

COLD FORMING STAINLESS STEEL BAR AND WIRE

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Design Versatility of Stainless Steels



Probably the most significant characteristic of stainless steels, from the design viewpoint, is versatility. This unique family of corrosion-resistant metals has few limitations to restrict the free flow of fresh ideas from design drawing boards. For example, consider the following:

Stainless steels resist rusting and corrosive attack in a broad range of environments, from benign rural atmospheres to harshly aggressive, hot acid solutions. The selection of the right stainless steel type for a specific end-use requirement can be made from a wide variety of standard AISI grades or from numerous proprietary alloys.

Stainless steels are versatile in terms of mechanical properties, with some grades, for example, having yield strengths exceeding 250,000 psi (1724 MPa). This versatility is enhanced by the fact that strength and hardness values can be altered either by heat treatment or by cold working, depending upon the stainless steel type involved.

Versatility in appearance is an important quality of stainless steels. In lustrous elegance, stainless flatware and tableware grace fashionable dining tables; shining sculptures are bright focal points at museums, office building courtyards, and neighbourhood shopping malls; and architectural components, in a variety of surface finishes, add lasting beauty and character to many a structure.

On the other hand, stainless steels are used throughout industry for other applications in which function rather than appearance is of primary concern such as coal-handling conveyors, steam generators in nuclear power plants, pipe, pumps and valves in petroleum refining and for pressure vessels in chemical processing.

The product forms in which stainless steels are available provide designers with a multiplicity of sizes and shapes from which to choose. These include sheet, strip, plate, bar, wire, rod, tubing, pipe, and extrusions or other special shapes.

Versatility is also reflected in the fabricability of stainless steels, which is the ability to be made into finished products by any of the manufacturing techniques in common use.

Cold forming is one method used in the manufacture of stainless steel products, which is performed without the necessity of heating the work piece beyond the recrystallization temperature. Cold forming embraces several metalworking techniques, including brake forming or roll forming of sheet and strip, and heading, extrusion, or thread rolling of bar and wire. This publication deals with the last three methods, with emphasis on cold heading.

Cold Forming – The Processes

If cold forming of products from bar and wire is justified on the basis of volume, size, and material, the cold forming processes offer substantial advantages over methods such as hot forging or machining. The advantages can be expressed in terms of

Materials Savings—Cold forming minimizes waste. Cold heading, for example, which is one method for cold forming wire, can keep waste to less than 10-20%, whereas a similar machined part might result in scrap losses of up to 65%.

Increased Production Rates—Parts cold formed by heading can be produced at rates about 10 times faster than machining. Modern cold heading machines, for instance, turn out 35,000 or more pieces per hour, depending on part complexity.



Hospital equipment—Type 430

Enhanced Material Properties—Cold forming improves the strength and other mechanical properties of the stainless steels, especially the chromium-nickel 300 Series stainless steels. From the design standpoint, this means that the designer can create a smaller, lighter weight part without sacrificing strength, or he can utilize the advantages of a stronger component elsewhere in his product design.

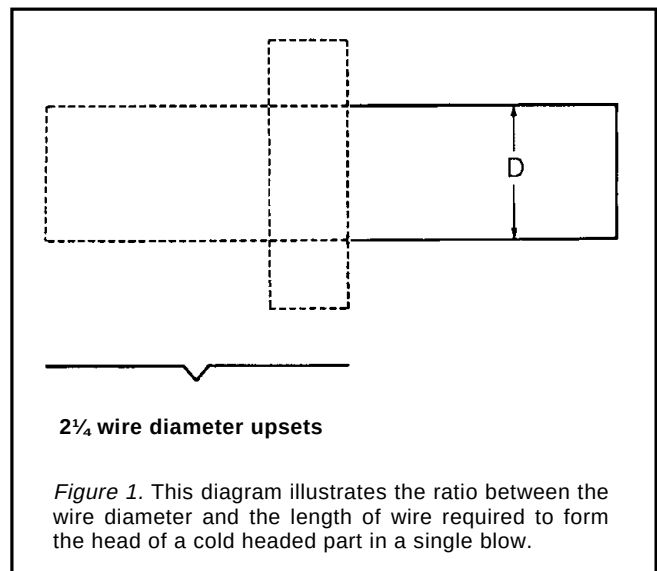
Good Surface Finishes—Cold forming offers good surface finishes and dimensional accuracies. Parts can be complete and in many instances ready to use as they come from the cold forming equipment.

