Materials Selection for Mechanical Design III

A Brief Overview of a Systematic Methodology

Process Selection

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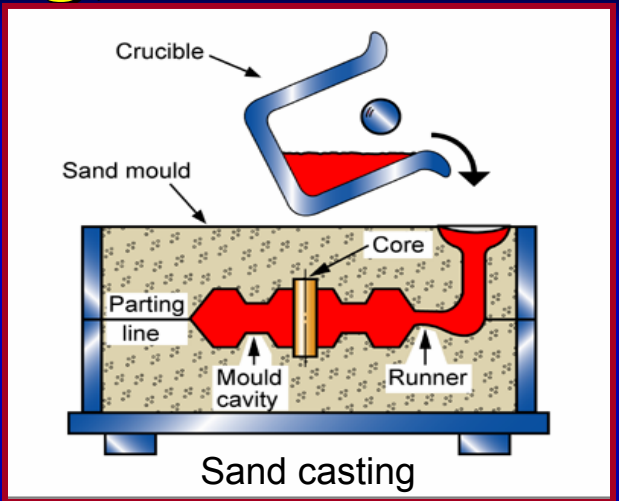
Process Selection

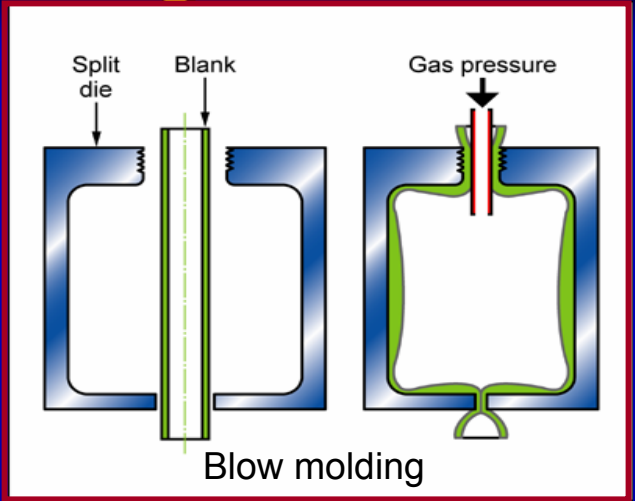
- A process is a method for shaping, joining, or finishing materials
- Processes have many attributes
  - Tolerance
  - Surface Roughness
  - Mass Range
  - Size Range
  - Economic Batch Size
  - Capital Costs
  - Production Rate
- Only certain materials can be shaped or formed by certain processes
- Certain designs can be achieved with certain processes and certain materials

