

Drawing

Drawing is a metalworking process which uses tensile forces to stretch metal. It is broken up into two types: sheet metal drawing and wire, bar, and tube drawing. The specific definition for sheet metal drawing is that it involves plastic deformation over a curved axis. For wire, bar, and tube drawing the starting stock is drawn through a die to reduce its diameter and increase its length. Drawing is usually done at room temperature, thus classified a cold working process, however it may be performed at elevated temperatures to hot work large wires, rods or hollow sections in order to reduce forces

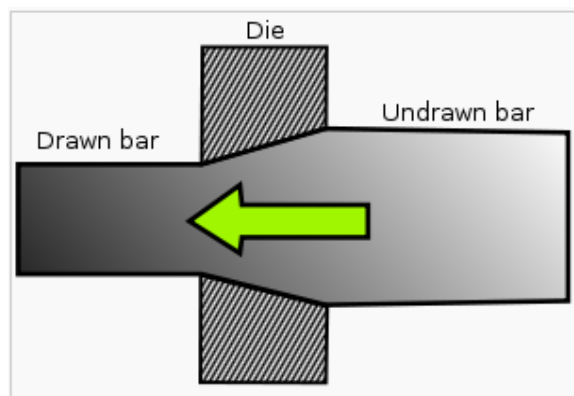


Fig. 1 Drawing

Bar, tube, and wire drawing all work upon the same principle: the starting stock drawn through a die to reduce the diameter and increase the length. Usually the die is mounted on a draw bench. The end of the workpiece is reduced or pointed to get the end through the die. The end is then placed in grips and the rest of the workpiece is pulled through the die. Steels, copper alloys, and aluminium alloys are common materials that are drawn.

Drawing Dies

Drawing dies are typically made of tool steel, tungsten carbide, or diamond, with tungsten carbide and manufactured diamond being the most common. Synthetic diamond is usually used in the early stages of the drawing process, whereas natural diamond dies are used in the final stages. For drawing very fine wire a single crystal diamond die is used. For hot drawing, cast-steel dies are used. For steel wire drawing, a tungsten carbide die is used. The dies are placed in a steel casing, which backs the die and allow for easy die changes. Die angles usually range from 6–15° and each die has at least 2 different angles: the entering angle and

approach angle. Wire dies usually are used with power as to pull the wire through them. There are coils of wire on either end of the die which pull and roll up the wire with a reduced diameter. Drawing can also be used to produce a cold formed shaped cross-section. Cold drawn cross-sections are more precise and have a better surface finish than hot extruded parts. Inexpensive materials can be used instead of expensive alloys for strength requirements, due to work hardening

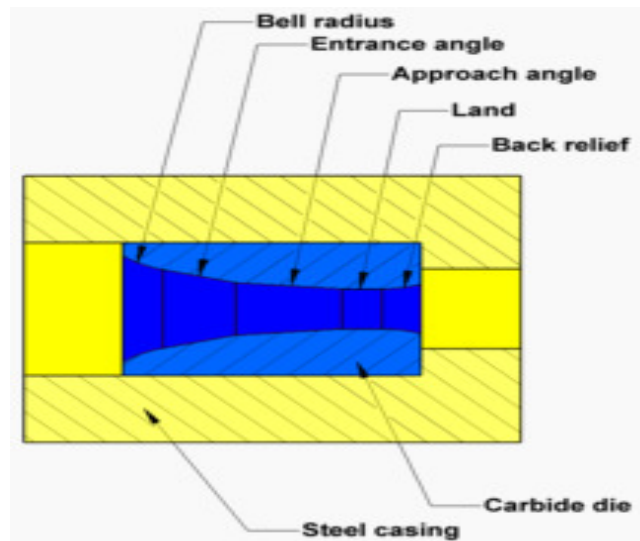


Fig. 2 Drawing Die

Wire Drawing

Wire drawing is a metal-reducing process in which a wire rod is pulled or drawn through a single die or a series of continuous dies, thereby reducing its diameter. Because the volume of the wire remains the same, the length of the wire changes according to its new diameter. Various wire *tempers* can be produced by a series of drawing and annealing operations. (*Temper* refers to toughness.) The process of wire drawing involves the production of wire of close diameter and tolerance by drawing descaled hot-rolled rod through a die. The finished wire is coiled onto a motor driven block. The dies are manufactured from hard material e.g tungsten carbide. Diamonds dies are used for small diameter wire. Soap is used for lubrication. If large diameter reductions are required the rod is progressively drawn through several stages of dies and blocks. Wire can be extruded at speeds of up to 2000 m/min.

Wire drawing is primarily the same as bar drawing except that it involves smaller - diameter material that can be coiled. It is generally performed as a continuous operation on draw bench like the one shown in Fig. 3. The rotating draw block provides a continuous pull on the incoming wire.

Large coil of hot rolled material of nearly 10 mm diameter is taken and subjected to preparation treatment before the actual drawing process. The preparation treatment for steel wire consists of,

- Cleaning. This may be done by acid pickling, rinsing, and drying. Or, it may be done by mechanical flexing.
- Neutralization. Any remaining acid on the raw material is neutralized by immersing it in a lime bath. The corrosion protected material is also given a thin layer of lubricant.

To begin the drawing process, one end of coil is reduced in cross section upto some length and fed through the drawing die, and gripped. A wire drawing die is generally made of tungsten carbide and has the configuration shown in Fig. 4 for drawing very fine wire, diamond die is preferred.

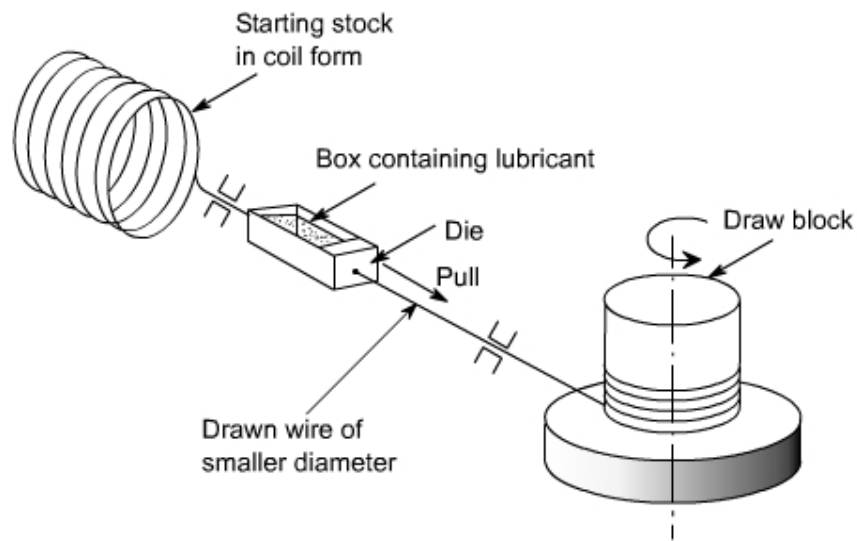


Fig. 3 Wire drawing on a continuous draw block

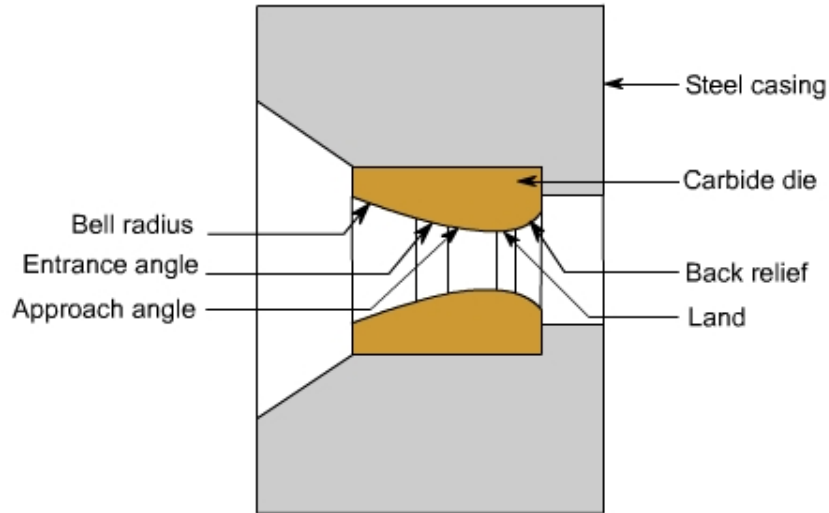


Fig. 4 Cross section through a typical carbide wire drawing die

Small diameter wire is generally drawn on tandom machine which consists of a series of dies, each held in a water cooled die block. Each die reduces the cross section by a small amount so as to avoid excessive strain in the wire. Intermediate annealing of material between different states of wire may also be done, if required.

Process Characteristics

- Pulls a wire rod through a die, reducing its diameter
- Increases the length of the wire as its diameter decreases
- May use several dies in succession (tandem) for small diameter wire
- Improves material properties due to cold working
- Wire temper can be controlled by swaging, drawing, and annealing treatments

Wire drawing consists of pulling a metal wire through a small circular opening called a die. This results in a stretching or elongation of the material along with a reduction in cross sectional area. The pulling force is limited by the strength of the material: pull too hard and the metal will break. The force needed to pull the wire through the die is determined by the extent of the reduction in cross-sectional area: the larger the reduction, the greater the force needed. Thus it can be seen that the maximum achievable reduction in diameter is limited by the yield strength of the wire.

Yield strength depends on material composition but typically the reduction in area through a die is in the region of 20 to 40%. If a greater reduction is needed this must be done by drawing the wire through a series of dies, each one smaller than the one before.

However, the plastic deformation experienced by the metal as it is pulled through the die tends to increase hardness and reduce ductility. (Ductility refers to the ease with which metal can be deformed.) As this will make it harder to reduce the cross-section, it is often necessary to perform an annealing process between successive draws to improve the way the metal deforms. On the other hand, the increased tensile strength resulting from drawing is often seen as a very desirable material property.

Wire drawing is usually performed cold, although there are some cases where metal is drawn hot to improve ductility. Die lubrication is essential in cold drawing to achieve a good surface finish as well to maximize the life of the die.

In contrast to wire drawing, deep drawing is a sheet metal process where the material is stretched over a male form. This can be used to create complex three-dimensional shapes such as sinks or beverage cans. This is often carried out in progressive dies, where the metal workpiece is moved through a series of tools that gradually stretch the material to the required form. One design issue to be addressed in deep drawing is that as the metal stretches it also becomes thinner. Unless care is taken in engineering the way the metal deforms this can result in hole in the workpiece.

Both wire drawing and deep drawing involve stretching metal to the required shape, and as such are considered deformation rather than removal processes. A significant advantage of drawing is that there is very little material waste. However, this benefit has to be set against the high cost of the dies and the possible need to carry out annealing to counteract work hardening.

Wire drawing terms:

$$\text{Draft} = D_o - D_f$$

$$\% \text{ reduction in area} = \frac{A_o - A_f}{A_f} \times 100 = \frac{D_o^2 - D_f^2}{D_f^2} \times 100$$

$$\% \text{ elongation} = \frac{L_f - L_o}{L_o}$$

Where D_o , D_f , L_o and L_f are the original and final diameter and length. A_o and A_f are original and final cross sectional area.

For a single cold drawing pass, the percent area reduction that can be done depends upon many factors. These include the type of material, its size, initial metallurgical condition, the final size and mechanical properties desired, die design and lubrication efficiency. The percent of area reduction per pass can range from near zero to 50%.

Die pull

The force required to pull the stock through the die (under frictionless conditions) can be computed as follows.

$$F = Y_{avg} \cdot A_f \cdot \ln \left(\frac{A_o}{A_f} \right)$$

Where F = die pull, i.e. the force required to pull the stock through the die

Y_{avg} = average true stress of the material in the die gap

A_o , A_f = original and final areas of cross section of material.

Alternatively, the following expression can be used

$$F = c s_t (A_o - A_f)$$

where c is a constant whose value is in the range 1.5 to 3.0 depending upon the % area reduction, (lower value for higher % reduction), and s_t is tensile strength of material before drawing.

The pull force determines the machine capacity needed.

Tube Drawing

Tube drawing is very similar to bar drawing, except the beginning stock is a tube. It is used to decrease the diameter, improve surface finish and improve dimensional accuracy. A mandrel may or may not be used depending on the specific process used.

The diameter and wall thickness of tubes that have been produced by extrusion or other processes can be reduced by tube drawing process. The process of tube drawing shown in Fig. 5 is similar to wire or rod drawing except that it usually requires a mandrel of the requisite diameter to form the internal hole. Tubes as large as 0.3 m in diameter can be drawn.

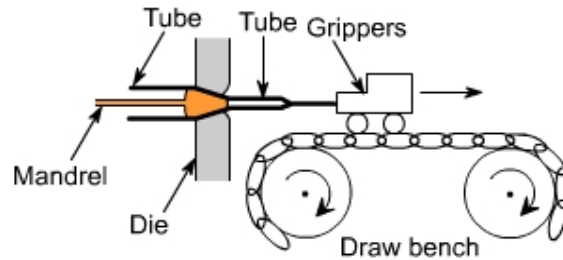


Fig. 5 Tube Drawing

Drawing Equipment

Drawing equipment can be of several designs. These designs can be classified into two basic types; Draw bench, and Bull block. A draw bench (Fig. 5) uses a single die and the pulling force is supplied by a chain drive or by hydraulic means. Draw bench is used for single length drawing of rod or tube with diameter greater than 20mm. Length can be as much as 30 m. The drawing speed attainable on a draw bench ranges from 5 m/min to 50 m/min. Draw benches are available having capacities to provide pull force of upto 1 MN.

Bull block or rotating drum (Fig. 3) is used for drawing rods or wires of very long length.

Production of this kind of products is far beyond the reach of the hot rolling, and so a substantial proportion of tubing is still cold drawn for the following reasons.

- To produce tubes with thinner walls than can be hot rolled.
- To produce tubes with smaller diameters.
- To produce tubes longer than can be hot rolled in certain sizes.
- To secure better surface finishes.
- To obtain closer dimensional tolerances.
- To increase certain mechanical properties, such as tensile strength.
- To produce shapes other than round.
- To produce tubes with varying diameters and wall thicknesses from end to end.
- To make small lots of tubing of odd sizes and gages that do not justify a hot mill run.

The practical minimum tube diameter produced by hot rolling is 33.3 mm (1 5/16 inches), and 2.1 mm (0.083 inch) is the thinnest wall of commercial hot-rolled tube.

Tube Drawing Processes

When a hollow tube is drawn through a die, generally a mandrel or plug is used to support the inside diameter of the tube, this process is called tube drawing. The function of the plug is to effect wall reduction and to control the size of the hole. However, the mandrel may be omitted if it is not necessary to make a reduction in the wall thickness, or if the dimensions and surface of the inside are not important. The process to draw a pipe without any mandrel is known as *tube sinking*.

In drawing tubes over a stationary mandrel, the maximum practical sectional area reduction does not exceed 40 per cent per pass the increased friction from the mandrel. If a carefully matched mandrel floats in the die throat of the die, it is possible to achieve a reduction in area of 45 percent, and for the same reduction the drawing loads are lower than for drawing with a fixed plug. This style is called the drawing with *floating plug*. To be mentioned is that in this style, tool design and lubrication can be very critical. Problems with friction in tube drawing are minimized in drawing with a long *mandrel*. The mandrel consists of a long hard rod or wire that extends over the entire length of the tube and is drawn through the die with the tube. In this design, the area reduction can be 50 per cent. However, after drawing, the mandrel must be removed from the tube by rolling (reeling), which increases the tube diameter slightly and disturbs the dimensional tolerances.

The drawing process discussed above can be illustrated in the Fig. 6.

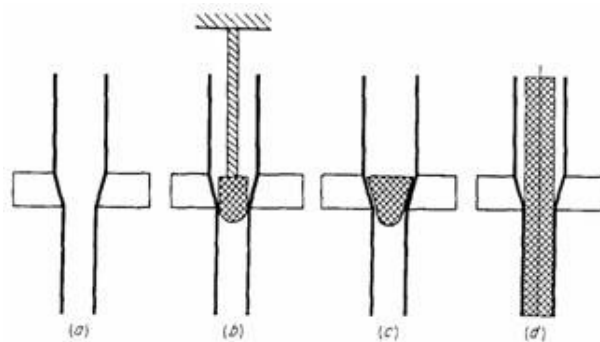


Fig. 6: Tube drawing processes
(a) Sinking; (b) fixed plug; (c) floating plug; (d) moving mandrel

A cold-draw bench for tubes consists of a heavy steel frame or bench, in the middle of which is located a die head for holding the die. At one end of the bench is located an adjustable

holder to anchor the mandrel rod. At its other end a shaft is mounted carrying a sprocket wheel over which passes a heavy, endless, square-linked chain. This chain lies in a trough on top of the bench, which extends from the sprocket wheel to the die head, where the chain passes around an idler and returns underneath the bench to the sprocket wheel. The sprocket wheel is driven by a variable speed motor through suitable reduction gearing.

