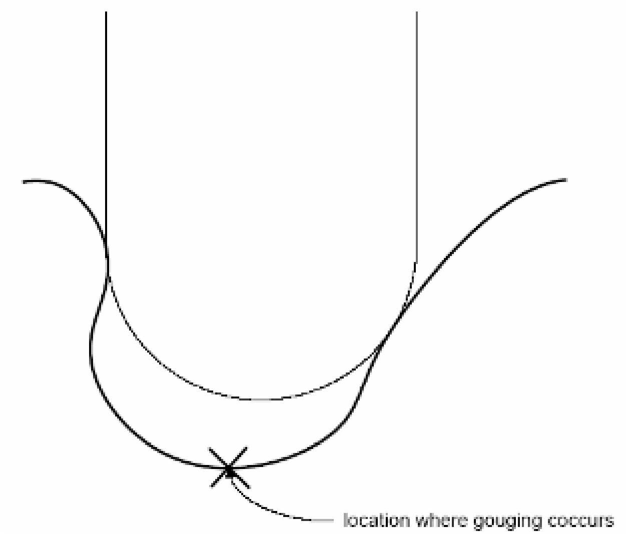
- Relationship between the CC point and the CL point



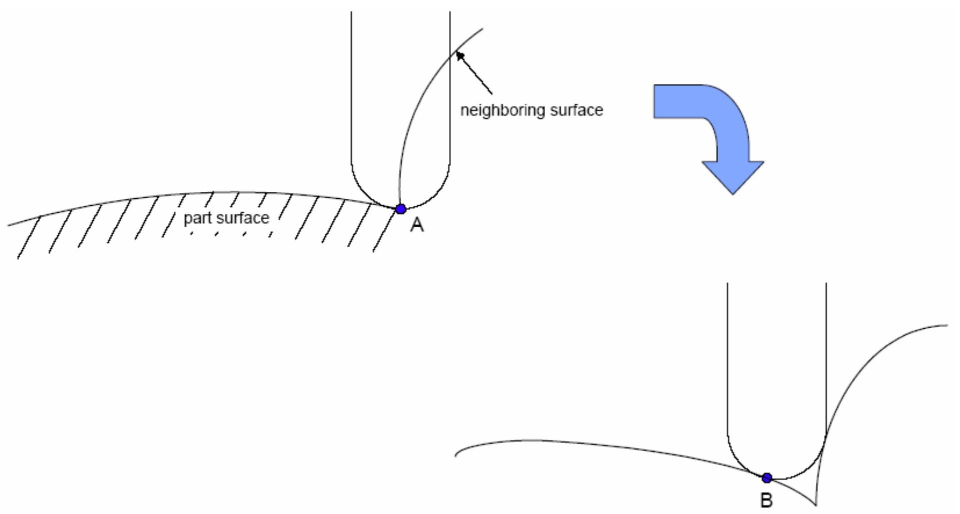

$$\mathbf{r}_{cl} = \mathbf{r}_{cc} + R\left(\mathbf{n}(u,v) - \mathbf{a}\right)$$

# Tool Path Generation (cont.)

- Gouging Problem
  - Choosing a tool whose radius is smaller than the minimum radius of curvature of the part surface
  - However, too small tool may result in inefficient machining




< Gouging of a surface >




< Gouging at a neighboring surface >

# Cost Estimation for Machining

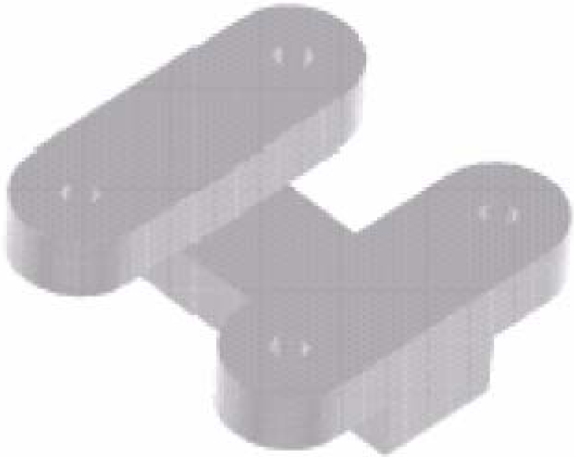
- The cost to produce each component in a batch is given by

$$C_{PER\ PARC} = WT_L + WT_M + WT_R[T_M/T] + y[T_M/T]$$

**Source: Kalpakjian, Manufacturing processes for engineering material**

- In this equation, the symbols indclude
  - $W$ = the machine operator's wage plus the overhead cost of the machine.
  - $WT_L$ = "nonproductive" costs, which vary depending on loading and fixturing.
  - $WT_M$ = actual costs of cutting metal.
  - $WT_R$ = the tool replacement cost shared by all the components machined. This cost is divided among all the components because each one uses up TM minutes of total tool life, T, and is allocated of TM/T of WTR.
  - Using the same logic, all components use their share TM/T of the tool cost, y.

# Actual Cost and Time for Machining



| | |
|---|---|
| No. of Setups | 3 |
| No. of Features | 9 |
| Planning Time | 0.75 |
| Setup Time | 55.22 |
| Machining Time | 33.80 |
| Material | ABS |

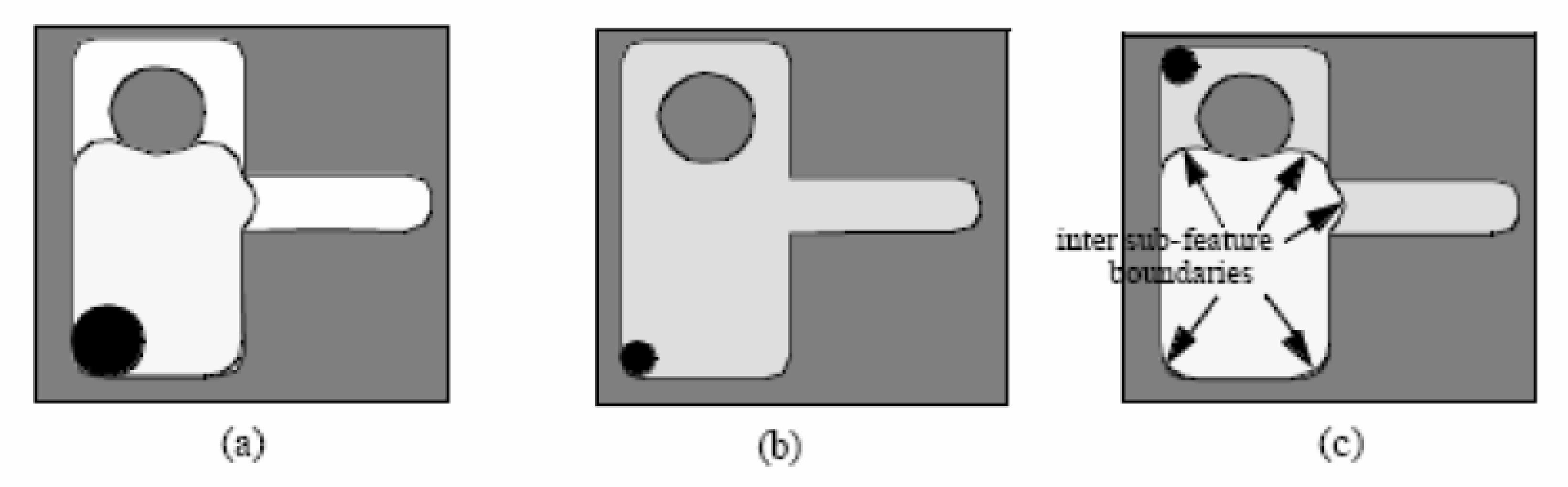
| | |
|---|---|
| Cost of material | $2.69 |
| Cost of tool | $2.25 |
| Cost of planning | $0.36 |
| Cost of setup | $26.69 |
| Cost of machining | $16.33 |
| Total Cost | $48.32 |

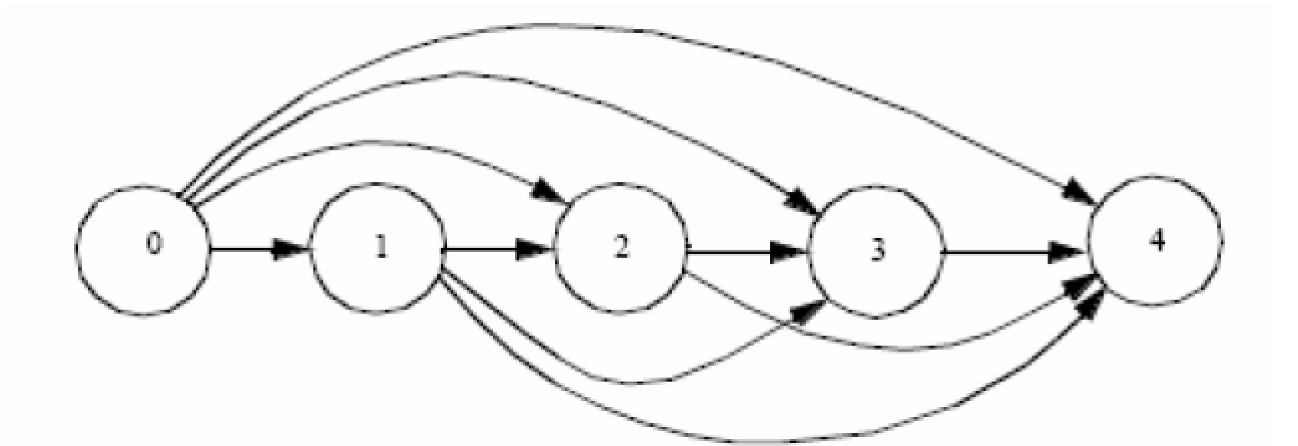
| | |
|---|---|
| No. of Setups | 3 |
| No. of Features | 9 |
| Planning Time | 0.83 |
| Setup Time | 40.60 |
| Machining Time | 13.33 |
| Material | ABS |

| | |
|---|---|
| Cost of material | $1.34 |
| Cost of tool | $0.88 |
| Cost of planning | $0.40 |
| Cost of setup | $19.65 |
| Cost of machining | $6.44 |
| Total Cost | $28.71 |

# Selection of tool size

- Considering cost and time



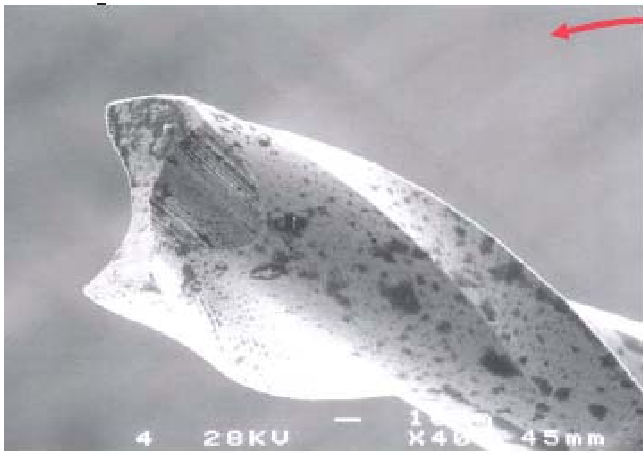



# Process Selection

- At conceptual design stage
  - Manufacturing Analysis Service (MAS) at U.C. Berkeley
  - Design for X at Stanford Univ.

