Module 3

Selection of Manufacturing Processes
Lecture 9
Case Studies - III
Instructional objectives

By the end of this lecture, the student will learn how to implement design requirements: material, shape, size, minimum section, precision, and finish for a few practical applications.

Example 1: Forming of fan for vacuum cleaners

The selected material for the fan blade is considered as nylon based on certain design inputs. The goal is to identify a suitable manufacturing process considering the material and typical shape of fan blades, and also based on certain inputs about the dimensional tolerance, batch size, etc. The selection process first starts with translating the design requirements into a set of function, constraints, objective and free variables as follows.

<table>
<thead>
<tr>
<th>Function</th>
<th>Fan Blade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constraints</td>
<td>[a] <strong>Material</strong>: nylon</td>
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<td></td>
<td>[b] <strong>Shape</strong>: three-dimensional solid</td>
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<td></td>
<td>[c] <strong>Mass</strong>: 0.1–0.2 kg</td>
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<td></td>
<td>[d] <strong>Minimum section thickness</strong>: 4 mm</td>
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<td></td>
<td>[e] <strong>Tolerance</strong>: ±0.5 mm</td>
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<td></td>
<td>[f] <strong>Maximum allowable surface roughness</strong>: &lt;1 µm</td>
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<td></td>
<td>[g] <strong>Batch size</strong>: 10,000</td>
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</tbody>
</table>

Objective: Minimize cost

**Free variables**: Choice of process

The fan blade has a fairly complex shape and we classify it as a three-dimensional solid. *Figures 3.9.1, 3.9.2, 3.9.3 and 3.9.4* depict typical compatibility charts of manufacturing process vis-à-vis material, range of mass (of a part) vis-à-vis manufacturing process, part shape (complexity) vis-à-vis manufacturing process, and minimum achievable section thickness vis-à-vis manufacturing process. *Figure 3.9.1* indicates that various polymer processing processes such as injection molding, blow molding, compression molding, rotational molding, etc. can be suitable processes for the manufacturing of typical nylon based part. *Figure 3.9.2* shows the typical mass of a fan (fan blade) by a rectangular box and it is clear that most of the processes highlighted in *Figure 3.9.1* are well suited to produce the nylon fan with the mass indicated in the list of constraints. *Figure 3.9.3* depicts that out of many polymer processing processes, blow molding, rotational molding and thermoforming are not very suitable for the manufacturing of three-dimensional shapes analogous to a nylon fan. *Figure 3.9.4* indicates that thermoforming and polymer casting...
are unsuitable to yield the requisite section thickness indicated in the list of constraints for typical nylon fan.

A compilation of the observations from Figures 3.9.1 to 3.9.4 depict that the injection molding and compression molding are seemingly two suitable processes for the manufacturing of nylon fans. Further selection of the manufacturing process would be arrived at based on other considerations such as capital investment, local / available skills, overhead rate, etc. which cannot be answered from the charts shown above. However, the procedure detailed above has been helpful in narrowing the choice, suggesting alternatives, and providing a background against which a final selection can be made.

Figure 3.9.1 Compatibility chart between material and manufacturing process. A red dot indicates that the pair is compatible [2]
Figure 3.9.2 Compatibility chart between manufacturing process and range of mass (of part) [2]
Figure 3.9.3 Compatibility chart between manufacturing process and shape of a part or component. The material compatibility is also included at the extreme left [2]
Example 2: Manufacturing of Pressure Vessels

Pressure vessels, from the simplest aerosol to large boilers, are designed, for safety considering either yield or leak before break criterion as outlined in earlier lectures in module 2. The procedure for material selection based on material indices for pressure vessels is already explained earlier. We consider here for simplicity that the selection of material and the selection of the manufacturing process are exclusive, which may not be the reality. The selection process can be translated to the design requirements i.e. in to a set of function, constraints, objective and free variables as follows.
Function: Pressure Vessel

Constraints:
[a] Material: steel
[b] Shape: circular prismatic
[c] Mass: 2720 kg
[d] Minimum section thickness: 80 mm
[e] Batch size: 10

Objective: Minimize cost

Free variables: Choice of process

The design of pressure vessels depends on the wall thickness. The goal of the pressure vessels must safely contain the pressure. The design also depends on safety factor. Neither the precision nor the surface roughness of the vessel is important in selecting the primary forming operation since the end faces and internal threads will be machined, regardless of how it is made.

Figures 3.9.5, 3.9.6, 3.9.7, 3.9.8 and 3.9.9 depict typical compatibility charts of manufacturing process vis-à-vis material, minimum achievable section thickness vis-à-vis manufacturing process, range of mass (of a part) vis-à-vis manufacturing process, maximum achievable tolerance vis-à-vis manufacturing process, and lastly, manufacturing process vis-à-vis economic batch size.

Figure 3.9.5 indicates various manufacturing possibilities for pressure vessel including forging, casting, welding or joining, etc. The large section thickness required for the intended pressure vessel clearly indicates casting as one of the most suitable processes [Figure 3.9.6] which is obvious as casting is considered to be one of most suitable process with large section thickness. However, typical requisite size (mass) of the pressure vessel eliminates other casting processes except sand casting and indicated forging as a candidate process [Figure 3.9.7]. Joining of small parts (plates) to manufacture a large pressure vessel also appears as a strong candidate in Figure 3.9.7. A comparison of Figures 3.9.5 to 3.9.9 clearly indicates that the vessels can be machined from solid, forged cast, or fabricated (by welding plates together, for instance). The tolerance and roughness do not matter except on the end faces and thread. Figure 3.9.8 also considers a second process; an additional machining or grinding step can achieve it. A cast pressure-vessel is not impossible, but it would be viewed with suspicion by an expert because of the risk of casting defects and would need proof testing or elaborate non-destructive inspection. Forging is not also a suitable process as it becomes impossible to handle very large pat during forging. The only way to make pressure vessels is to weld them from previously rolled sheets. As several defects may occur during welding process, the welded joints have to be examined properly.
Figure 3.9.5  Compatibility chart between material and manufacturing process. A red dot indicates that the pair is compatible [2]
Figure 3.9.6  Compatibility chart between manufacturing process and minimum achievable section thickness. Material compatibility is also included at the extreme left [2]
Figure 3.9.7  Compatibility chart between manufacturing process and range of mass (of part) [2]
Figure 3.9.8 Compatibility chart between manufacturing process and maximum achievable tolerance (of part) [2]
Figure 3.9.9  Compatibility chart between manufacturing process and economic batch size [2]
Exercise

1. Examine the suitable manufacturing process or processes that can be used to manufacture connecting rod for a racing bi-cycle considering the material of connecting rod to be high-strength steel. Study literature and develop the suitable constraints to set-up the design problem.

Reference: