2

Projections Used in Engineering Graphics

SECTIONS
• 2.1 Projections
• 2.2 3-D Projections
• 2.3 Multiview Projections
• 2.4 Working Drawings
• Key Terms

OBJECTIVES
• Understand the spatial relation between 3-D projections and multiview projections
• Be able to differentiate isometric, trimetric, perspective, and oblique 3-D projections
• Understand how multiview projections are related to the views of the sides of an object
• Know the proper placement of orthographic views
• Know the difference between third-angle and first-angle orthographic projections
• Be able to differentiate the various kinds of working drawings
Chapter 2 Projections Used in Engineering Graphics

OVERVIEW

Engineering graphics is a highly stylized scheme to represent three-dimensional objects on a two-dimensional paper or computer screen. This can be accomplished by representing all three dimensions of an object in a single image or by presenting a collection of views of different sides of the object. Working drawings are the practical result of using engineering graphics to represent objects.

2.1 PROJECTIONS

The goal in engineering graphics, whether it is freehand sketching or CAD, is to represent a physical object or the mind’s eye image of an object so that the image can be conveyed to other persons. Objects can be shown as 3-D projections or multiview projections. Figure 2.1 shows the handle of a pizza cutter shown in both ways. The 3-D projection clearly suggests the three-dimensional character of the handle, even though it is displayed on a two-dimensional medium (the page). 3-D projections are useful in that they provide an image that is similar to the image in the designer’s mind’s eye. But 3-D projections are often weak in providing adequate details of the object, and there is often some distortion of the object. For instance, a circular hole at the right end of the handle becomes an ellipse in an isometric 3-D projection.

Multiview projections are used to overcome the weaknesses of 3-D projections. Multiview projections are a collection of flat 2-D drawings of the different sides of an object. For instance, the side and bottom end of the pizza cutter handle are shown in the multi-view projection in Figure 2.1. Because there are two views, it is quite easy to depict details of the object. In addition, taken together, multiview projections provide a more accurate representation of the object than the 3-D projection—a circular hole appears as a circle in a multiview projection. On the other hand, multiview projections require substantial interpretation, and the overall shape of an object is often not obvious upon first glance. Consequently, the combination of the overall image provided by 3-D projections and details provided by multiview projections yield a representation of an object that is best. The shape of the object is immediately evident from the 3-D projection, and the detail needed for an accurate description of the object is available from the multiview projection.

2.2 3-D PROJECTIONS

Three different types of 3-D projections are available in most CAD software: isometric, trimetric, and perspective. These three views of a cube are shown in Figure 2.2. In all three cases, these 3-D projections represent all three dimensions of the cube in a single planar image. Although it is clear in all three cases that the object is a cube, each type of 3-D projection has its advantages and disadvantages.

The isometric projection has a standard orientation that makes it the typical projection used in CAD. In an isometric projection, the width and depth dimensions are sketched at 30° above horizontal as shown in Figure 2.2. This results in the three angles at the upper front corner of the cube being equal to 120°. The three sides of the cube are also equal, leading to the term iso (equal) -metric (measure). Isometric drawings work quite well for objects of limited depth. However, an isometric drawing distorts the
object when the depth is significant. In this case, a pictorial perspective drawing is better.

**Figure 2.1**

In general, the *trimetric projection* offers more flexibility in orienting the object in space. The width and depth dimensions are at arbitrary angles to the horizontal, and the three angles at the upper front corner of the cube are unequal. This makes the three sides of the cube each have a different length as measured in the plane of the drawing; hence the name tri-metric. In most CAD software, the trimetric projection fixes one side along a horizontal line and tips the cube forward as shown in Figure 2.2. A *dimetric* projection sets two sides of the cube, usually those of the front face, equal.

A pictorial perspective, or simply *perspective*, projection is drawn so that parallel lines converge in the distance as shown in Figure 2.2, unlike isometric or trimetric projections where parallel lines remain parallel. A *perspective projection* is quite useful in providing a realistic image of an object when the object spans a long distance, such as
the view of a bridge or aircraft from one end. Generally, small manufactured objects are adequately represented by isometric or trimetric views.

Two types of pictorial sketches are used frequently in freehand sketching: isometric and oblique. The isometric projection was discussed with respect to 3-D CAD projections. The isometric projection is often used in freehand sketching because it is relatively easy to create a realistic sketch of an object. But the oblique projection is usually even easier to sketch. The oblique projection places the principal face of the object parallel to the plane of the paper with the axes in the plane of the paper perpendicular to one another. The axis into the paper is at an arbitrary angle with respect to the horizontal. Figure 2.3 compares an isometric projection and an oblique projection of a cube with a hole in it. The advantage of the oblique projection is that details in the front face of the object retain their true shape. For instance, the circle on the front face is circular in the oblique projection, while it is elliptical in the isometric projection. This feature often makes oblique freehand sketching somewhat easier than isometric sketching.

2.3 MULTIVIEW PROJECTIONS

The standard means of multiview projection in engineering graphics is what we have referred to earlier as the orthographic projection. Although 3-D projections provide a readily identifiable visual image of an object, multiview projections are ideal for showing the details of an object. Dimensions can be shown easily and most features remain undistorted in multiview projections.

An orthographic projection is most easily thought of as a collection of views of different sides of an object—front, top, side, and so forth. For instance, two orthographic projections could be used for a coffee mug. The front view would show the sidewall of the mug along with the loop forming the handle. The top view would show what one would see looking down into the mug—a circular rim of the mug, the bottom of the inside of the mug, and the top of the handle that sticks out of the side of the mug. Dimensions of the mug could easily be added to the projections of each side of the mug to create an engineering drawing.

One useful way of looking at multiview projections is to imagine a glass box surrounding the object as shown in Figure 2.4. The image of each side of the object can be projected onto the wall of the glass box. Now an observer on the outside of the box can see each side of the object as projected on each of the six walls of the box. Solid lines show the edges evident in the projection, and dashed lines show lines that are hidden by the object. Now imagine unfolding the glass box as if each of the edges of the glass box were a hinge, so that the front view is in the middle. Now the unfolded glass box repre-
Section 2.3 Multiview Projections

presents all six sides of the object in a single plane as shown in Figure 2.5. In unfolding the glass box, the top view is positioned above the front view, the bottom view is below the front view, the right-side view is to the right of the front view, and so on. The dimensions of the object remain the same in all views. For example, the horizontal dimension (width of the object) in the front view is identical in that same dimension in the top view and bottom view. The views also remain aligned so that the bottom edge in the front view is even with the bottom edge in the right side, left side, and rear views. Likewise, the top edges remain aligned. Finally, the same edges in adjacent views are closest together. For instance, the same edge of the object is at the left side of the front view and the right side of the left side view. This edge in the front view is closest to the same edge in the left-side view.

In many cases, three views are needed to represent an object accurately, although in some cases (like a coffee mug) only two views are necessary, and in other cases more than three views are needed to show complex features of the object. It is helpful to select the side of the object that is most descriptive of the object as the front view. Sometimes this may place an object so that what is normally thought of as the front of the object is not shown in the front view of the multiview projection. For example, what is usually described as being the side of a car should be chosen as the front view, because this view is probably most descriptive and easily recognizable as a car. A view of the front of a car (grille, bumper, and windshield) is not as descriptive or as obvious as the side of the car. Furthermore, the object should be properly oriented in the front view. For instance, a car should be shown with its wheels downward in their normal operating position for the front view. The other views that are shown in addition to the front view should be views that best represent features of the object. Normally the minimum number of views necessary to accurately represent the object is used. The standard practice is to use the front, top, and right-side views. But the choice of which views to use depends on the object and which details need to be shown most clearly.

A complication that arises in multiview projections is that two different standards are used for the placement of projections. In North America (and to some extent, in
Great Britain) the unfolding of the glass box approach places the top view above the front view, the right-side view to the right of the front view, and so on. This placement of views is called third-angle projection. But in most of the rest of the world an alternative approach for the placement of views is used. In this case the placement of views is what would result if the object were laid on the paper with its front side up for the front view and then rolled on one edge for the other views. For instance, if the object were rolled to the right so that it rests on its right side, then the left side would be facing up. So the left-side view is placed to the right of the front view. Likewise, if the object were lying on the paper with the front view up and then rolled toward the bottom of the paper, it would be resting on its bottom side, so that the top side faces upward. Thus, the top view is placed below the front view. This placement of views, known as the first-angle projection, simply reverses the location of the top and bottom views and the location of the left-side and right-side views with respect to the front view compared to the third-angle projection. The views themselves remain the same in both projections.

Although, the difference between the two projections is only in the placement of the views, great potential for confusion and manufacturing errors can result in engineering drawings that are used globally. To avoid misunderstanding, international projection symbols, shown in Figure 2.6, have been developed to distinguish between third-angle and first-angle projections on drawings. The symbol shows two views of a truncated cone. In the first-angle projection symbol, the truncated end of the cone (two concentric circles) is placed on the base side of the cone, as it would be in a first-angle projection. In the third-angle projection symbol, the truncated end of the cone is placed on the truncated side of the cone, as it would be in a third-angle projection. Usually these symbols appear in or near the title block of the drawing when the possibility of confusion is anticipated. Most CAD software automatically uses the third-angle projection for engineering drawings.