If cold drawn seamless tubing is require with small diameters, thin walls, or a smooth surface finish then the tubes manufacturing process is completed using cold drawing. Prior to cold drawing the scale resulting from rotary forging is removed by pickling.

A draw bench is used to pull the tube through a drawing die. One end of the tube to be drawn is collapsed and fed through the die. This end is then clamped to a travelling carriage. The carriage is then move away from the die using either mechanical or hydraulically traction. In practice several tubes may be drawn in parallel to increase productivity.

A number of process options are available as shown in the figure below.

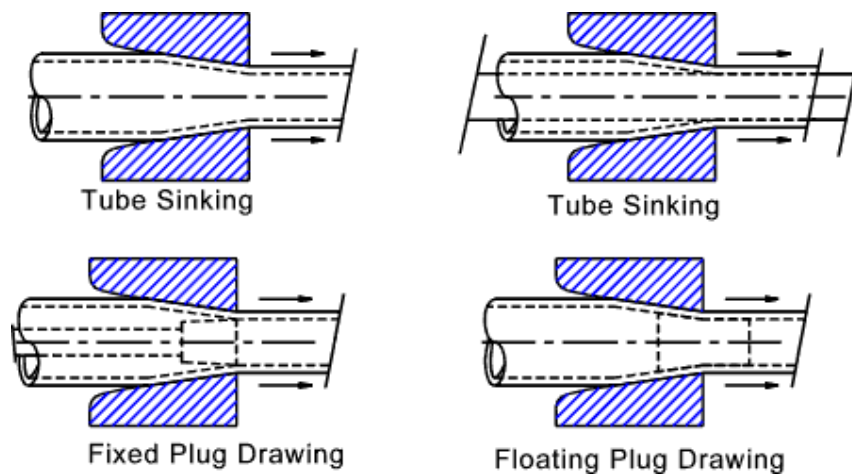


Fig. 7 Process options

Production Operation

The hot-rolled tubes after cooling are pointed on one end. This pointing consists of reducing the outside diameter, for a distance of about 150 mm (6 inches), sufficiently to permit the reduced portion to enter the hole in the draw die freely, so that the jaws of the pincer can grip

this end of the tube. If more than one cold-draw pass is to be given the tube, the point is made slightly under the final die size, if possible.

In most cases, one cold-draw pass is sufficient to reach close dimensions, good surface, and required mechanical property of the products. Additional passes may be necessary to secure: (1) thinner walls, (2) better surface finishes, (3) smaller diameters, or (4) longer length.

For production with multiple passes, it is necessary to anneal them after each cold drawing operation. Before further cold-drawing, the annealed tubes must be pickled and lubricated. All tubes, except unannealed mechanical tubes, receive a final anneal or heat treatment after the last cold-draw pass. Many tubes receive a special normalizing treatment before the last pass in order to obtain the proper grain structure in the finished tube; this annealing is performed in either continuous tunnel or car-bottom batch furnaces fired with gas. The continuous furnaces are provided with heat-resisting driven rolls used to carry the tubes through the furnace at a predetermined rate depending on the tube section, annealing temperature, time at temperature, etc. The car-bottom batch furnaces are arranged in a battery and are served by a special charging crane. Further, the cold-drawn, annealed tubes are subjected to the finishing operation such as straightening, cutting, inspecting and testing.

Residual Stresses

For tube sinking and tube drawing over a plug and mandrel, assume the deformation is relatively uniform throughout the tube wall, the longitudinal residual stresses are tensile on the outer surface and compressive on the inner surface of the tube. The residual stresses in the circumferential direction follow the same pattern, while the stresses in the radial direction are negligible. Change of circumferential stresses on the outer surface of sunk tubes with increasing diameter reduction follows the same rate of the yield stress change.