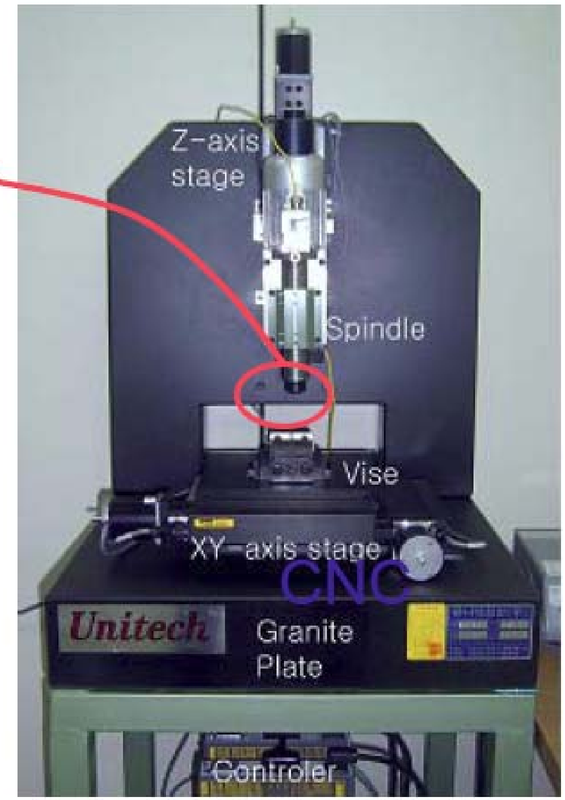
- For your term project, you may use following processes:
  - CNC machining – metal, polymer
    - Micro machining
  - Injection molding – polymer
  - Rapid Prototyping – polymer

# Micro Machining System (example)



Tip of 100$\mu$m endmill

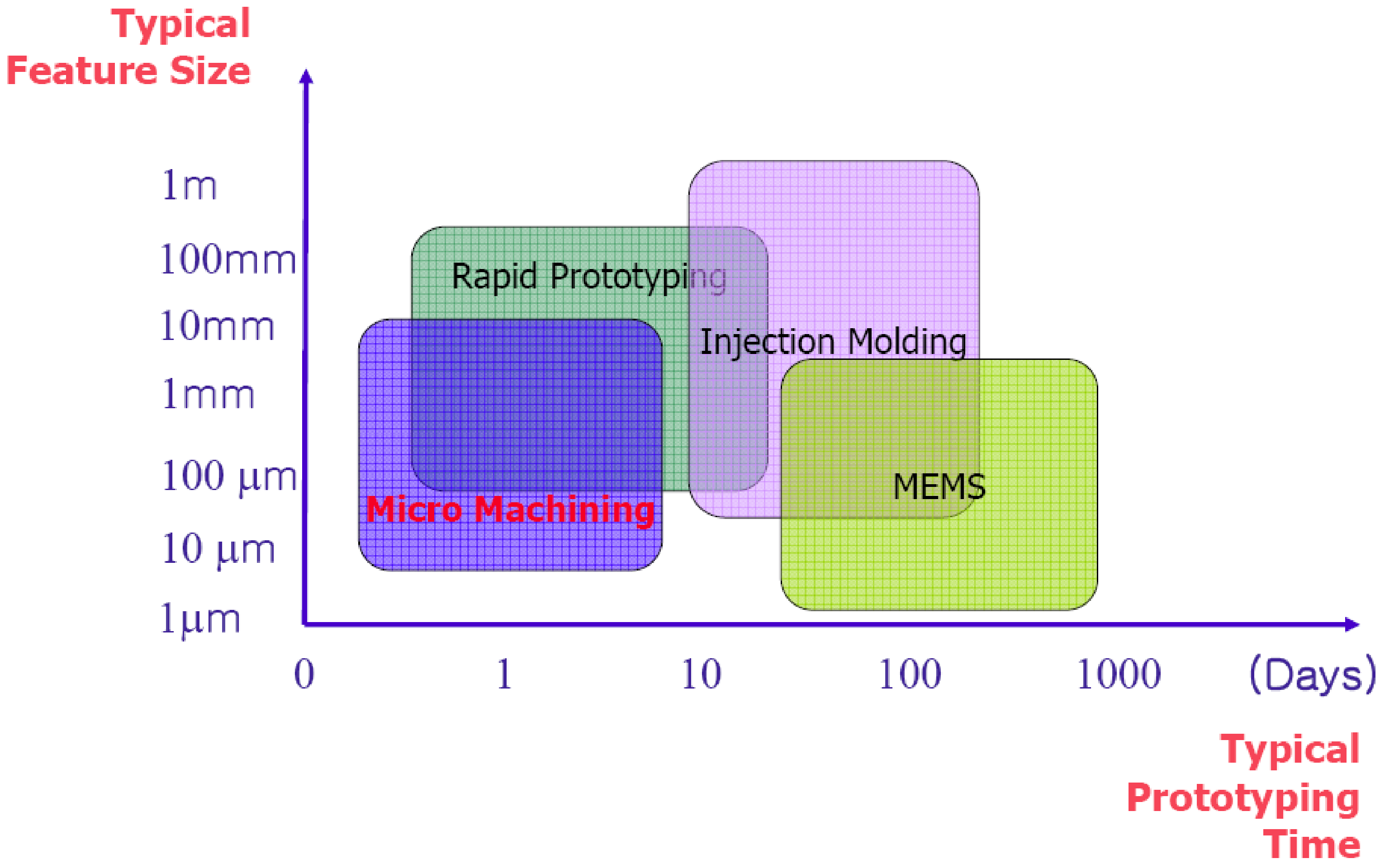

Micro endmills




Precision stage

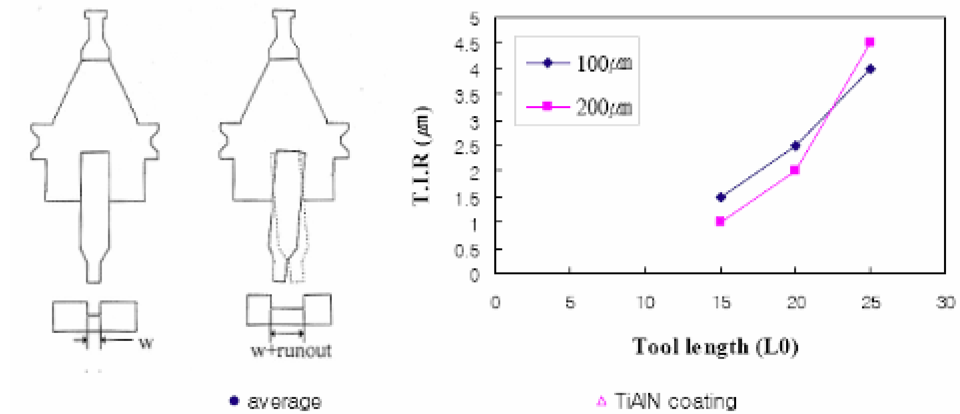
- Standard input: STL
- High speed: 46,000 RPM
- Tool material: HSS & TiN coating
- Work piece: Metal, Polymer, etc

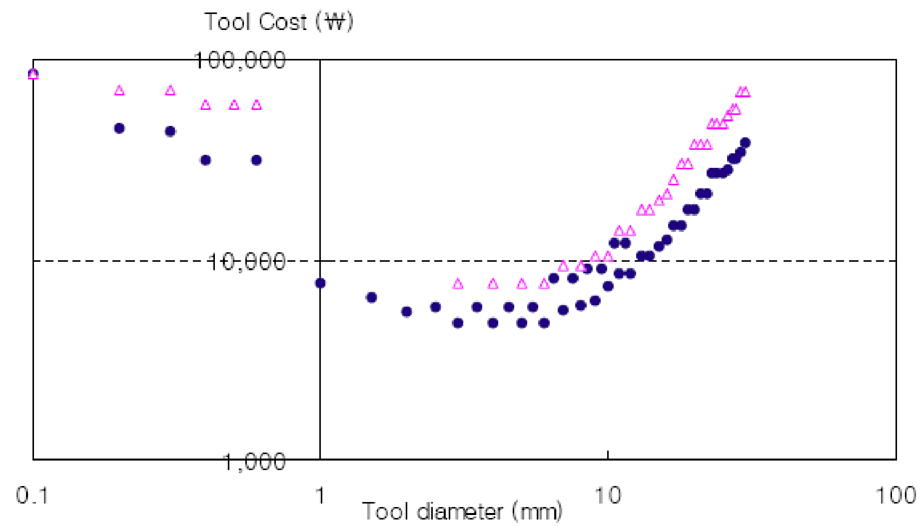
# Prototyping Size and Time



# Design for Manuf. (DFM): Micro Milling

- 10mm endmill
  - 10μm stage error
  - 0.1% for slot cutting
- 100μm endmill
  - 10μm stage error
  - 10% for slot cutting
- Cost structure is different form macro machining
  - Tool cost dominates

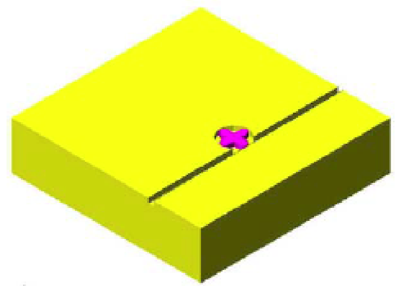


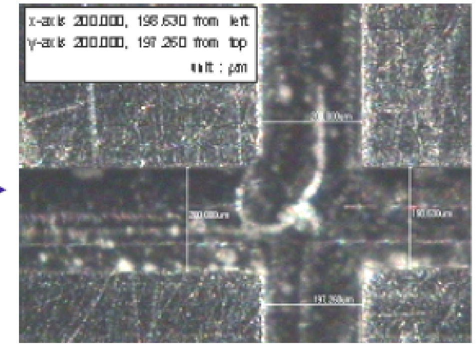
# From Concept to Part

- Part for UAV/MAV
- ABS plastic
- l = 2.9mm,
- t= 300µm,
- Pivot D=250 µm

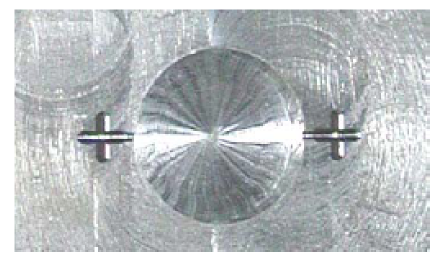
Specification



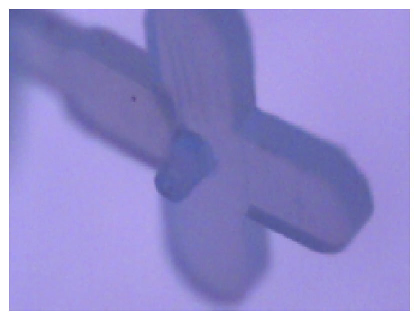
CAD design



Micro machining



Aluminum mold

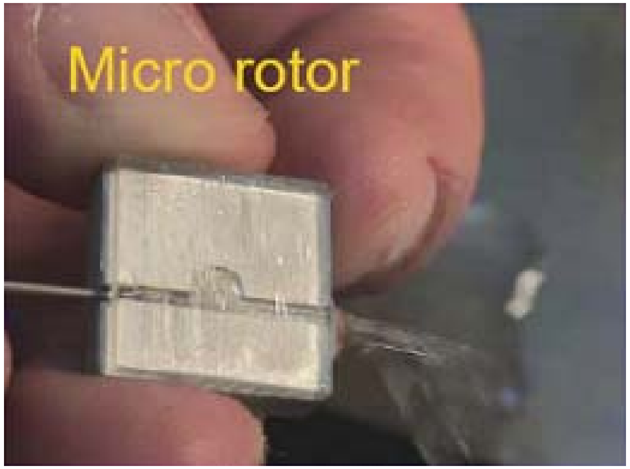


Micro injection molded rotor

Rotor with micro channel

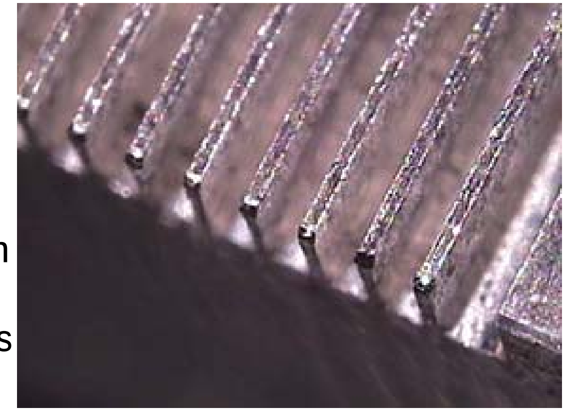
Total time: 5 days