Manufacturing Processes: Shaping, Joining, or Surface Treating

Shaping



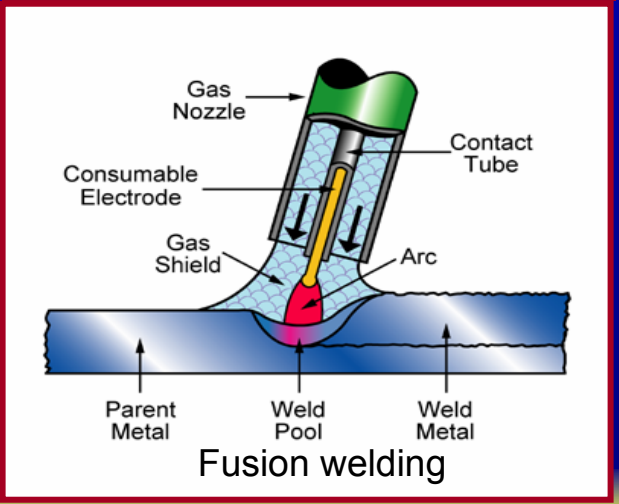
Sand casting



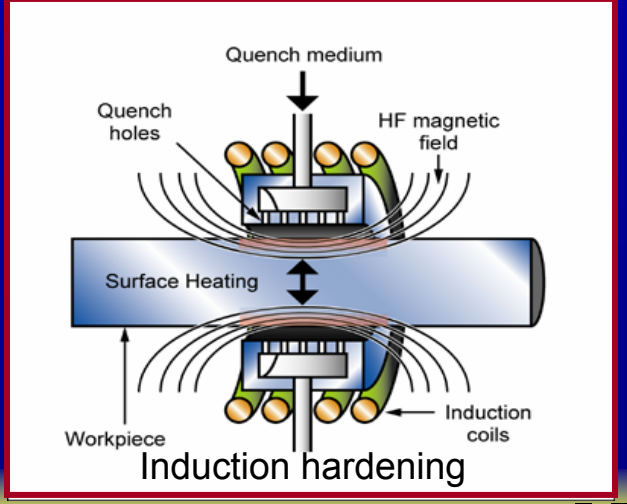
Blow molding

Shaping

Joining



Fusion welding



Induction hardening

Surface treating

Important Factors in Process Selection

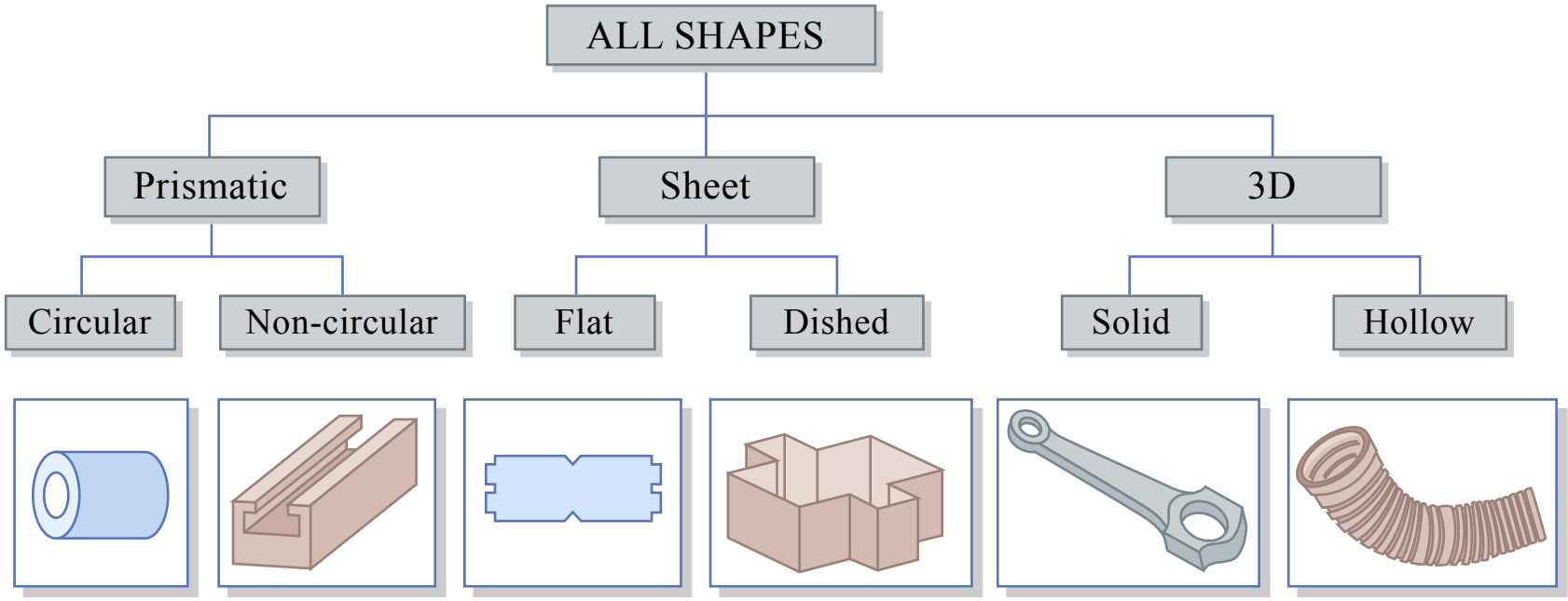
- **Shaping**
  - The *material* to be shaped
  - The *shape* of the part
- **Joining**
  - The *material(s)* to be joined
  - The *geometry* of the joint
- **Surface Treating**
  - The *purpose* of the treatment
  - The *material* to which it will be applied

Examples of Process Selection Issues

- Can't use molding processes with wood
- Machining of Composites and Ceramics is very rare
- Can't use high pressure casting processes with refractory metals
- Shape can determine which processes can be used to form a material

Shape Classification

Some processes can make only simple shapes, others, complex shapes



Wire drawing, extrusion, rolling, shape rolling: **prismatic shapes**

Stamping, folding, spinning, deep drawing: **sheet shapes**

Casting, molding, powder method: **3-D shapes**

Figure by MIT OCW.

Example: Polyethylene Bottles

- Function:
  - Shape a PE bottle
- Objective: N/A
- Constraints:
  - Material: PE (thermoplastic)
  - Shape: 3D Hollow
  - Mass: 0.02 – 0.04 kg
  - Minimum Section: 0.7-1 mm
  - Tolerance: 1 mm
  - Surface Roughness: 10 μm
  - Batch Size: $>10^6$
- Free variables:
  - Choice of process

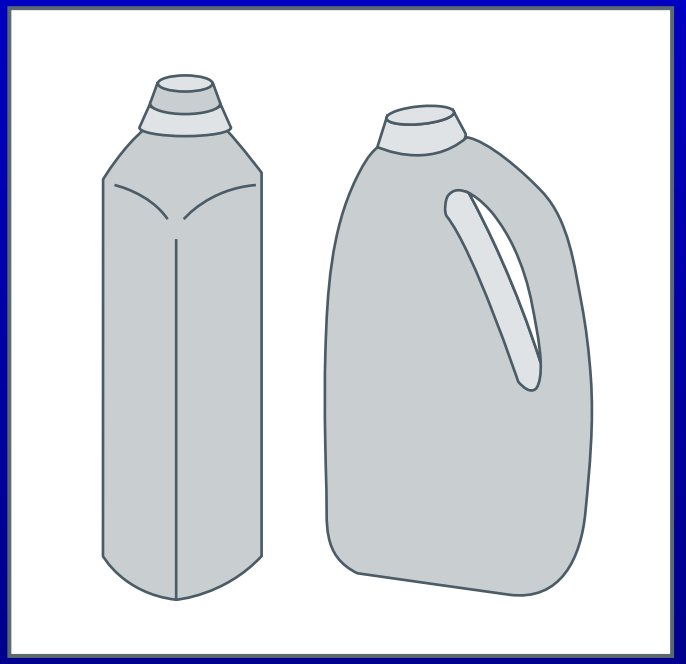


Figure by MIT OCW.

Using constraints in limit stage, selected process is injection blow molding

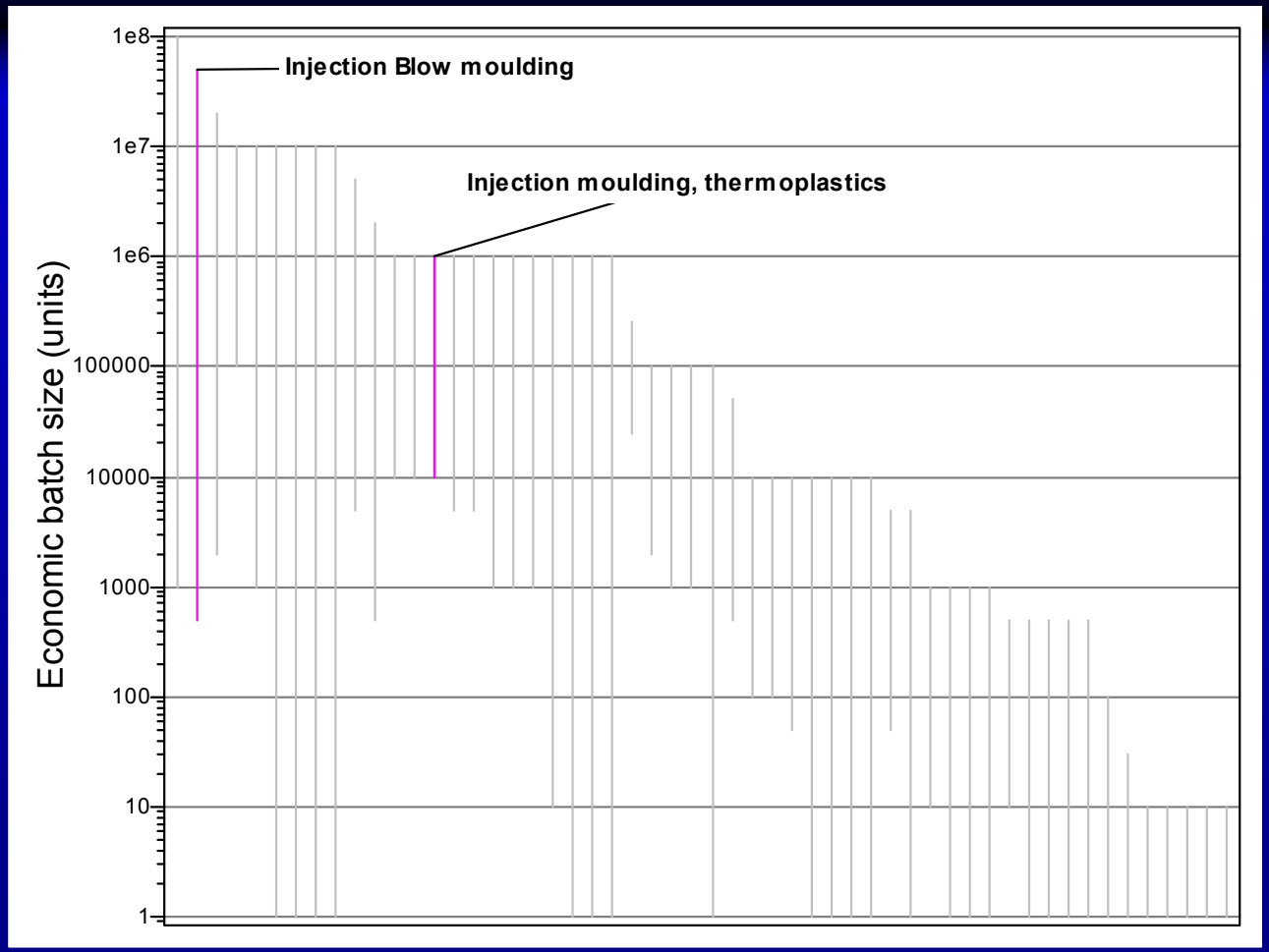


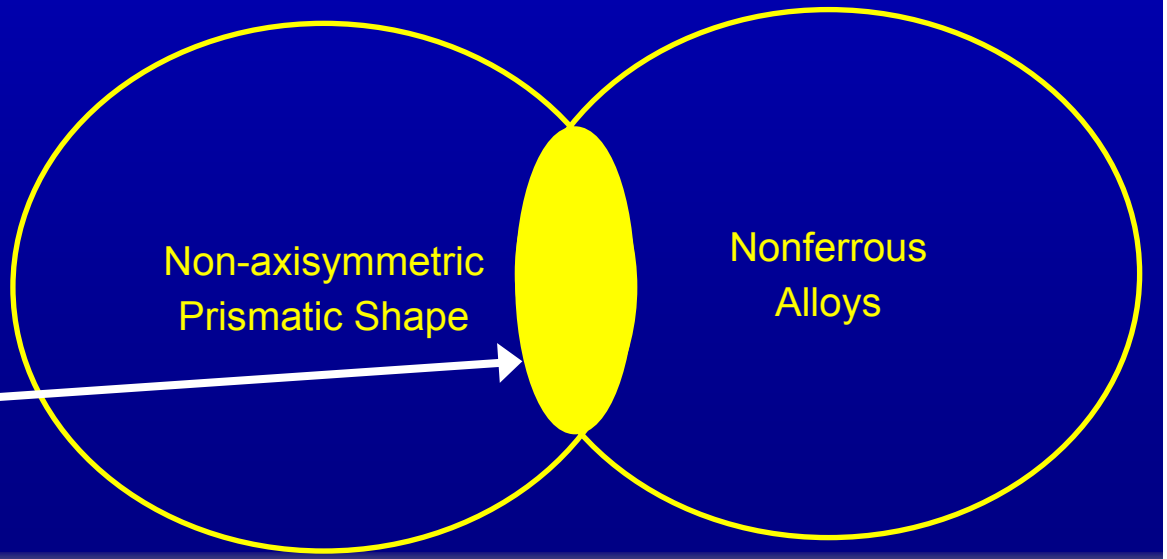
Chart from the CES EduPack 2005, Granta Design Limited, Cambridge, UK. (c) Granta Design. Courtesy of Granta Design Limited. Used with permission.

Example combining material, shape, process: Lightweight Member Loaded in Bending

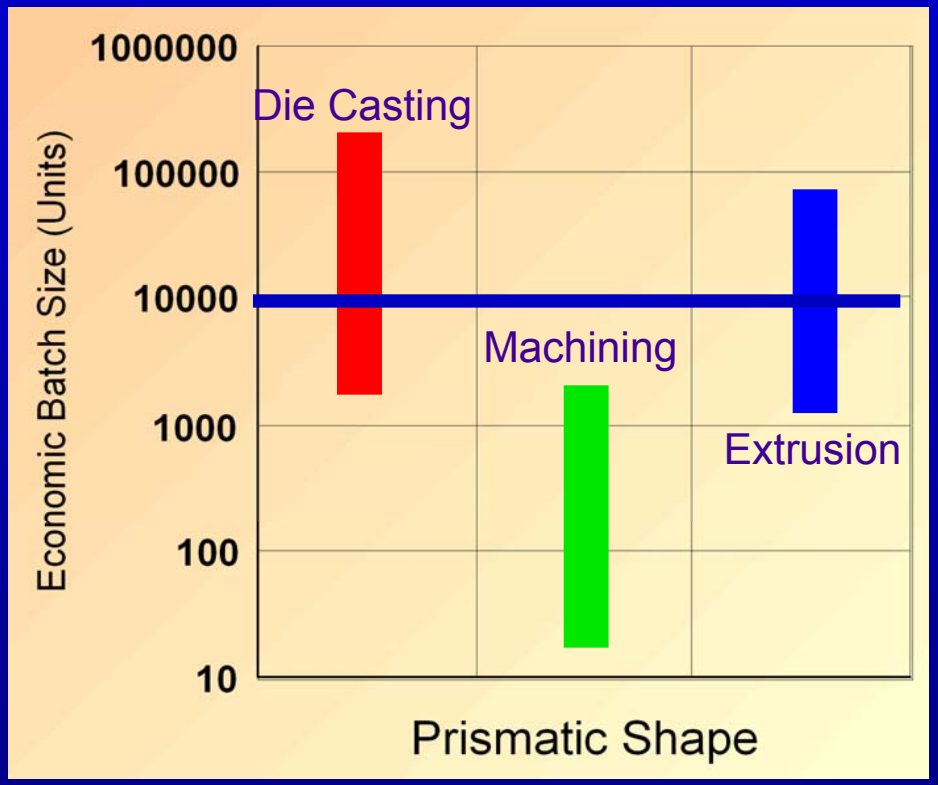
- From material index, nonferrous alloys are best choice
- Process Selection: Choose process that makes non-axisymmetric prismatic shapes *and* can be used with nonferrous alloys

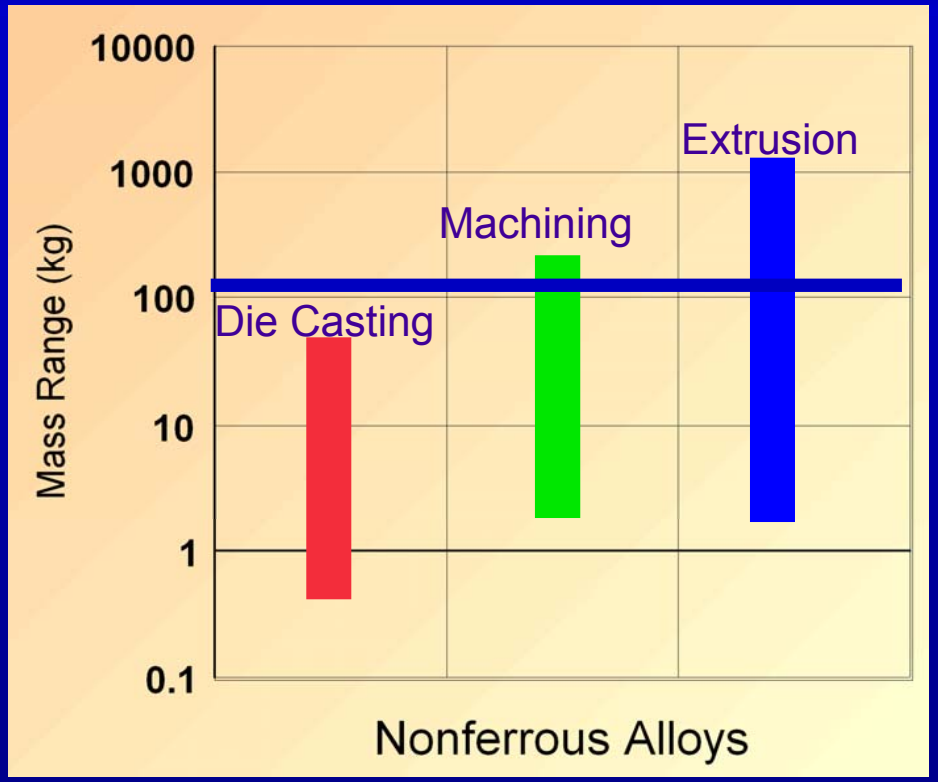
Material Index including shape factor

$$M = \frac{\left(\phi_B^e E\right)^{1/2}}{C_m \rho}$$



Bending Member Example: Process Selection Procedure

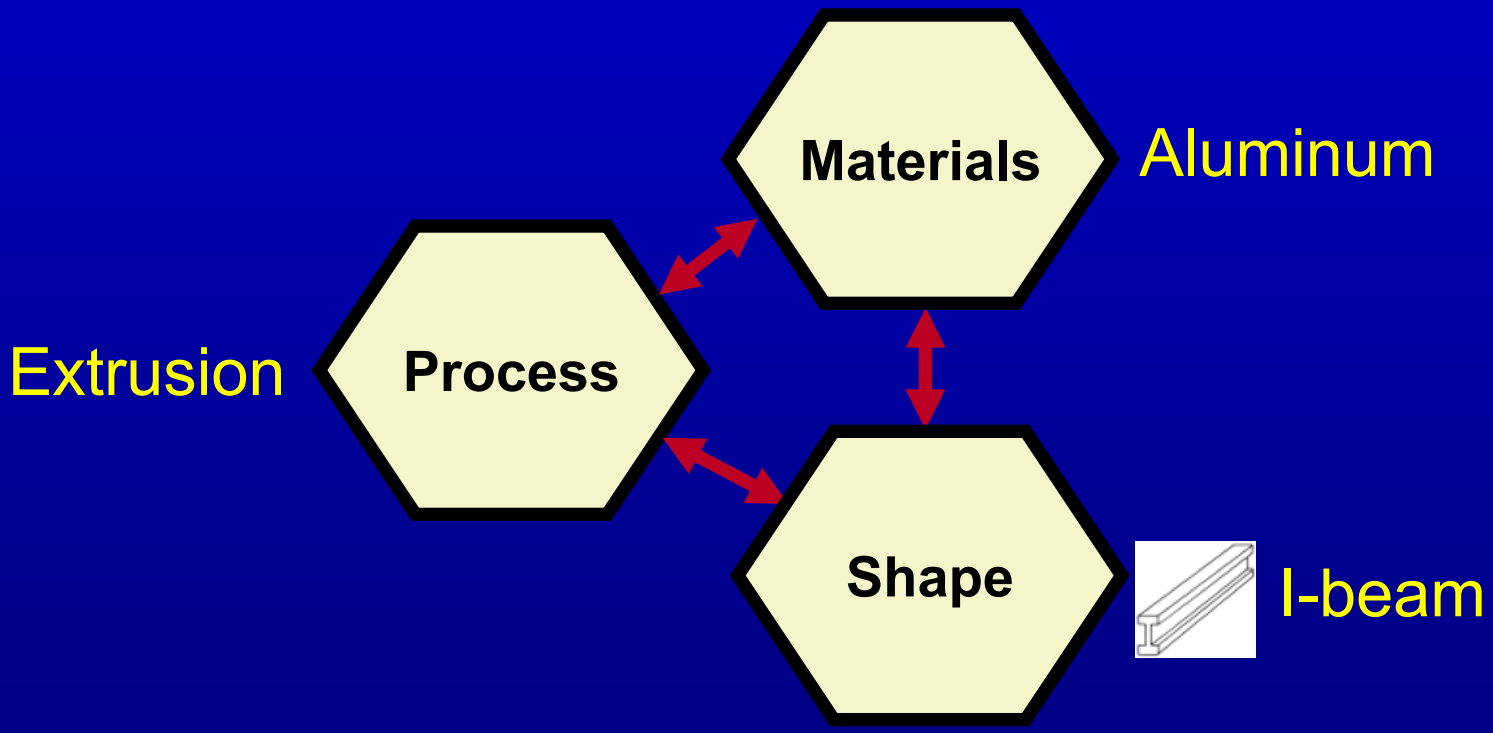




Only extrusion satisfies *both* processing constraints

Bending Member Example: Final Selection

Material, shape, and process combine to meet performance criteria



Summary

- Selection procedure should start early and keep all possibilities until eliminated by project considerations and constraints
- Use project objectives to establish constraints and project attributes
- Usually will have to rank priorities and make tradeoffs
- Material, shape, and process can be used in concert to meet project objectives