

10.1 BASIC CONCEPTS

Engineering drawings are used to communicate designs to others, document design solutions, and communicate design production information. These types of drawings are called **working drawings** or **production drawings**.

Documenting is the process of communicating and archiving design and manufacturing information on a product or structure. The documents created include drawings, models, change orders, memos, and reports.

10.2 WORKING DRAWINGS

Working drawings are used to produce products, structures, and systems.

Working drawings show how complex assemblies are put together.

Working drawings are the complete set of standardized drawings specifying the manufacture and assembly of a product based on its design. The complexity of the design determines the number and types of drawings. Working drawings may be on more than one sheet and may contain written instructions called **specifications**.

Working drawings are the blueprints used for manufacturing products. Therefore, the set of drawings must:

- ▮ completely describe the parts, both visually and dimensionally
- ▮ show the parts in assembly
- ▮ identify all the parts
- ▮ specify standard parts.

Generally, a complete set of working drawings for an assembly include:

- ▮ detail drawings of each nonstandard part.
- ▮ an assembly or subassembly drawing showing all the standard and nonstandard parts in a single drawing.
- ▮ a bill of materials (BOM).
- ▮ a title block.

A **detail drawing** is a dimensioned, multiview drawing of a single part, describing the part's shape, size, material, and finish, in sufficient detail for the part to be manufactured based on the drawing alone. Standard parts are not drawn as details because they are normally purchased, not manufactured, for the assembly.

When more than one detail is placed on a sheet, the spacing between details is carefully planned, including leaving sufficient room for dimensions and notes.

An **assembly drawing** shows how each part of a design is put together. If the design depicted is only part of the total assembly, it is referred to as a **subassembly**. An assembly drawing normally consists of:

A **parts list** or **bill of materials (BOM)** shows the detail number for each part, the quantity needed for a single assembly the description or name of the part, the catalog number if it is a standard part, and the company part number.

Leader lines with balloons, assigning each part a **detail number**, in sequential order and keyed to the list of parts in the parts list.

Assembly drawings are used to describe how parts are put together as well as the function of the entire unit; therefore, complete shape description is not important. The views chosen should describe the relationships of parts and the number of views chosen should be the minimum necessary to describe the assembly.

Dimensions are not shown on assembly drawings unless necessary to provide overall assembly dimensions, or to assist machining operations necessary for assembly. Also, hidden lines are omitted in assembly drawings, except when needed for assembly or clarity.

An **outline assembly** gives a general graphic description of the exterior shape. Outline assemblies are used for parts catalogs and installation manuals or for production when the assembly is simple enough to be visualized without the use of other drawings.

A **sectioned assembly** gives a general graphic description of the interior shape by passing a cutting plane through all or part of the assembly. Sectioned assembly drawings are used for the manufacture and assembly of complicated devices.

A **pictorial assembly** gives a general graphic description of each part, and uses center lines to show how the parts are assembled.

A 3-D CAD model can also be used to create pictorial assemblies by positioning each part in a pictorial view. With constraint-based modelers, the alignment and location of parts in an assembly is done as part of the constraining process

Every part in an assembly is assigned a **part number**, which is usually a string of numbers coded in such a way that a company can keep accurate records of its products. Large aircraft have thousands of parts, and considerable documentation is necessary to design, manufacture, assemble, and maintain the aircraft.

Every drawing used in industry is assigned a number. Each company develops its own standard numbering system, based on various criteria such as sequential numbers, combinations of numbers and letters, sheet sizes, number of parts in the assembly, model numbers, function, etc. Both part numbers and **drawing numbers** are commonly used to name CAD files and code information for companywide CIM databases.

Title blocks are used to record all the important information necessary for the working drawings. The title block is normally located in the lower right corner of the drawing sheet. Title blocks should contain the following:

N Name and address of the company or design activity.

N Title of the drawing.

N Drawing number.

N Names and dates of the drafters, checker, issue date, contract number, etc.

N Design approval, when subcontractors are used.

- N Additional approval block.
- N Predominant drawing scale.
- N Federal supply code for manufacturers (FSCM) number.
- N Drawing sheet size letter designation.
- N Actual or estimated weight of the item.
- N Sheet number, if there are multiple sheets in the set.
- N ANSI recommended minimum letter heights for engineering drawings.

A complete set of working drawings must include a detailed parts list or bill of material. Based on ANSI standards, a parts list should be located in the lower right corner above the title block. The information normally included in a parts list is as follows:

- N Name of the part.
- N A detail number for the part in the assembly.
- N The part material, such as cast iron or bronze.
- N The number of times that part is used in the assembly.
- N The company-assigned part number.
- N Other information, such as weight, stock size, etc.

Information on standard parts, such as threaded fasteners, includes the part name and size or catalog number.

Parts are identified in assembly drawings by a leader line with an arrow that points to the part. The other end of the leader has a **balloon** showing the part detail number.

The information is normally placed in a **revision block** which is normally in the upper right corner of the drawing.

When a drawing is revised because of design changes, errors, etc., an accurate record of the change should be created. This information includes:

- N the person making the change
- N description of the change
- N the change number
- N approval for the change

The designations **METRIC** or **SI** appear in or near the title block to show that metric dimensions and scale are used on the drawing. A graphics scale can also be used, especially on mapping drawings. This graphics scale has calibrations for transferring distances from the drawing to the scale to determine distances.

Tolerances are specified in a drawing using toleranced dimensions. For those dimensions that are not specifically toleranced, a **general tolerance note** is used.

The general tolerance note can also contain a general note for angles.

Zones are used on large sheets for reference purposes. Zones in engineering drawing are similar to the zones used on highway maps.

Tabular drawings are used when several similar parts have common features. Such parts can be grouped together into a family of parts.

A **working assembly drawing**, also known as a **detailed assembly**, combines on a single sheet the detail drawing and the assembly drawing, usually a section view. Such drawings are used for relatively simple assemblies that use some standard parts.

10.3 THREADED FASTENERS

Fastening is a method of connecting or joining two or more parts together, using processes or devices. One of the most common methods used for fastening is **mechanical fastening**, a process that uses manufactured devices such as screws, pins, or rivets to hold parts of an assembly together.

A **threaded fastener** is a mechanical fastener used to join together two or more parts. The first use for a screw thread was probably not as a fastener, but as a means of lifting water.

10.3.1 THREAD TERMINOLOGY

The terms described in this section are the ones used most for representing threads on engineering drawings.

Axis-the longitudinal center line that passes through the screw thread cylinder.

Chamfer-the angular relief at the last thread, to allow easier engagement with the mating part.

Crest-the peak or top surface of a screw thread.

Depth-the distance between the crest and root of a thread, measured normal to the axis.

Die-a tool used to form external threads.

External thread-the screw thread on the outside of a cylindrical or conical surface.

Internal thread-the screw thread on the inside of a cylindrical or conical surface.

Lead-the distance a screw will travel when turned 360 degrees, or one revolution.

Major diameter-the largest diameter on an internal or external thread.

Minor diameter-the smallest diameter on an internal or external thread.

Pitch-the distance between corresponding points on adjacent thread forms, measured parallel to the axis. The pitch is equal to the number divided by the number of threads per inch. For example, a screw thread with 12 threads per inch would have a pitch of 1/12.

Pitch diameter-the diameter of an imaginary cylinder that is located equidistant between the major and minor diameters.

Root-the bottom of a screw thread cut into a cylinder.

Screw thread-a continuous and projecting helical ridge on a cylindrical or conical surface.

Side-the screw thread surface that connects the crest and root.

Tap-a tool used to make threads in holes.

Tap drill-a drill bit used to make a hole in metal before tapping an internal thread.

Thread angle-the angle between the surfaces of two adjacent threads.

Thread form-the profile or shape of a thread cut into a cylinder.

Thread series-the number of threads per inch for a given diameter.

Threads per inch-the number of threads in one inch, measured axially (parallel to the axis); the reciprocal of the pitch.

10.3.2 THREAD SPECIFICATIONS: ENGLISH SYSTEM

To specify a thread using the English system, you must provide a minimum of five pieces of information:

- N Thread form
- N Thread series
- N Major diameter
- N Class of fit
- N Threads per inch

10.3.3 FORM

Thread form is the shape or profile of a screw thread. Many types of thread forms have been developed.

N The *sharp-V* thread was originally developed by William Sellers.

N The *American National* thread replaced the sharp-V thread and is stronger than the sharp-V thread.

