Module 3

Selection of Manufacturing Processes
Lecture 8

Co-selection of Materials and Processes
Instructional objectives

By the end of this lecture, the student will learn

(1) how to categorise various manufacturing processes depending on materials, shape and requisite dimensional tolerances, etc.

(2) how to choose the most suitable manufacturing process for a given part and material,

Introduction

The procedure for the selection of materials and shapes is illustrated in the module 2. In particular, it is outlined how the functional needs, the constraints and the free variables are converted to typical design parameters that are utilized to develop the material indices and the shape factors. Finally, a proper processing route to manufacture a specific part or component has to be finalized that calls for a through methodology for the selection of a suitable manufacturing process. Figure 3.8.1 schematically outlines the steps to select a suitable manufacturing process for a given part provided the material and the shape of the part are finalized. The manufacturing requirements are expressed as constraints on material, shape, size, tolerance, roughness, and other process-related parameters. The constraints are used to screen out processes that are incapable of meeting them, using process selection diagrams. The surviving processes are then ranked according to economic measures and then the top ranked candidates are explored for supporting information to be enabled as final choice.
Selection charts

Each manufacturing process can be characterized by a set of attributes similar to what have been illustrated for materials in the earlier lectures.

**Process-Material matrix:** Figure 3.8.2 represents a typical process-material matrix indicating the general compatibility between manufacturing process and engineering material. The processes are also broadly classified as shaping, joining and finishing. The dot indicates that the pair of the material and the process is compatible. For example, sand casting or die casting process cannot be used for processing of composite materials. Thus, an initial screening of processes for a given material can be easily performed based **Figure 3.8.2**.
**Process–Material matrix** with the dot indicating a compatibility between the material and the corresponding manufacturing process [2]

**Process-Shape matrix:** Figure 3.8.3 presents a broad classification of different shapes that are commonly encountered in product design. Various manufacturing processes are capable of making these shapes. For example, a typical turning operation creates axisymmetric shapes while extrusion, drawing and rolling make prismatic shapes – both circular and non-circular. The sheet forming processes can make flat or dished shapes. Certain manufacturing processes can make three-dimensional shapes. Figure 3.8.4 depicts a typical Process vis-à-vis Shape compatibility chart indicating the ability of various manufacturing processes in producing different shapes. Often a single process is unable to give the final shape of a product and it is necessary to combine two or more processes.
Figure 3.8.3 General classification of shapes [2]

Figure 3.8.4 Process–Shape matrix with the dot indicating a compatibility between the shape and the corresponding manufacturing process [2]

**Process-Mass bar-chart:** Figure 3.8.5 shows the typical mass-range of components that each process can make. Large components can be built up by joining smaller ones. For this reason the ranges associated with joining are shown in the lower part of Figure 3.8.5. It can be noted
that sand casting process, for example, is capable of producing large component while die casting or investment casting processes can make relatively smaller sized parts.

**Figure 3.8.5** Process–Mass bar chart indicating compatibility between the requisite mass of a part and the corresponding manufacturing process [2]

**Process-Section thickness bar-chart:** The selection of a manufacturing process also depends on the section thickness of the part to be made. Each process has its limit over the range of the section thickness, which it can produce. For example, surface tension and the typical nature of heat flow limit the minimum section and slenderness of gravity-die cast shapes. Bulk deformation processes cover a wider range of section thickness. Limits on forging pressures also set a lower limit on the section thickness and slenderness that can be forged. Powder forming methods are more limited in the section thicknesses they can create, but they can be used for ceramics and very hard metals that cannot be shaped in other ways. Special techniques such as electro-forming, plasma spraying allow manufacturing of slender shapes.
Figure 3.8.6 depicts the typical manufacturing processes and the range of section thickness that each process can manufacture.

![Process–Section thickness bar chart indicating compatibility between the manufacturing process and the range of section thickness that each process can produce](image)

**Figure 3.8.6** Process–Section thickness bar chart indicating compatibility between the manufacturing process and the range of section thickness that each process can produce [2]

**Process – Dimensional Tolerance bar-charts:** Tolerance and surface roughness that a specific manufacturing process can provide is an important characteristic. Manufacturing processes vary in the levels of tolerance and roughness they can achieve economically. *Figures 3.8.7 and 3.8.8 show the process vis-à-vis range of achievable dimensional tolerance and the process vis-à-vis range of minimum achievable surface roughness bar charts, respectively.* For example, die casting process with the permanent metallic dies can give better surface finish compared to the same achievable in sand casting. Machining is capable of delivering high dimensional accuracy and surface finish when the process parameters are controlled properly. Grinding can be adopted to achieve very high tolerance while such precision and finishing operations are generally expensive.
Figure 3.8.7 Process – Tolerance Limit bar chart indicating compatibility between the manufacturing process and tolerance limit [2]
Figure 3.8.8  Process – Surface roughness Limit bar chart indicating compatibility between the manufacturing process and minimum surface roughness limit [2]

How to use the process selection charts?

The charts described above provide a quick overview and comparison of the capabilities of various manufacturing processes. However, these charts must be used sufficiently carefully for a given shape, material, dimension, requisite tolerances and surface roughness considering the both the capabilities and limitations of various processes. Often, the major cost associated with a given part lies from the wrong choice of manufacturing process(es). Following are some generic steps which are often followed in the selection of manufacturing process such as:

- keep things standard
- keep things simple
• design the parts so that they are easy to assemble
• do not specify more performance than is needed

Economic criteria for selection

The choice of the process also depends on the batch size that is required to produce. Often manual processing is suitable when the quantity to be produced is low. However, the cost to manufacture increases with the increase in batch size e.g. the manual cost that warrants automated manufacturing process for medium to large batch size. Figure 3.8.9 typically represents the broad relation between various manufacturing processes and the corresponding economic batch size.

![Figure 3.8.10 Schematic Process vis-à-vis Economic Batch Size (in units) of various manufacturing processes [2]](image-url)
Exercise

1. Examine the suitable manufacturing process or processes that can be used to manufacture seamless steel pipes.
2. Examine the suitable manufacturing process or processes that can be used to manufacture welding electrodes.

Reference: