CONVENTIONAL DEEP DRAWING VS INCREMENTAL DEEP DRAWING

A. Chennakesava Reddy
Professor, Department of Mechanical Engineering
JNTUH College of Engineering, Hyderabad

1. Conventional Deep Drawing Process:

Deep drawing is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch. It is thus a shape transformation process with material retention. The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter. This is achieved by redrawing the part through a series of dies. The flange region (sheet metal in the die shoulder area) experiences a radial drawing stress and a tangential compressive stress due to the material retention property. These compressive stresses (hoop stresses) result in flange wrinkles (wrinkles of the first order). Wrinkles can be prevented by using a blank holder, the function of which is to facilitate controlled material flow into the die radius.

Figure 1: Example of deep drawn part.

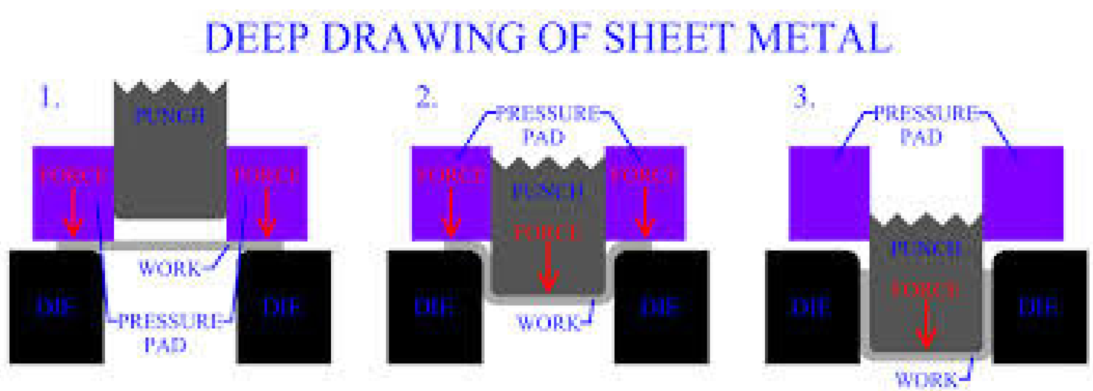

Figure 2: Conventional deep drawing process.

The total drawing load consists of the ideal forming load and an additional component to compensate for friction in the contacting areas of the flange region and bending forces as well as unbending forces at the die radius. The forming load is transferred from the punch radius through the drawn part wall into the deformation region (sheet metal flange). In the drawn part wall, which is in contact with the punch, the hoop strain is zero whereby the plane strain condition is reached. In reality, mostly the strain condition is only approximately plane. Due to tensile forces acting in the part wall, wall thinning is prominent and results in an uneven part wall thickness, such that the part wall thickness is lowest at the point where the part wall loses contact with the punch, i.e., at the punch radius.

The thinnest part thickness determines the maximum stress that can be transferred to the deformation zone. Due to material volume constancy, the flange thickens and results in blank holder contact at the outer boundary rather than on the entire surface. The maximum stress that can be safely transferred from the punch to the blank sets a limit on the maximum blank size (initial blank diameter in the case of rotationally symmetrical blanks). An indicator of material formability is the limiting drawing ratio (LDR), defined as the ratio of the maximum blank diameter that can be safely drawn into a cup without flange to the punch diameter. Determination of the LDR for complex components is difficult and hence the part is inspected for critical areas for which an approximation is possible. During severe deep drawing the material work hardens and it may be necessary to anneal the parts in controlled atmosphere ovens to restore the original elasticity of the material.

Commercial applications of this metal shaping process often involve complex geometries with straight sides and radii. In such a case, the term stamping is used in order to distinguish between the deep drawing (radial tension-tangential compression) and stretch-and-bend (along the straight sides) components. Deep drawing is always accompanied by other forming techniques within the press. These other forming methods include:

Beading: Material is displaced to create a larger, or smaller, diameter ring of material beyond the original body diameter of a part, often used to create O-ring seats.

Bottom Piercing: A round or shaped portion of metal is cut from the drawn part.

Bulging: In the bulging process a portion of the part's diameter is forced to protrude from the surrounding geometry.

Coining: Material is displaced to form specific shapes in the part. Typically coining should not exceed a depth of 30% of the material thickness.

Curling: Metal is rolled under a curling die to create a rolled edge.

Extruding: After a pilot hole is pierced, a larger diameter punch is pushed through, causing the metal to expand and grow in length.

Ironing / Wall Thinning: Ironing is a process to reduce the wall thickness of parts. Typically ironing should not exceed a depth of 30% of the material thickness.

Necking: A portion of the part is reduced in diameter to less than the major diameter.

Notching: A notch is cut into the open end of the part. This notch can be round, square, or shaped.

Rib Forming: Rib forming involves creating an inward or outward protruding rib during the drawing process.

Side Piercing: Holes are pierced in the side wall of the drawn part. The holes may be round or shaped according to specifications.

Stamping / Marking: This process is typically used to put identification on a part, such as a part number or supplier identification.

Threading: Using a wheel and arbor, threads are formed into a part. In this way threaded parts can be produced within the stamping press.

Trimming: In the Trimming process, excess metal that is necessary to draw the part is cut away from the finished part.

Often components are partially deep draw in order to create a series of diameters throughout the component (as in the image of the deep draw line). It common use to consider this process as a cost saving alternative to turned parts which require much more raw material.

1.1 Other types of presses:

Die-Set Transfer Press: Part is transferred via transfer fingers as the part progresses through the forming process. Tooling components attached to die plates enable the die to be installed in the press as one unit. Deep drawing has been classified into conventional and unconventional deep drawing. The main aim of any unconventional deep drawing process is to extend the formability limits of the process. Some of the unconventional processes include hydromechanical deep drawing, Hydroform process, Aquadraw process, Guerin process, Marform process and the hydraulic deep drawing process to name a few.

The Marform process, for example, operates using the principle of rubber pad forming techniques. Deep-recessed parts with either vertical or sloped walls can be formed. In this type of forming, the die rig employs a rubber pad as one tool half and a solid tool half, similar to the die in a conventional die set, to form a component into its final shape. Dies are made of cast light alloys and the rubber pad is 1.5-2 times thicker than the component to be formed. For Marforming, single-action presses are equipped with die cushions and blank holders. The blank is held against the rubber pad by a blank holder, through which a punch is acting as in conventional deep drawing. It is a double-acting apparatus: at first the ram slides down, then the blank holder moves: this feature allows it to perform deep drawings (30-40% transverse dimension) with no wrinkles.

2. Incremental Deep Drawing:

Incremental deep drawing or Incremental sheet forming (or ISF, also known as Single Point Forming) is a sheet metal forming technique where a sheet is formed into the final workpiece by a series of small incremental deformations. However, studies have shown that it can be applied to polymer and composite sheets too. Generally, the sheet is formed by a round tipped tool, typically 5 to 20mm in diameter. The tool, which can be attached to a CNC machine, a robot arm or similar, indents into the sheet by about 1 mm and follows a contour for the desired part. It then indents further and draws the next contour for the part into the sheet and continues to do this until the full part is formed. ISF can be divided into variants depending on the number of contact points between tool, sheet and die (in case there is any). The term Single Point Incremental Forming (SPIF) is used when the opposite side of the sheet is supported by a faceplate and Two Point Incremental Forming (TPIF) when a full or partial die supports the sheet.

he ISF process is generally implemented by clamping a sheet in the XY plane, which is free to move along the Z axis. The tool moves in the XY plane and is coordinated with movements in the Z axis to create the desired part. It is often convenient to retrofit a CNC milling machine to accommodate the process. Spherical, flat-bottomed, and parabolic tool profiles can be used to achieve differing surface finishes and forming limits.

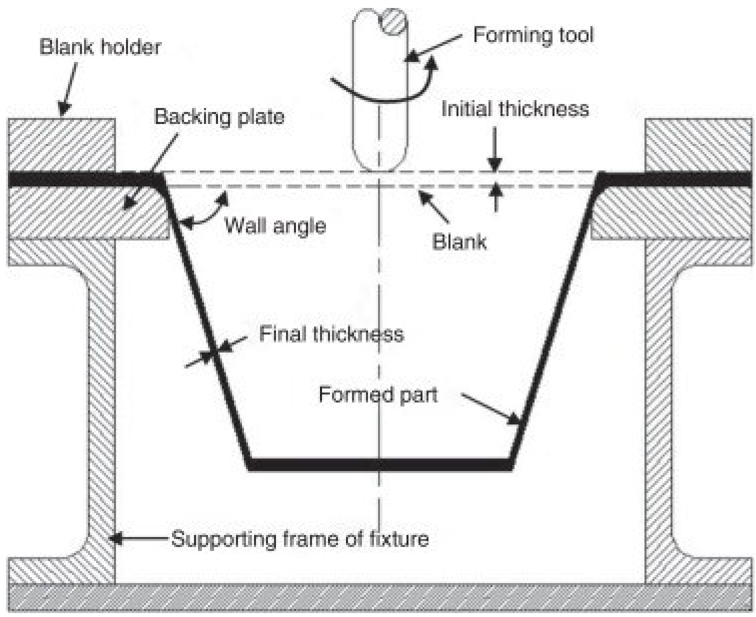

Figure 3: Incremental sheet forming process.

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