N The *Unified* thread is the current standard used in the United States, Canada, and England.

N A variation on the Unified thread is the *Unified National Round* thread, abbreviated UNR.

N The *metric* thread is the international standard thread that is similar in shape to the Unified thread.

N The *Acme*, *square*, and *buttress* threads are used primarily to transmit power in gearing and other types of machines.

^N The *knuckle* thread is usually rolled from sheet metal or cast, and it is used for lightbulb bases, bottle caps, and glass jars.

10.3.4 SERIES

The thread series refers to the standard number of threads per inch, and there are four classes: coarse (C), fine (F), extra fine (EF), and constant pitch (See Appendix).

^N **Coarse series** fasteners are used for quick assembly or disassembly of cast iron, soft metals, and plastic, and are designated NC or UNC.

^N **Fine series** fasteners are used when a great deal of force is necessary for assembly, and are designated NF or UNF. These fasteners are used extensively in the aerospace and automotive industries.

^N **Extra fine** series fasteners are used when the length of engagement is short and the application calls for high degrees of stress.

^N **Constant pitch series** is specified by writing the number before the form designation. These threads are for special purposes, such as large-diameter or high-pressure environments.

10.3.5 CLASS OF FIT

There are three classes of fit established by ANSI for general use.

^N **Class 1**-a loose fit where quick assembly is required and looseness or play between parts is acceptable.

^N **Class 2**-a high-quality, general purpose, commercial class of fit for bolts, nuts, and screws widely used in mass production.

^N **Class 3**-a very high-quality threaded fastener with a close fit, used for precision tools and for high stress and vibration applications.

10.3.6 THREAD NOTES

Threads are only symbolically represented on drawings; therefore, thread notes are needed to provide the required information. A thread note must be included on all threaded parts, with a leader line to the external thread or to an internal thread in the circular view.

10.3.7 THREAD SPECIFICATIONS: METRIC SYSTEM

Metric thread specifications are based on ISO recommendations and are similar to the Unified standard.

The basic designation for a metric thread.

A complete metric thread note should contain the following information, in the order given:

Thread form symbol. The letter M is used to designate the metric profile. The J profile class is a modified M profile.

Nominal size (basic major diameter) in millimeters, followed by an X.

Pitch in millimeters, followed by a dash. The pitch can be eliminated for coarse threads, but it is preferred in the American use of the standards.

General purpose tolerance, which for external metric threads is 6g, and for internal metric threads is 6H. For closer fits, 6H is used for internal threads and 5g6g is used for external threads. The tolerance class designation, then includes:

Pitch diameter tolerance: grade, position

Minor diameter tolerance: grade, position.

10.3.8 THREAD DRAWINGS

Most threads are difficult to represent graphically in their true form. The three conventional methods for drawing thread forms are: detailed, schematic, and simplified. The **detailed thread** representation is the most realistic, and is rarely used on engineering drawings. Its use is normally limited to illustrations. The **schematic** and **simplified** representations are easier to draw and are more widely used in engineering drawings, with the simplified representation being the most common.

The simplified method of representing threads is the quickest and easiest technique, whether using hand tools or CAD, and can be used for all thread forms, including metric.

A bottom tapped hole is one in which the tapping tool cuts threads all the way to the bottom of the drilled hole.

Schematic representation of internal threads for through, blind, and bottom tapped holes.

A threaded fastener in an assembly section is not sectioned. Because they are too small to be shown clearly in section, nuts, bolts, screws, studs, and other fasteners are shown whole, unless a section view is necessary to show some internal feature.

Pipe threads are used for piping systems that carry liquids and gases, for drilling, and for other applications where pipes must be joined.

Graphic representation of tapered pipe threads can include the tapering angle.

10.4 STANDARD BOLTS, STUDS, AND SCREWS

The five general types of standard threaded fasteners are:

Bolt—a mechanical threaded device with a head on one end and threads on the other end. Bolts are paired with nuts. A **nut** is a mechanical threaded device used on the end of a bolt, a stud, or a machine screw.

Stud—a rod that is threaded on both ends and joins two mating parts. A nut may be used on one end.

Cap screw—a mechanical threaded device with a head on one end and threads on the other end. Cap screws join two mating parts and have longer threads than bolts. Also, cap screws can be made with slotted heads.

