BOKER'S, INC.
STAMPING & WASHER SPECIALISTS SINCE 1919

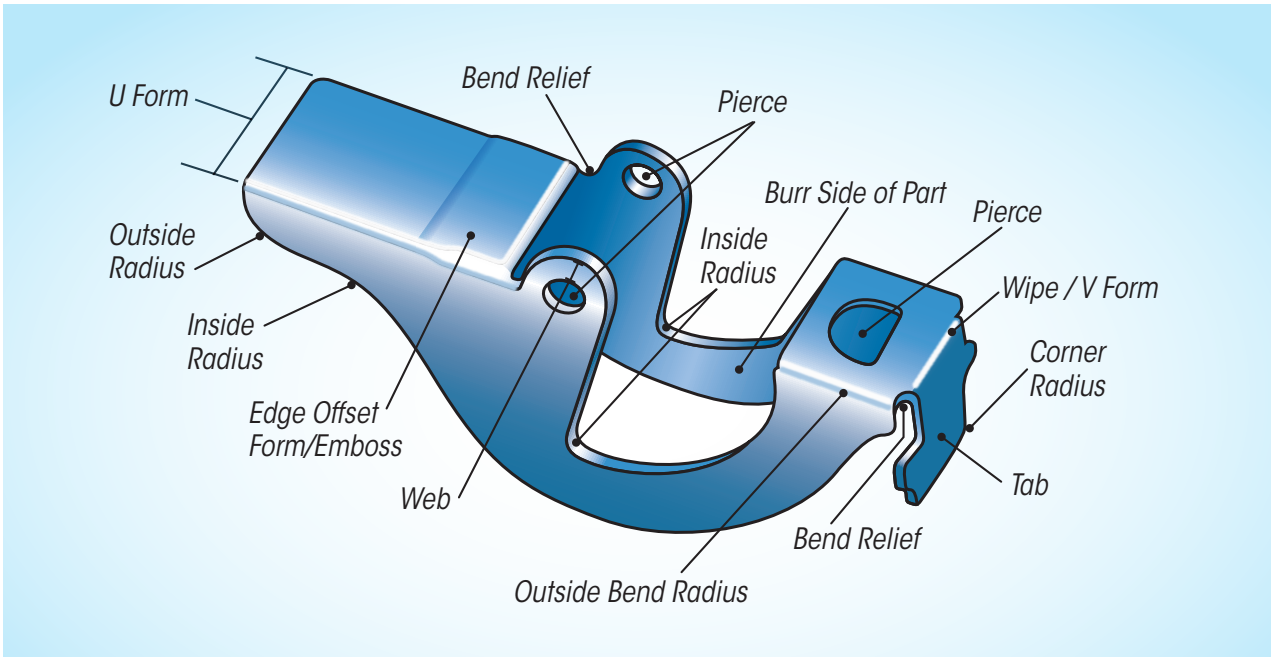
THE DESIGNER'S GUIDE TO PRECISION METAL STAMPINGS

CHAPTER 1
INTRODUCTION

The basics of metal stampings.

Precision metal stampings are produced by converting flat metal sheet or coil into engineered component parts for manufacturers. Parts can be flat and simple or complex profiles. Stampings are produced using a variety of punch presses that brings to bear ten to hundreds-of-tons of stamping pressure onto the sheet or coil. In their most basic operation, punch presses use a corresponding die and punch tool for **flat blanking**—a flat metal cutout of the exact periphery shape and size of the part. Additional metal forming stages are often employed to produce complex parts and profiles including **piercing**, and **metal forming operations** such as **bending**, **drawing, flanging, embossing, rolling,** and others.

In addition to traditional, compound dies (single-stage tools), more advanced stamping providers offer **progressive tooling** capabilities that accomplish multiple automated operations at once (in progression), including stamping, blanking, piercing and forming. Progressive tooling and automation further decreases secondary operations and lead times and increases the capacity and economy for longer production runs.

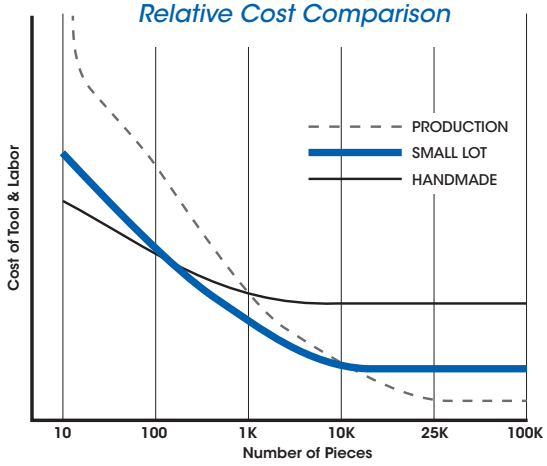


What are the advantages of short-run custom stampings?

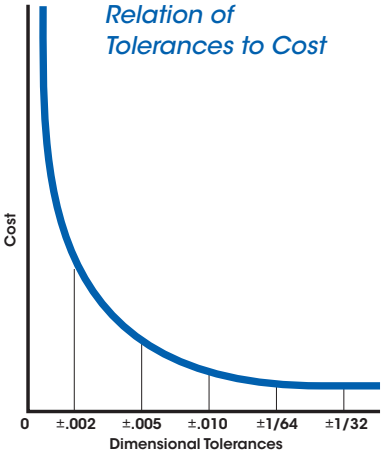
Compared to permanent production tooling, short-run stamping offers high quality and **durability** plus considerable **manufacturing advantages—primarily in cost and time.** Significantly lower initial tooling costs versus permanent tooling offers savings that gives manufacturers greater design and component inventory flexibility. Small quantity needs, customization, pilot runs, testing, frequently-changing designs, functional prototypes and limited production runs are all opportunities for short-run stampings that would be less feasible with expensive permanent tooling.

In addition, the dies for short-run stampings require only a fraction of the time to produce, reducing lead time demands and creating greater production agility for manufactured components. Tooling design for stamping is generated by CAD drawings, accommodating factors including the performance characteristics of the end material, thickness, machine clearances and bend radii. A highly capable stamping provider will also offer **3D rapid prototype technology** to quickly validate designs, providing their customer a precision model to test for form and fit prior to investing in final tooling design and process.

Relative Cost Comparison



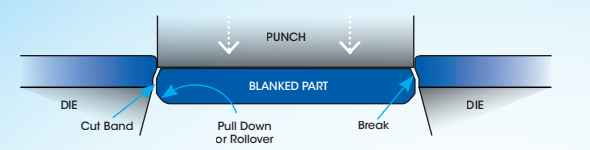
Relation of Tolerances to Cost



CHAPTER 2
STAMPING OPERATIONS

Flat Blanking

Flat blanking is the process of stamping out the perimeter of a product from sheet or coil material to produce more complex metal blanks. Blanking can also be performed with flat non-metallic sheet or coil material.



Pull-down and breakage

Blanking of parts by punch press requires a punch and die combination between which the material is fed. **Die clearance** is required between the punch and die to create the ability to punch through the material. As this occurs, some material is subjected to **pull-down**, plastic deformation that rounds the edges of the punched surface to the point of **breakage** where the blank separates the remaining material thickness, and may leave behind a **burr** on the edge. The amount of pull-down and breakage are affected by a number of factors including die clearance, material temper (hardness) as well as the granular structure of the material.

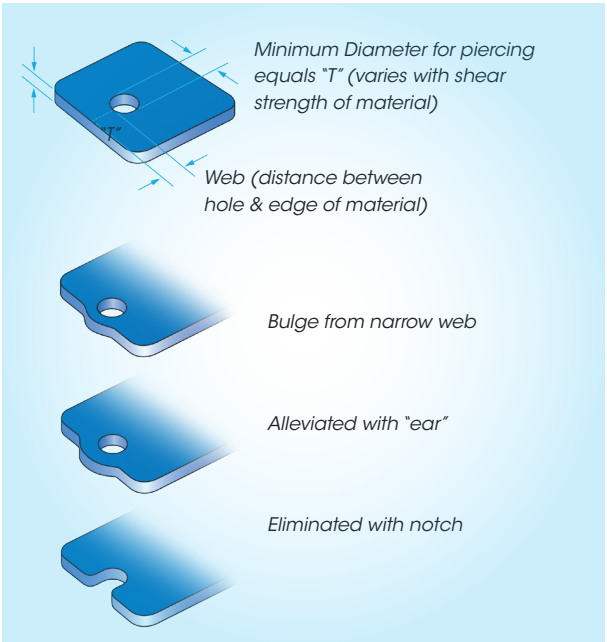
Blank design considerations

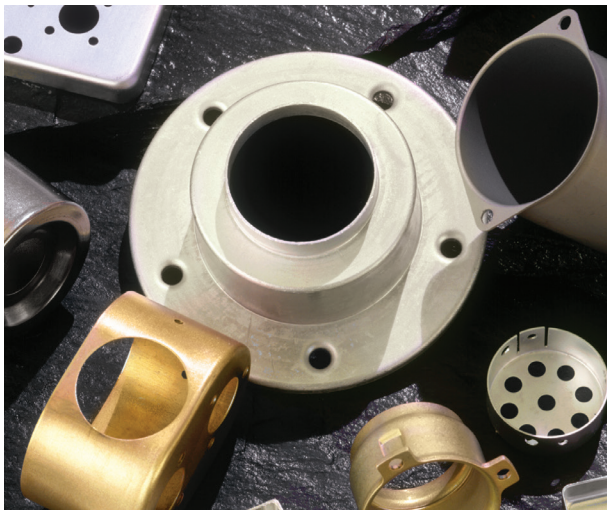
- Minimum blank size should never be less than 1½x to 2x material thickness in width and not less than 1/32".
- Corner radii should be a minimum of ½x material thickness; corner radii may be relatively sharp if material thickness is 1/16" or less depending on material temper.
- If a close tolerance notch is required in a single stage operation, avoid sharp corners by adding a radius. If sharp corners are required, a secondary operation may be required.
- For cutting a blank to length from a strip of material that has been rolled, sheared or slit in a previous operation, a sharp 90-degree cut is recommended and most economical while tighter radius cuts may result in a distorted edge and heavy burring.

Flat blanking can be done in a variety of ways depending on the specific project. A compound die or single-stage tool allows a part to be passed on to additional machinery (punch press, press brake, etc.) for additional processing such as **piercing** or **forming**. A progressive tool can be used for flat blanking while performing additional operations simultaneously without the need of creating or setting up additional tools.

Metal Piercing

Piercing metal is a shearing process used to produce holes, slots and/or notches with tight tolerances within a component part or raw material. The punched side of pierced metal produces a clean cut with high output rates often making it a more productive method than drilling, machining, or using a laser. Boker's utilizes a CAD drawing system, over 70 different punch presses, digital servo feeders and compound as well as progressive dies to transform raw material into your most complex components.





Draws up to 3" deep and 8" in diameter

Complex metal forming needs in thicknesses from .005" to .190" (varies by material)

Flat blanking and piercing up to 12" by 12"

Piercing considerations

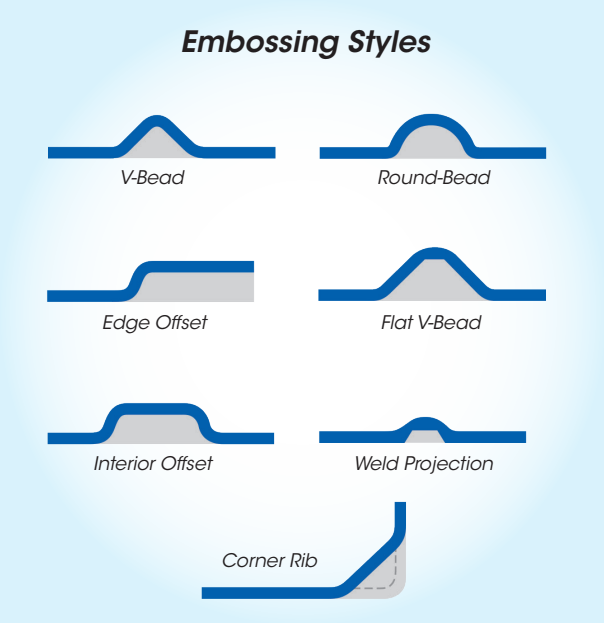
- Precise round holes and slots can generally be produced with tight tolerances if the hole diameter is equal to or greater than the material thickness. A material with high shear strength such as stainless steel may require a minimum diameter of 2x material thickness.
- Tolerances on hole diameters apply only to the punched side; a degree of breakage on the reverse side occurs on all punched holes due to clearance between the punch and die. If a precise hole diameter is required all the way through the material, the punched hole should be undersized and reamed to the correct size.
- Punching a hole or slot adjacent to the material edge will likely produce a deformity along the edge if the distance, i.e., the **web**, is less than material thickness. This bulge or deformity will also be present on a narrow web between holes.
- Piercing a hole adjacent to designed bends requires a minimum distance from the edge of the opening to the bend centerline. This distance is calculated at 1½x the material thickness PLUS the bend radius measurement. Punching a slot adjacent to a bend requires even more distance. If spacing requirements cannot be met, an additional operation may be required.
- Formed tabs located within the blank must be either punched and formed, or sheared and formed. Punched holes or relief at the bend line prevents fracturing and tapered tabs prevent binding during shearing and forming operations.
- **Countersinking** can be produced through machining or coining, creating a conical flared-angle on a hole to recess the fastener head. In formed countersinking, a raised surface and burr is created on the reverse side of the countersunk surface. Machined countersinking with a drill press largely eliminates the raised surface.

Metal Forming

Metal forming is the process of converting a flat piece of metal into a three-dimensional part. Metal **forming** can be done in a variety of ways including **bending**, **drawing**, embossing, rolling etc.

Forming and bending considerations

- In design for bending forms in blanks, allow 1½x to 2x material thickness for relief. Ensure the form is completely outside the blank profile and create a relief notch or radius on the form to avoid material tearing and fatigue failure at the bend.
- Extend the stock on the inside height of forms to accommodate the radius of bends and the thickness of stock. A rule of thumb is adding 2½x material thickness plus the required bend radius to arrive at the desired form height, which may or may not require to be cut off in an additional operation.
- Material distortion can occur on the inside of bent forms, particularly with a tight inside forming radius and/or thicker materials. To alleviate the compression created on inside and tension on the outside of bends, a relief notch can be added at the bend line.
- Tension is also present on the burr side of a blank that has been bent to an outside edge. This condition will likely create fractures. Either reversing the form so the burr side is on the inside of the bend, or if this is not possible, performing tumbling or deburring before forming will help reduce fractures.
- Numerous styles of embossing include v-bead, flat v-bead, round bead, interior offset, edge offset, weld projection, spherical offset and corner rib (see illustration at top of page).
- Available edge conditions include as-formed, die trimmed, hemmed edges in open, teardrop or closed styles, curled edge and lance-formed.



Drawing considerations

- Drawing is the process of taking a piece of flat metal and forming it into a three-dimensional shaped part such as a can, box, cup or pan.
- The process is defined as a "deep draw" when the depth of the drawn part meets or exceeds its diameter.
- Softer metals, such as aluminum and brass, are much easier to deform and require less force to draw than harder materials such as cold-rolled or stainless steel.

Boker's has been drawing metal since 1919 and has the capabilities to produce complex parts with draws up to 3" deep and 8" in diameter. Utilizing a CAD drawing system, flat metal blanks are transformed into complex cylindrical, rectangular, square, or multi-faceted shells. The 3-dimensional shells are machined on-site, with additional services provided by approved vendors for plating and heat treating. Boker's in-house tooling, with up to 180-ton capacity, enables them to produce draws with material thickness from .005" to .190".

CHAPTER 3
SELECTING A PROVIDER

Finding a provider that meets your design and production criteria.

While there are perhaps thousands of stamping providers, it's vital they first meet essential design requirements, in-house capabilities and achieve manufacturing tolerances, quality and delivery. With over 100 years in precision stamping and washer manufacturing, Boker's sets the standards for companies in this industry.

Capabilities and capacity

- The Boker's goal of World-class Precision Metal Stamping Manufacturing begins with an in-house tool department and CNC-produced tooling that provides control of dimensional tolerances.
- In-house CAD/CAM capabilities to convert flat blanks into precisely sized complex dimensional profiles including cylindrical, rectangular, square or multifaceted shells.
- Housed in over 165,000 square feet, Boker's operates over 70 (10- to 180-ton) mechanical punch presses, high-speed progressive die presses, servo presses and digital servo feeders to produce the most complex "complete to print" component parts with exceptional repeatability.

Sizing, thickness and draw depth

- Flat blanking and piercings up to 12" x 12"
- Thicknesses from .005" to .190" (varies by material)
- Draws up to 3" deep and 8" in diameter

Material selection and availability

- Immediate access to over 2,000 commonly specified and hard-to-find materials including: low carbon, cold rolled strip and sheet steel, SAE 1050, 1075, and 1095 spring steel, blue and black temper spring steel, low alloy steel sheets, brass, copper, nickel silver, beryllium copper, phosphor bronze, stainless steel, aluminum, and various superalloys. Numerous non-metallic materials are also available such as Acetal, PTFE, Polyester, Nylon, fiber, polyethylene, and various NEMA grade phenolics.
- Certificates of Compliance or chemical/physical analyses are available upon request.
- Draw materials include copper, brass, beryllium copper, nickel silver, aluminum, stainless steel, low and high carbon steel sheet, low alloy steel, nickel alloys and numerous other metals.
- Custom non-metallic stamping capabilities
- Boker's also has the capabilities to stamp your flat non-metallic parts from a wide variety of materials including laminates, Fluoroplastics, Polyolefins, Polyvinyl Chloride (PVC) and Acrylonitrile Butadiene Styrene (ABS).
- Non-metallic stampings can be provided in a range of sizes up to 12" x 12" (flat) with thicknesses from .005" to .125".

Secondary operations and finishing

- Boker's also provides all of the secondary operations you expect from your stamping manufacturer including deburring, tapping, reaming, counterboring, and spotfacing. Boker's also has approved vendors for heat treating, plating,non-destructive testing (NDT) and others.

What are other important considerations when sourcing stamped components?

In addition to often critical time and cost considerations, a capable provider of custom stampings should be prepared to document their practices to a rigorous set of quality requirements.

Quality assurance standards and practices

At Boker's, we are committed to comply with and continually improve the effectiveness of our Quality Management System (QMS) which is AS 9100:2016 / ISO 9001:2015 certified. These rigorously-maintained practices provide confidence to customers that parts will meet precise and repeatable specifications. Complete Statistical Process Control (SPC) is available upon request to further assure accuracy throughout the manufacturing process. In addition, Boker's offers all of the following certification documents:

- C of C – Certificate of Compliance
- PPAP – Production Part Approval Process
- DFARS – Defense Federal Acquisition Regulation Supplement
- RoHS – Restriction of Hazardous Substances
- S.P.C. – Statistical Process Control
- F.A.I. – First Article Inspection
- AS9102 – First Article Inspection
- Dock-to-Stock
- Conflict Minerals
- ITAR – International Traffic in Arms Registered
- REACH
- IMDS
- CA Proposition 65
- Latex-free
- Woman-Owned Business Certificate
- Better Business Bureau Accreditation

When you've been successful for 100 years, quality isn't just a promise, it's a mission. Boker's dedicates every department to the task, and the personal commitment of every Boker's employee. The goal of our Quality Assurance process is to certify that all component parts manufactured by Boker's comply with all specifications and standards prescribed by our customers.

Customer service and order processing

- Boker's specializes in short, medium, and long run orders with refined production and order handling processes shaped over decades of service to provide the fastest delivery. Orders require a minimum production run of 100 pieces, however deliveries of lesser quantities can be arranged.
- Boker's also has the production capacity and enhanced technology to manufacture high-volume stamping runs quickly, well into the millions. This includes runs of precision stampings in both commonly specified and hard-to-find materials such as low carbon sheet steel, a variety of spring steels and stainless steels, aluminum, brass, copper and nickel silver, and many non-metallic materials such as ABS, acetal, polyester, nylon, MD nylon, polycarbonate, fiber, polyethylene and NEMA-grade phenolics.
- Flexibility is assured with "Dock-To-Stock" and "Just-In-Time" programs.
- The experience of our team ensures that you're getting the best precision stamped component parts for your application. In this capacity, Boker's has several individuals whose knowledge in the industry is second-to-none, and whose dedication to helping meet your custom stamping needs is unparalleled.
- To ensure efficient and timely completion of your custom stamping or washer order, Boker's Production Control department constantly optimizes our workflow to complete orders ahead of schedule.
- While no inventory of stampings or washers is maintained at Boker's, quick turnaround is our standard practice. When necessary, your order may be expedited for even faster delivery.
- Experience and industry reputation
- In business since 1919, Boker's is recognized as both a pioneer and an industry leader in metal stamping for generations. Today, Boker's is still a privately-held, family-owned and operated business in its fifth generation.
- Boker's is a woman-owned company dedicated to consistently meeting or exceeding quality objectives, on-time delivery and customer service expectations through continuous process improvements, trained and engaged employees, and cost-effective processes.

APPENDIX

Glossary of Precision Metal Stamping Terms*

Bar Coding	Machine readable alphabetic and/or numeric information used for identification of packaged parts.
Barrel Tumbling	Process in which parts to be deburred are put together with abrasive material into a barrel and rotated for prolonged periods for the purpose of burr removal.
Bend Radius	Inside radius.
Bend Relief	Clearance notch at the bend line to allow bending without distorting or tearing adjacent material.
Bending	Generally applied to forming. Creation of a formed feature by angular displacement of a sheet metal workpiece. See also "Drawing" and "Forming."
Blank	(1) Sheet metal stock from which a product is to be made. (2) Workpiece resulting from blanking operation.
Blanking	Die cutting of the outside shape of a part.
Bow Distortion	Out of flatness condition in sheet material commonly known as "Oil Canning" in which, with the edges of the sheet restrained, the center of the sheet can be popped back and forth but cannot be flattened without specialized equipment.
Breakout	Fractured portion of the cross-section of a cut edge of stock. A condition naturally occurring during shearing, blanking, punching and other cutting operations.
Burn Mark	Heat discoloration created in the contact area of a welding electrode.
Burr	Raised, sharp edge inherent in cutting operations such as shearing, blanking, punching and drilling.
Burr Direction	Side of the stock on which burrs appear.
Burr-Free	Edge without sharp protrusions.
Burr Height	Height to which burr is raised beyond the surface of the material.
Burr Rollover	Condition of burr displacement resulting from mechanical deburring operation.
Chain Dimensioning	Drafting practice which dimensions repetitive features from each other rather than a common datum.
Clamp Marks	Slight indentations at the edge of one side of stock caused by pressure from turret press holding devices.
Coining	Compressive metal flowing action.
Compound Die	Tool used to pierce, form and blank a part at the same time, with one stroke of the press.

