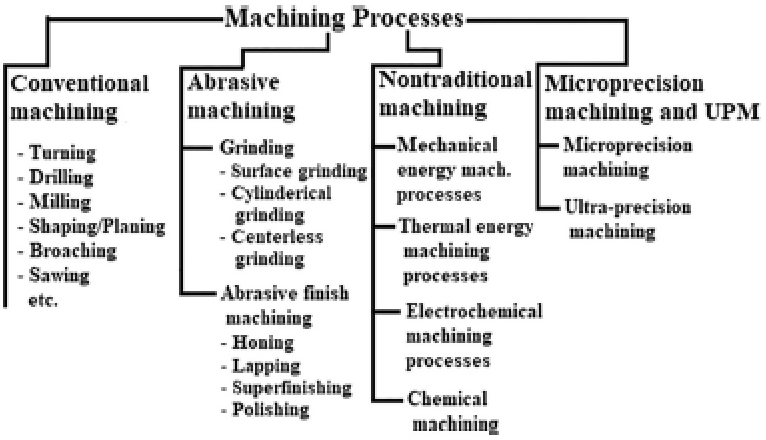

FIGURE 1.2 Classification of machining processes

the like. *Turning* involves the removal of material from a rotating cylindrical workpiece by the use of a single-point cutting tool; the latter has a feed motion (see Figure 1.1). *Milling* involves the use of a rotating cutter with multiple-point cutting edges; here, the cutting tool has the speed motion, and the work has feed motion. A detailed account of conventional machining processes is given in Part II (Chapters 5–10).

1.3.3 ABRASIVE MACHINING PROCESSES

An abrasive machining process involves the use of a grinding wheel, an abrasive stick, or an abrasive suspension to remove material from a workpiece. *Grinding* is a material removal operation by the action of hard and abrasive particles that are bonded usually in the form of a wheel (grinding wheel). As indicated in Figure 1.2, a grinding operation may be surface grinding, cylindrical grinding, or center-less grinding. The abrasive finishing machining operations include honing, lapping, superfinishing, and the like. Grinding and other abrasive machining processes are explained in detail in Part III (Chapters 11 and 12).

1.3.4 NON-TRADITIONAL MACHINING

Non-traditional machining (NTM) processes are chip-less material removal processes that involve use of energy for material cutting. The NTM processes may be classified into four groups: (a) mechanical energy-based machining processes, (b) thermal energy-based machining processes, (c) electro-chemical machining (ECM) processes, and (d) chemical machining process (see Figure 1.2). The mechanical energy machining involves the removal of material by mechanical erosion or abrasion; these processes include ultra-sonic machining (USM), water jet machining (WJM),

1.4 ROUGHING AND FINISHING IN MACHINING

In conventional machining processes, it is often desirable to remove high stock from the bulk material (solid) as well as to achieve reasonably good surface quality. However, the achievement of both the objectives in a single pass is not possible. Thus, machining is usually carried out in two steps with varying cutting conditions (cutting speed, feed, and depth of cut). The two steps in machining are (a) roughing pass and (b) finishing pass. In the *roughing pass*, a bulk amount of material is quickly removed from the workpiece as per required feature. In this step, higher feed rate and depth of cut are employed so as to achieve a high material removal rate from the work. The roughing pass creates a shape close to desired geometry but leaves some machining allowance (material unremoved) for finish cutting. The roughing pass cannot provide good surface finish and close tolerance. This is why a *finishing pass* is carried out to improve surface finish, dimensional accuracy, and tolerance level; here, the feed rate and depth of cut are low. Thus, the material removal rate (MRR) is reduced in the finishing pass, but the surface quality is improved. Table 1.1 presents the main differences between roughing and finishing in conventional machining processes.

1.5 MACHINABILITY AND MACHINABLE MATERIALS

1.5.1 MACHINABILITY

Machinability refers to the ease of machining a material to obtain desired results at low cost. There are a number of quantitative measures of machinability; these measures include (a) tool life, (b) surface finish, and (c) other measures, such as cutting force, power, temperature, and chip formation. The tool life refers to the service time in minutes or seconds to a total failure of the cutting tool at certain cutting speed. The surface finish refers to the acceptable surface finish produced at standardized cutting speeds and feeds. A good machinability may mean one or more of the following: (a) minimum cutting forces, power, and temperature; (b) longer tool life (minimum tool wear); and (c) a good surface finish.

TABLE 1.1
Difference between Roughing and Finishing

Roughing in Machining	Finishing in Machining
It is performed prior to finishing pass	It is performed only after roughing pass
Its objective is to remove bulk excess material from workpiece in every pass	Its objective is to improve surface finish, dimensional accuracy, and tolerance
It involves higher feed rate and depth of cut	It involves higher cutting speed
It results in higher MRR	The MRR is low
The surface finish is poor	The surface finish is good
It cannot provide high dimensional accuracy and close tolerance	It can provide high dimensional accuracy and close tolerance
It permits the use of an old cutter	It requires the use of a sharp cutting tool

1.5.2 Machinable Materials

In order to perform machining with good machinability, the workpiece material should have the following properties/characteristics: (a) medium ductility; (b) reasonably low strain hardening exponent, shear strength, and fracture toughness; (c) presence of non-metallic inclusions that soften at high temperatures; (d) high thermal conductivity; and (e) a low metallurgical bond (adhesion) between cutting-tool and wokpiece.

Ductility directly affects the type of chip produced, which, in turn, affects surface finish. A brittle material (with a low ductility) may cause tool damage. On the other hand, very ductile materials tend to produce continuous chips that are difficult to control. Thus, medium ductility is desirable for good machinability. A work material with high thermal conductivity is helpful for dissipating heat to chips, resulting in cooler work during machining. It is important to avoid the embedding of very hard compounds (such as carbides, some oxides, and silicon) in the work material since these hard compounds accelerate tool wear.

Because steels are among the most commonly used engineering materials that are machined, the machinability of steel is generally improved by adding elements (e.g., lead, sulfur, etc.) or by heat treatment to change their properties. Besides free-machining steels, other good machinable materials include aluminum and its softer alloys, nodular cast irons, plastics, and nano-ceramics (Kalpakjian and Schmid, 2008).

1.6 INDUSTRIAL IMPORTANCE OF CALCULATIONS IN MACHINING

The calculations for various machining variables are of great technological importance in industrial practice. For example, the computation for spindle rotational speed in turning/drilling/milling enables a machinist to select the right spindle rpm in the machine tool. The computations for MRR in both traditional and NTM are also important for determining the efficiency and productivity. The calculation for the cutting time enables the machinist to complete the machining job well in time (Huda, 2018). The cutting time for a machining job also enables a machine shop manager to compute the labor cost in machining the job. The calculations for taper angle and tailstock offset in taper turning are important in the manufacture/machining of tapered shafts and other similar machine elements. The computation for MRR in NTM processes (e.g., AJM and ECM) is also important since the MRR enables a manufacturing manager to assess the efficiency and productivity of an NTM process.

The selection of an electric motor of correct horse-power (HP) to be attached to a machine tool is very important. In order to calculate the power required in machining, a machine-shop manager must calculate the cutting force by using a dynamometer as well as appropriate mathematical models. The cutting force calculations also enable a machinist to determine the degree of clamping required to hold a workpiece during machining. In gear manufacturing, the indexing calculations for both