A problem that frequently occurs in orthographic projections is that one of the faces of the object is at an angle to the orthographic planes that form the imaginary glass
Section 2.4 Working Drawings

Several types of working drawings are produced during the design process. Initially freehand sketches are used in the ideation phase of the design process. These are usually hand-drawn pictorial sketches of a concept that provide little detail, but enough visual information to convey the concept to other members of the design team. An example is the isometric sketch of a sheet metal piece that holds the blade of a pizza cutter, shown in Figure 2.8. The general shape of the object is clear, although details such as the thickness of the sheet metal and the radius of the bends in the sheet metal are not included. These conceptual sketches eventually evolve to final detailed drawings that define enough detail and information to support production.

Detail drawings document the detailed design of individual components using orthographic views. The detail drawing is the final representation of a design that is specific enough so that all of the information necessary for the manufacture of the part is provided. As a result, it is imperative that it includes the necessary views, dimensions,
Chapter 2 Projections Used in Engineering Graphics

and specifications required for manufacturing the part. Figure 2.9 shows an example of a detail drawing of the part of the pizza cutter that was sketched in Figure 2.8. The detail drawing includes fully dimensioned orthographic views, notation of the material that the part is to be made from, information on the acceptable tolerances for the dimensions, and a title block that records important information about the drawing. Often an isometric view is included in the detail drawing to further clarify the shape of the part. Detail drawings provide sufficient detail so that the part can be manufactured based on the drawing alone.

Assembly drawings show how the components of a design fit together. Dimensions and other details are usually omitted in assembly drawings to enhance clarity. Several styles of assembly drawings are commonly used. Sometimes the assembly drawing is just an isometric view of the fully assembled device. But an exploded isometric view is often helpful to show the individual parts are assembled, as shown in Figure 2.10 for a pizza cutter. In some cases, a sectioned assembly, or cut-away view, shows how complicated devices are assembled. A cutting plane passes through the assembly and part of the device is removed to show the interior of the assembly. Numbers or letters can be assigned to individual parts of the assembly on the drawing and keyed to a parts list.

Finally a parts list, or bill of materials, must be included with a set of working drawings. The parts list includes the part name, identification number, material, num-

Figure 2.7

Figure 2.8
Figure 2.9

Figure 2.10
ber required in the assembly, and other information (such as catalog number for standard parts such as threaded fasteners). An example is shown in Figure 2.11 for a pizza cutter. The parts list is used to ensure that all parts are ordered or manufactured and brought to the central assembly point.

<table>
<thead>
<tr>
<th>QTY</th>
<th>PART NO.</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52806</td>
<td>handle</td>
</tr>
<tr>
<td>2</td>
<td>52825</td>
<td>cap</td>
</tr>
<tr>
<td>3</td>
<td>42886</td>
<td>guard</td>
</tr>
<tr>
<td>4</td>
<td>97512</td>
<td>rivet</td>
</tr>
<tr>
<td>5</td>
<td>55654</td>
<td>arm</td>
</tr>
<tr>
<td>6</td>
<td>56483</td>
<td>blade</td>
</tr>
</tbody>
</table>

**Figure 2.11**

Taken together, the detail drawings of each individual part, the assembly drawing, and the bill of materials provide a complete set of working drawings for the manufacture of a part.

**KEY TERMS**

- 3-D projections
- Assembly drawings
- bill of materials
- Detail drawings
- first-angle projection
- freehand sketching
- multiview projection
- multiview projections
- oblique projection
- orthographic projection
- perspective projection
- third-angle projection
- trimetric projection
- working drawings

**Problems**

1. Describe or sketch the front view that should be used in an orthographic projection of:
   a. a stapler.
   b. a television set.
   c. a cooking pot.
   d. a hammer.
   e. a pencil.
   f. a bicycle.
   g. an evergreen tree.
   h. a paper clip.
   i. a coffee mug.
   j. a padlock.
2. Identify the views shown in Figure 2.12 as isometric, trimetric, or perspective.

![Figure 2.12](image)

3. For the drawings shown in Figure 2.13, determine whether the multiview projection is first-angle or third-angle.

![Figure 2.13](image)
4. Develop a bill of materials for:
   a. a pencil.
   b. a squirt gun.
   c. a click-type ball point pen.
   d. a videocassette (take an old one apart).
   e. an audio cassette (take an old one apart).
   f. a disposable camera (ask a local photo developer for a used one to take apart).
   g. eyeglasses.
   h. a household cleaner pump bottle.
   i. a claw-type staple remover.
   j. an adhesive tape dispenser.
   k. a bicycle caliper brake.
   l. a floppy disk (take an old one apart).
   m. a utility knife.
   n. a Vise-Grip wrench.