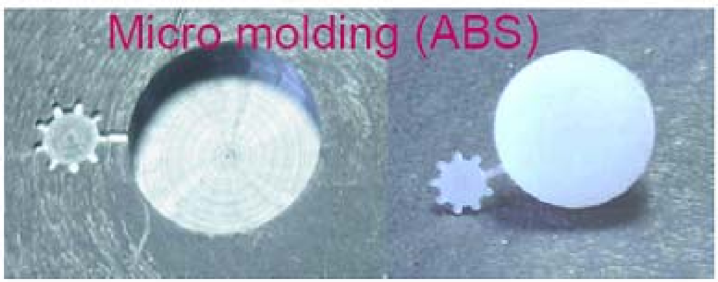
# More Meso/Micro Parts

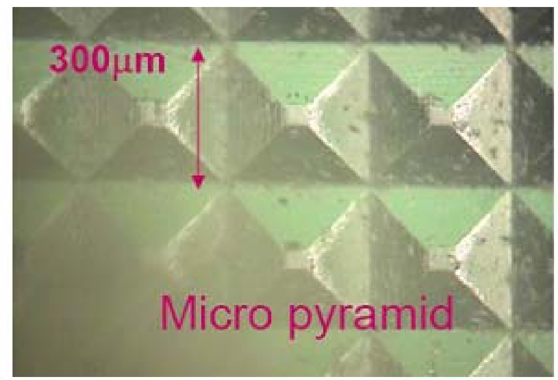



Rib width: 60μm
Height: 500μm
Tool: ϕ200μm

Spindle: 24,000rpm
DOC: 25μm
Feed rate: 100μm/s
Time: 3hr 28min

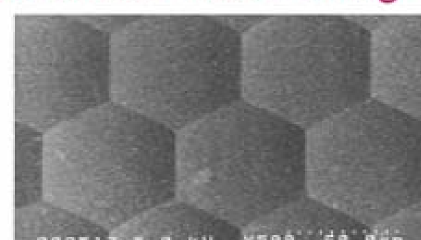





Freeform surface

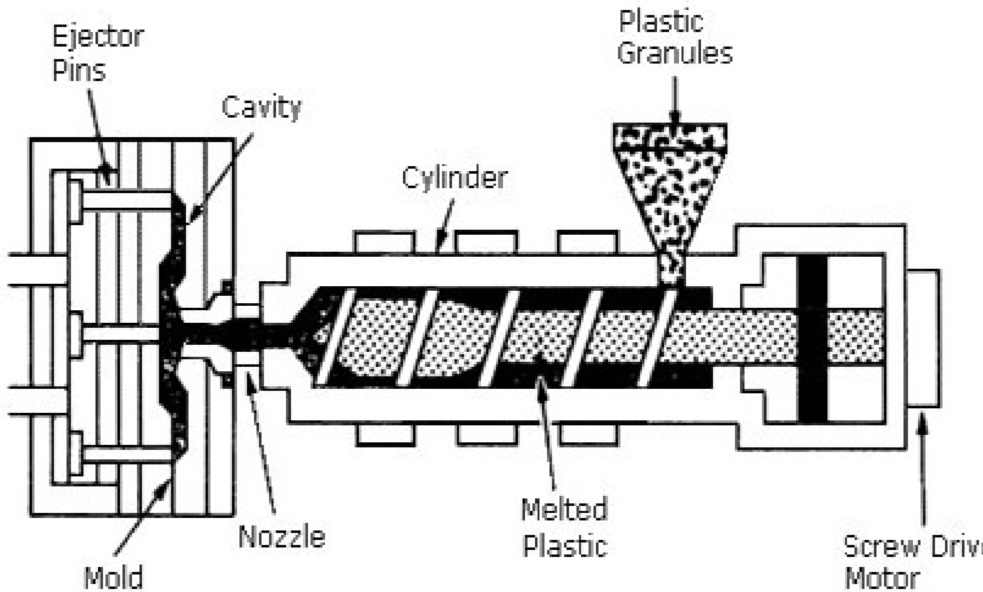

Ultraprecision machining



# Injection Molding

- One of the most common methods of shaping plastic resins
- Accomplished by large machines called injection molding machines

Mold & specimens




**Source: OSHA Technical Manual**

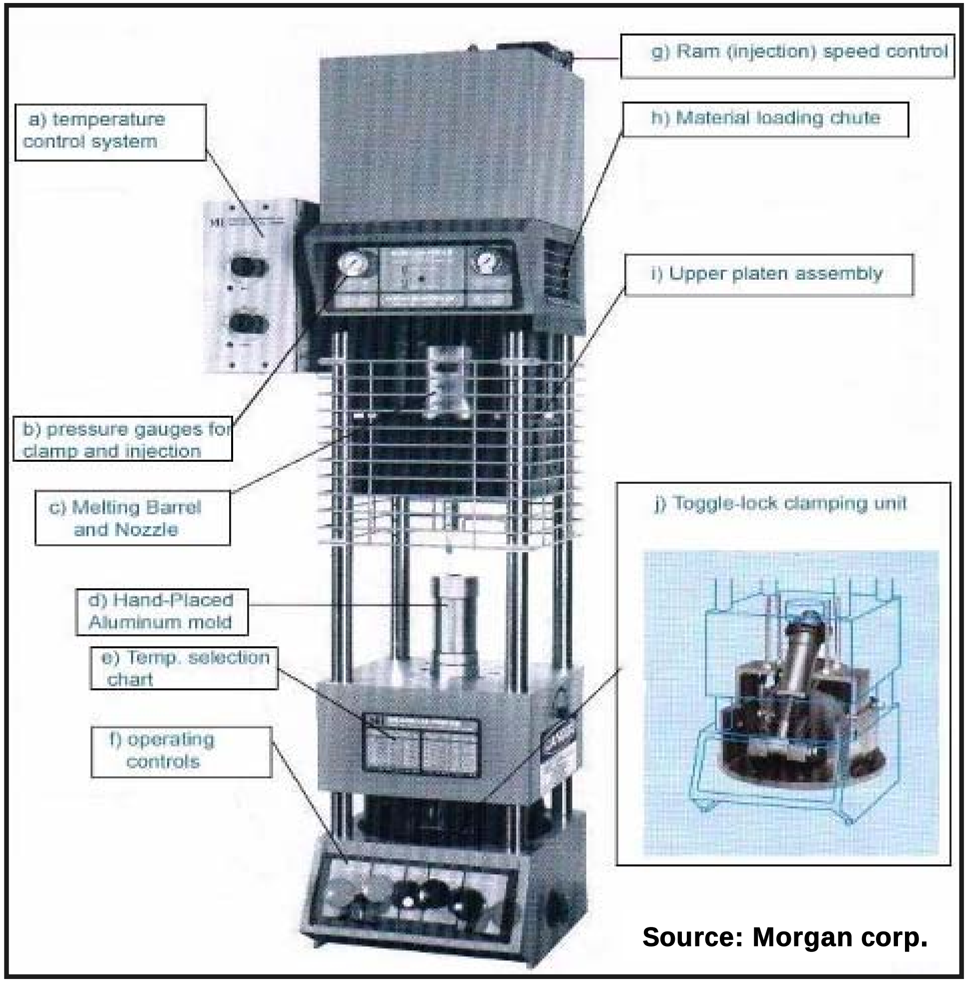
< Diagram of a typical injection molding process >

# Injection Molding (cont.)

- Uniform wall thickness
- Sink mark
- Taper angle

# Injection Molding (cont.)

- Morgan G-100T Press
  - In IDIM lab.
    301BD Room 1255-1
  - 6 cu. in. (4 oz.) Max.
  - Single shot 20 ton max.
  - Clamping force (toggle).
  - 12,000 psi max.
    Injection pressure




**< Schematic of the Morgan G-100T press >**