Finally after the background on mechanics, simple micro models of what happens at the contact interface in machining or grinding, and continuously being reminded about needing empirical materials data, it is time to consider actual production machining processes. The background and cautions are still valid, but most of the time this chapter will proceed as if most things are known. This chapter will consider some of the analysis methods that are common, i.e., how to estimate the theoretical surface roughness or use the specific energy method to estimate forces when mechanics will not do or is too complicated for simple planning of a process. It will also consider three common machining processes: turning, milling and drilling. Using the cutting edge geometry and number of edges as a classification scheme, this progression can be thought of as going from a case that is similar to the orthogonal and oblique models of Chapter 3, to multiple cutting edges that make intermittent cuts, to the complicated multiple edges of the drill.

In each case, as Figure 5.1 illustrates, the geometry and materials or the cutting edge and the workpiece will be assumed known, with the kinematics, mechanics and empirical relationships serving as the basis for estimating the practical output of finish, forces and power and estimated time to produce a workpiece. While each process is different, the basics are common and have been discussed in the previous chapters. This chapter and Chapter 6 on grinding are aimed at applying the basic principles to calculations on real processes. However, one important assumption remains, the practical process and workpieces are perfectly rigid and all inertial effects are neglected. Not until chapter 8 will this restriction be relaxed.

5.1 Common Factors and Analysis Methods

In an attempt to show that all processes are not special cases, the starting point will be defining terms and relationships that are common. Then they can be used for reference later on.

5.1.1 Definition of Cutting Conditions

The term cutting conditions has a very specific meaning in machining. It does not refer to: the geometry and material of the cutting edge(s), continuous or intermittent cutting, whether or not a fluid is used, or the type of material being machined. These are all important variables in planning, but they are usually selections or specifications that cannot be changed on the spot. All require at least going to the tool crib to get new tools or fluids. The variables called cutting conditions can be changed on the spot, by either changing settings or the NC program on the machine tool. They are: cutting speed, feed rate and depth of cut.

Cutting Speed (v) is the largest relative velocity between the cutting edge and workpiece, and it may be generated either by the workpiece moving (lathes or planing...
Figure 5.1 The Inputs, Constraints, Outputs and Mechanisms considered when analyzing and modeling a practical machining process.

mills) or by the cutting edges moving (milling or drilling). The cutting speed is the same as the scalar \( v \) component of the velocity vector in Section 3.1 for orthogonal and oblique cutting. Also, from consulting the equations in Chapter 3, it has the least effect on forces (but force components in this direction represent most of the power consumed at the cutting edge). From Example 2.7 and empirical modeling of tool life in Section 4.3, of the three cutting conditions \( v \) has the greatest effects on temperatures and tool life. At low \( v \), because of the built up edge, surface finish is poor, but operating at high speed which is desirable anyway, or using a fluid that acts as a lubricant are ways to improve the surface finish when BUE occurs. The standard SI units for specifying \( v \) are \( (m/s) \), with \( (ft/min) \) the common English units.

**Feed or feed engagement** \( (a) \) specifies the relative lateral motion between the cutting edge and workpiece normal to \( v \). There are two types of feed: the **relative feed** \( a \), that depends on the specific machining process and how the lateral motion is generated, and the **absolute feed**, **feed speed** or **feed rate** \( v_a \). The feed rate is actually a second velocity component in the velocity vector \( v = [v, v_a, 0]^T \); in Chapter 3 it would be the velocity component in the \( F_q \) or \( y \) direction. The most important thing to remember about the relative feed \( a \), is that it is the most important variable in the function to compute the uncut chip thickness i.e., \( h(a, \text{edge geometry}) \). Over the years a number of jargon terms have been associated with \( a \) like **chip load**, but it can always be determined based on the number of cutting edges, geometry and cutting speed. Because it determines \( h \), the feed has an important effect on forces and power. As will be shown in the next section, it has an important geometric effect on surface finish too, but only a secondary effect on tool life. The common SI units for the feed rate are \( (mm/s) \); the English units are \( (in/min) \). Because