Problem Definition

⇒ Goal: Define the design space

- Define the service environment: loads, configurations, physical environment, system interactions, level of uncertainty
- Define performance requirements: weight, longevity, safety factor, robustness, ...
- Define project constraints: cost targets, time targets, physical constraints (manufacturing limitations, assembly limitations, ...), system interaction constraints (interfacing constraints, loadsharing, ...)

Preliminary Design

⇒ Goal: Manipulate design degrees of freedom (DDOF) to determine a reasonable preliminary solution in the design space

- Define the basic DDOF:
  - geometry
  - density
  - strength
  - stiffness
  - etc.
  - mechanics/materials
  - linkage
  - What are they?
  - How are they measured?
  - Why do they exist?
  - How can they be manipulated?
  - How are they related?

- Perform trade study: investigate various trades (compromises) among the DDOF
- Perform a failure modes effects analysis (FMEA)

Detailed Design

⇒ Goal: Provide the information (specifications, tolerances, materials, drawings, ...) necessary to achieve the design in an optimal manner

- Consider:
  - boundary conditions: contact, crushing, stress concentrations, ...
  - attachments: joining, stress concentrations, weight, ...
  - materials: corrosion, fatigue, “engineer” the material, ...
  - life cycle: cost, recyclability, maintainability, repairability, ...
  - optimization: with respect to specs., constraints, other trades, ...
- Define advanced DDOFs:
  - CTE
  - Fracture toughness
  - Resilience
  - Hardness
  - Fatigue strength
  - Creep compliance/relaxation modulus
  - Ductility
  - Thermal conductivity
  - Corrosion resistance
  - Abrasion resistance
List of factors to be considered in selecting polymeric materials

Mechanical
Type and magnitude of normal service stresses
Loading pattern and time under load
Fatigue resistance
Allowable deflections
Overloads and abuse; impact resistance

Thermal
Normal range of operating temperatures
Maximum and minimum service temperatures

Environmental
Solvent and vapor attack
Reactions with acids, alkalis water, etc.
Water absorption effects
Ultraviolet light exposure and weathering; oxidation
Erosion by sand, rain, etc.
Attack by fungi, bacteria, or Insects

Electrical
Resistivity
Dielectric loss
Antistatic properties
Tracking resistance
Flammability
Toxicity of additives or degradation products

Appearance
Transparency
Surface finish
Color matching and color retention

General
Tolerances and dimensional stability
Weight factors
Space limitations
Expected service life
Acceptance codes and specifications
Environmental acceptability
Leaching of additives
Permeability to vapors and gases
Wear resistance

Manufacturing
Choice of process
Method of assembly
Finishing and decoration
Quality control and inspection

Economics
Materials costs
Cost of capital plant: moulds, and processing machines
Speed of production
Number of moldings/units required
Operating costs of component, including maintenance and fuel consumption
<table>
<thead>
<tr>
<th>Material</th>
<th>HDPE</th>
<th>PP</th>
<th>LDPE</th>
<th>PVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_g/T_m$ ($^\circ$C)</td>
<td>130*</td>
<td>-20</td>
<td>-25</td>
<td>75</td>
</tr>
<tr>
<td>$K_{IC}$ (MPa*m$^{1/2}$)</td>
<td>~4</td>
<td>~4</td>
<td>~2</td>
<td>~2.5</td>
</tr>
<tr>
<td>$E$ (GPa)</td>
<td>0.8</td>
<td>1.5</td>
<td>0.3</td>
<td>3</td>
</tr>
<tr>
<td>$\sigma_y$ (MPA)</td>
<td>28</td>
<td>33</td>
<td>15</td>
<td>55</td>
</tr>
<tr>
<td>relative cost</td>
<td>1.1</td>
<td>1</td>
<td>1</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Stress Analysis

- for a cantilever beam:
  \[ \Delta = \frac{FL^3 \cos \theta}{3EI} = L \tan \theta \]

- for polypropylene (E = 1.5 GPa):
  \[ F = 3.2N \]

- internal stress:
  \[ \sigma_{\text{max}} = \frac{M \left( \frac{h}{2} \right)}{I} \approx \frac{FL \left( \frac{h}{2} \right)}{wh^3/12} = 28.8 \text{MPa} \]

- yield strength of PP = 33 MPa

L = 18 mm
h = 1 mm
w = 12 mm
\( \theta = 12.5 \) degrees
Model name: diskselector2
Study name: COSMOSXpressoStudy
Plot type: Static nodal stress Plot
Deformation scale: 0.003812

von Mises (N/mm²)

- Yield strength: 0.000e+000