Machine screw—a mechanical threaded device with a head on one end and threads on the other end. The threaded end may screw into a mating part, or may be used with a nut. A machine screw is similar to a cap screw, but it is normally smaller.

Set screw—a mechanical threaded device with or without a head, used to prevent rotation or movement between parts, such as a shaft and a collar. Set screws have different types of points and heads for different applications.

Standard fasteners can be created as blocks or symbols in CAD programs. Fastener symbol libraries are also available from 3rd party companies.

10.5 NONTHREADED FASTENERS

- 10.5 Nonthreaded fasteners are mechanical devices generally used to prevent motion between mating parts. Dowels, pins, keys, rivets, and retaining rings are examples of such fasteners. **Washers**, another type of nonthreaded fastener, are used to lock fasteners or to provide a smooth surface for a fastener.

Plain washers are used with bolts and nuts to improve the assembling surface and increase the strength. Plain washers are specified by giving the inside diameter, outside diameter, thickness, type, .

Lock washers are used to prevent a fastener from coming loose due to vibration or movement. Helical spring and tooth are the most common types of lock washers. Lock washers are specified by giving the name, inside diameter, strength, and material, as follows:

HELICAL SPRING LOCK WASHER— 5/16 HEAVY—ALUMINUM—ZINC ALLOY.

Common types of **pins** are dowel, straight, tapered, groove, and spring (see Figure 10.48). Dowel pins are used to keep parts in position, or to prevent slippage after assembly. Dowel pins are specified by giving the name, nominal pin diameter, material, and protective finish, as follows:

HARDENED GROUND MACHINE DOWEL—STANDARD SERIES, 1/4 X 2, STEEL

Keys are commonly used to attach two components such as a shaft and hub, to transmit power to gears, pulleys, and other mechanical devices. The key is placed into a keyseat, which is a groove cut into the shaft. Examples can be seen in Figure 10.49.

10.6 SPRINGS

Springs can be represented on engineering drawings either in detail or in schematic form.

10.7 MECHANISMS

A **machine** is a combination of interrelated parts for using or applying energy to do work.

An important emphasis of this chapter is that manufactured products — more often than not — are made up of numerous components, not a single component. Quite often a student will spend a majority of an introductory course drawing single parts without having an appreciation for how these parts are integral to larger mechanisms.

Another important point to make is that most assemblies contain components which are not manufactured on site, but are supplied by an outside manufacturer. Proper **specification** of these standard components are critical if the supplier is going to properly manufacture the components for your company. Part of the specification process is the technical drawing.

10.7.1 GEARS

The primary purpose of **gears** is to transmit rotational power and motion between portions of a mechanism. Typically a shaft is used to both apply and receive power from the gears. Most spur gear teeth use the **involute** as the basic geometric form. The involute of a circle creates a curve needed to produce smooth meshing of gear teeth and effective transmission of power.

The graphical representation of gears follows ANSI Y14.7.1-1971 and Y14.7.2-1978.

Normally, gear drawings contain a table of information, cutting data, for manufacturing.

10.7.2 CAMS

Cams are used to translate rotational motion into linear motion. Though cams often operate at high speeds, they usually aren't used to transfer large amounts of power. Instead, cams are typically used as mechanical actuators, such as opening and closing valves in an internal combustion engine.

Of primary interest in the design of cams is how the rotational motion of the cam is translated into **displacement** of the follower. A **displacement diagram** represents the pattern of travel over a single (360 degree) period of the cam. The diagram represents the different parts of the cycle of the cam, including:

_N Rise

_N Fall

_N Dwell

10.7.3 LINKAGES

Linkages are the most common type of mechanism in use to transmit force. A linkage consists of a (usually) linear element, called the **bar**, and one or two **joints**. The length and shape of the bar and the location of the joint(s) determine the movement of the linkage. Quite often more than one bar/joint combination are used, with joints being shared between the bars. Sliders are used to direct the motion of a bar via a joint. Some of the most common types of links are:

_N Crank

_N Lever or rocker

_N Rocker arm

_N Bell crank

_N Four-bar

Linkages can be analyzed graphically, mathematically, or both. As with cams, the *graphical analysis* can be either a graph representing the displacement of elements of the linkage or the actual geometry of the linkage. 3-D modeling and animation techniques can be powerful tools for analyzing the motion of the linkages (see Chapters 7 and 20).

10.7.4 BEARINGS

Bearings are used in conjunction with other mechanisms — such as gears and linkages — to minimize friction and wear between the parts. Bearings are usually used with some type of friction reducing compound (lubricant) such as grease or oil. Bearings are commonly used as an interface between rotating shafts and their stationary supports.

Plain bearings provide a sliding contact on which a lubricant can be applied. Note that these bearings are a single element and not multiple spherical or cylindrical elements as is commonly assumed.

Rolling contact bearings are what most people think of when they think of bearings. The bearings come in a number of shapes, determining their application. The geometries of the bearings include:

spherical (ball)

clindrical (roller or needle)

truncated cone (taper)

10.8 WELDING

10.9 **Welding drawings** are a specialized type of technical drawing which differs from many other types of drawings in that its main focus is to specify how parts are joined together. Since welds are both permanent and structural, proper location and orientation of the welded members and the type of weld used are important to properly specify.

As with other types of specialized technical drawings, there is a specific symbology used to represent the welding process. These symbols are specified by ANSI/AWS A2.4-1986.

The AWS/ANSI weld symbol standard has eight basic parts:

- N Reference line
- N Leader line and arrow
- N Basic weld symbol (location and depth of weld)
- N Finish symbol
- N Weld symbol (type of weld)
- N Dimensions
- N Supplementary symbols
- N Tail and specifications

As with geometric dimensioning and tolerancing (Chapter 9), a common set of symbols, a framework, and alphanumeric notation is used to specify the fabrication of the product.

10.9 REPROGRAPHICS

Reprographics refers to the technology and techniques of reproducing documents. After the engineering drawings have been created they are copied for others to use, carefully stored, and set up for easy future accessibility. After the original drawing is created, it must be carefully stored or archived. The process used to store and retrieve engineering drawings is called **archiving**.

Blueprinting is a photographic reproduction process in which the copy produced, called a **blueprint**, has white lines on a blue background.

Diazo is a more modern technique similar to the blueprint process. The diazo print, also called an ozalid dry print or a blueline print, is a direct print dry process.

Xerography is an electrostatic process that transfers images onto ordinary paper. A distinct advantage of the xerographic process is that multiple reduced or enlarged copies can be produced quickly and easily.

Engineering drawings produced on large sheets of paper present a significant storage and retrieval problem for industry. One technique for reducing the size of the originals is **microfilming**, which is a photographic process that produces a small film negative.

An **aperture card** is a long, rectangular card with a rectangular hole for mounting microfilm.

Just as CAD has revolutionized the engineering design/drafting process the use of computers for reprographics is revolutionizing the copying, storing, and retrieving of engineering drawings. However, a more modern approach would be to use the digital data as the basis for storing, copying, and retrieving the engineering drawings.

The digital storage of drawing files is accomplished by saving or copying the drawing files to the medium, then storing that medium in a safe place.

Engineering digital management systems (EDMS) are database software tools used in some offices to manage digital files. These computer programs, sometimes called drawing managers, are designed to locate and retrieve digitally stored drawing files quickly and easily.

After drawings are digitally stored, they can be retrieved using the EDMS software. Drawings can be viewed on screen, using either the CAD software or special viewing software without resorting to making prints or plots.

Files can be distributed to other sites either on disk or through telecommunications networks, such as phone lines or LANS.

10.10 SUMMARY

Working drawings are a fundamental part of any manufacturing or construction business. These drawings document the manufacturing and construction process for simple-to-complex assemblies. Typically, a set of working drawings includes dimensioned detail drawings, assembly drawings, and parts lists normally developed based on ANSI standards.

Most assemblies contain standard parts such as fasteners or mechanisms. These parts all have to be specified on the working drawings using ANSI standards. A basic knowledge of how these standard parts function in a product is critical both to its design and how it is notated on the drawings. Many industries have their own specialized drawings such as piping drawings and welding drawings. These drawings also have standardized methods of representing parts and processes on the drawings.

Traditionally, drawings have been created on paper, which must be stored, retrieved, and copied through a process called reprographics. Increasingly computers are being used to not only generate the original drawings, but also manage their storage, copying, and distribution electronically.