Concentricity	Dimensional relationship of 2 or more items sharing a common center line.
Corner	Three surfaces meeting at one point.
Corner Radius	Outside radius.
Counterboring	Machining or coining operation to generate a cylindrical flat-bottomed hole.
Countersinking	Machining or coining operation to generate a conical angle on a hole.
Cumulative Tolerance	Progressive accumulation of tolerances resulting from multiple operations or assembly of multiple parts.
Datums	Theoretically exact planes, lines or points from which other features are located on design drawings.
Deburr	To remove the sharp, knife-like edge from parts.
Dedicated Tooling	Commonly referred to as "hard tooling"— is tooling made to produce a specific part.
Die	Tool with a void or cavity which is precisely fitted to a "Punch" used to shear or form sheet metal parts.
Die Clearance	Amount of space between the punch and die opening.
Die Marks	Scratches, scrub marks, indentations, galling or burnishing of sheet metal workpieces by tooling.
Drawing	(1) Engineering document depicting a part or assembly. (2) In metal forming, the stretching or compressing of a sheet metal part into a die by a punch to create a 3-dimensional part. See also, "Bending".
Ductility	Ability of a material to be bent or otherwise formed without fracture.
Edge Bulge	Condition resulting from any forming, piercing, hardware insertion or spot welding operation too close to an edge.
Edge-to-Feature	A dimension between the edge of the part and a feature.
Feature-to-Feature	Dimension between two features on a part.
Fixture	Tooling designed to locate and hold components in position.
Flange	Formed projection or rim of a part generally used for stiffness or assembly.
Flat or Matte	Coating surface which displays no gloss when observed at any angle; a perfectly diffused reflecting surface.
Formed Tab	Small flange bent at an angle from the body of a metal workpiece.
Forming	Operation converting a flat sheet metal workpiece into a three dimensional part. See, also "Bending" and "Drawing".
Gauge	(1) Instrument for measuring, testing, or registering. (2) Numeric scale for metal thickness.

Go/No-Go Gauge	Measuring device with two registration elements which determine if a feature to be measured is between two established limits.
Gouge	Surface imperfection, deeper than a scratch, often with raised edges.
Grain Direction	(1) Crystalline orientation of material in the direction of mill rolling. (2) Orientation of a surface finish generated by abrasive method.
Grinding	Process of removing material by abrasion.
Half Shearing	Partial penetration piercing, creating a locating button with a height of about 1/2 material thickness.
Hard Tooling	Tooling made for a specific part. Also called "dedicated tooling".
Hem (Dutch Bend)	Edge of material doubled over onto itself for the purpose of safe handling or to increase edge stiffness.
Hold-Down Marks	Slight indentations or scuff marks on one side of the stock which can result from the pressure of hold down devices during shearing operations.
Hole Rollover	Rounding of the top edge of a pierced feature caused by the ductility of the metal, which flows in the direction of the applied force.
Hole-to-Form	Distance from the centerline of a hole to the inside edge of a formed feature.
Hole-to-Hole	Dimension between the centers of holes.
Hydraulic Press	Machine which exerts working pressure by hydraulic means.
Inspection Criteria	Characteristics by which the part will be evaluated both dimensionally and cosmetically.
Lead Time	Time required to manufacture a product from order placement until shipment.
Master Die	Universal tool receptacle for holding changeable tool systems.
Metal Thinning	Thickness reduction during any forming operation.
Model	Pre-production sample made with limited emphasis on tolerance to test a design concept. See, also, "Prototype".
Nesting	(1) Grouping of identical or different parts in multiples within a workpiece to conserve material. (2) In packaging, stacking of parts whose shape permits one to fit inside another. (3) Placement of a part in a tool.
Nibble Marks	Slight irregularities at the edge of the stock surface after progressive punching ("nibbling") operations in a turret press.
Notching	Operation in which the punch removes material from the edge or corner of a strip or blank.
Penetration	(1) Depth of a cutting operation before breakout occurs. (2) In welding, the depth of material through which fusion occurs.
Perpendicularity	Dimensional relationship of a part or datum located at right angles (90°) to a given feature.

Piercing	Punching of openings such as holes and slots in material.
Pinch Trim	Trimming excess material from a drawn part at the bottom of the stroke. Leaves drawn shell without an inside burr, but with an outside burr and a thinned edge.
Progressive Tool	Die using multiple stations or operations to produce a variety of options. Can incorporate piercing, forming, extruding and drawing, and is usually applied to high quantity production runs.
Prototype	First part of a design which is made to test tolerance capability, tooling concepts and manufacturability.
Pull Down	Area of material next to the penetrating edge of a piercing punch, or die edge of the blanking station, where the material yields, i.e. flows in the direction of the applied force, creating a rounded edge. Also known as "roll-over".
Punch Press	Machine supplying compression force for reshaping materials.
Punch Side	Opposite side from burr side for pierced features; side on which the punch enters the material.
Quick Change Inserts	Tool sections or parts which may be changed without removing the entire tool from the press.
Rerolling	Final cold rolling operation, usually done to achieve specific thickness control and improved finish.
Roundness	Extent to which a feature is circular.
Run Out Flange	Feature on a formed part which is designated by the designer to absorb the tolerance accumulations created by multiple forming operations.
Scrap	Leftover, unused material relegated to recycling.
Shear-to-Feature	Shearing of an edge of stock to an exact dimension from an already existing feature.
Shearing	Cutting force applied perpendicular to material causing the material to yield and break.
Shut Height	Clearance in a press between ram and bed with ram down and adjustment up.
Slide Forming	A high-volume stamping process in which a machine with multiple slides sequentially performs various operations (i.e. blanking, piercing, forming, etc.).
Slug	Scrap from a piercing operation.
Slug Marks	Surface defects caused by scrap being indented into the metal surface.
Spot Face	Circular flat surface as a bearing or electrical contact for hardware.
Squareness	Measure of perpendicularity of adjacent edges or surfaces.
Spring Back	Partial rebounding of formed material caused by its elasticity.

Staking	Method of fastening using displaced material for retention.
Stiffening Rib	Embossed feature in a sheet metal workpiece which is added to make the part more rigid.
Stretcher Leveled	A flattening process in which a material is stretched to achieve a desired flatness tolerance.
Stripper	Mechanical hold-down device applied to the workpiece during the punching process.
Stripper Marks	Imprints on one side of the stock around pierced holes, caused by punch strippers.
Stripping	Process of disengaging tooling from the workpiece.
Strips	Sheet material, sheared into narrow long pieces.
Stroke	RAM travel from top dead center (TDC) to bottom dead center (BDC).
Tapping	Operation to create internal threads by either cutting or forming.
Tolerance	Permissible variation from a specification for any characteristic of the product.
Transfer Die	Variation of a progressive die where the part is transferred from station to station by a mechanical system. Mainly used where the part has to be free from the strip to allow operations to be performed in a free state.
Turret Press	Automated punch press indexing the material and selecting the intended tool out of the rotary tool holding device (turret) totally by computer control for piercing, blanking and forming workpieces as programmed.
V Die	Tool used in conjunction with a V punch.
V Punch	V-shaped tool used for angle forming.
Vibratory Finishing	Burr removal process in which an appropriate number of parts, depending on part size and abrasive material, is accelerated and decelerated by mechanical means inside of a drum-like enclosure.
Webs	Material between two openings or edges.
Wipe Die	Forming tool using two opposing edges, separated by one material thickness, moving past each other to form material.

Acknowledgments

Some content inspired by the "SLS Manual of the Small Lot Stamping Institute";
now the Precision Metalforming Association | www.pma.org

Glossary of terms courtesy of the Precision Metalforming Association