Favourable Economics—When volume justifies its use, cold forming provides an economical edge over other methods. This edge is further enhanced when the design uses the inherent characteristics of stainless steels—corrosion resistance, strength, durability, attractiveness, low maintenance, etc.—to the fullest extent.

Cold Heading

One of the more important cold forming techniques is cold heading.

Basically, it is the reshaping of unheated metal by striking blows on a length of wire inserted in a die. The force of the blow (or blows, as the case may be) creates enough pressure to cause the metal to flow outward unrestricted into a die cavity. The head, or *upset* portion of the part, generally is larger in diameter than the original blank, and the length has been decreased. Generally speaking, normal cold heading permits upsets of about $2\frac{1}{4}$ times the diameter of the wire in a single blow, as diagrammed in Figure 1. Improved techniques and minor tooling changes can increase this ratio to a limited extent, as shown in Figures 2 and 3.



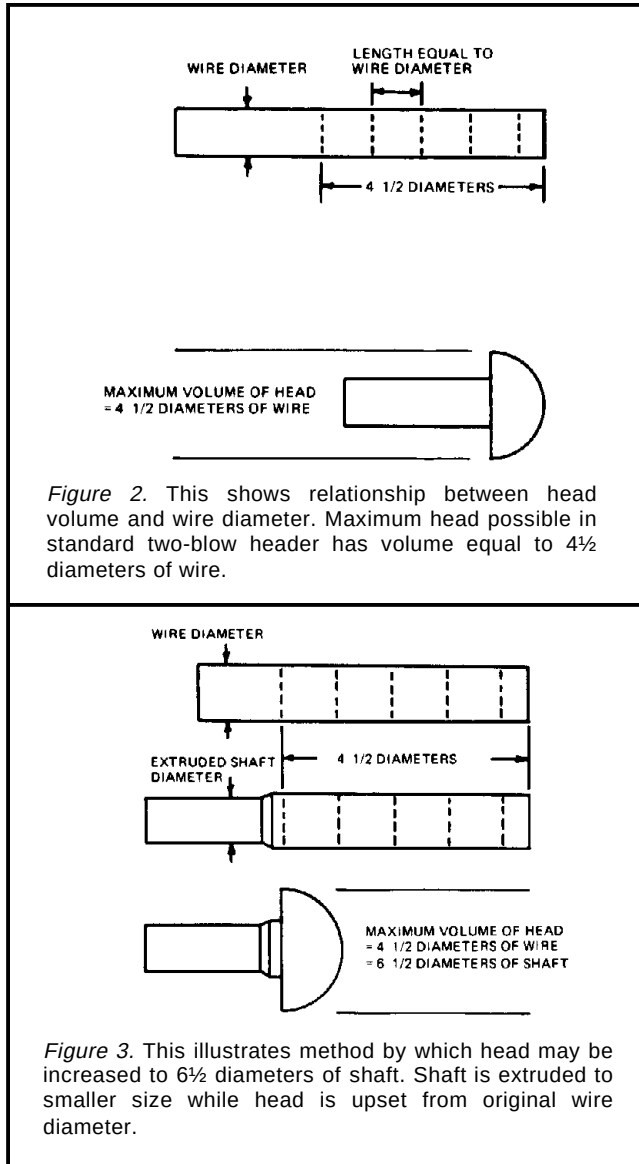


Figure 2. This shows relationship between head volume and wire diameter. Maximum head possible in standard two-blow header has volume equal to $4 \frac{1}{2}$ diameters of wire.

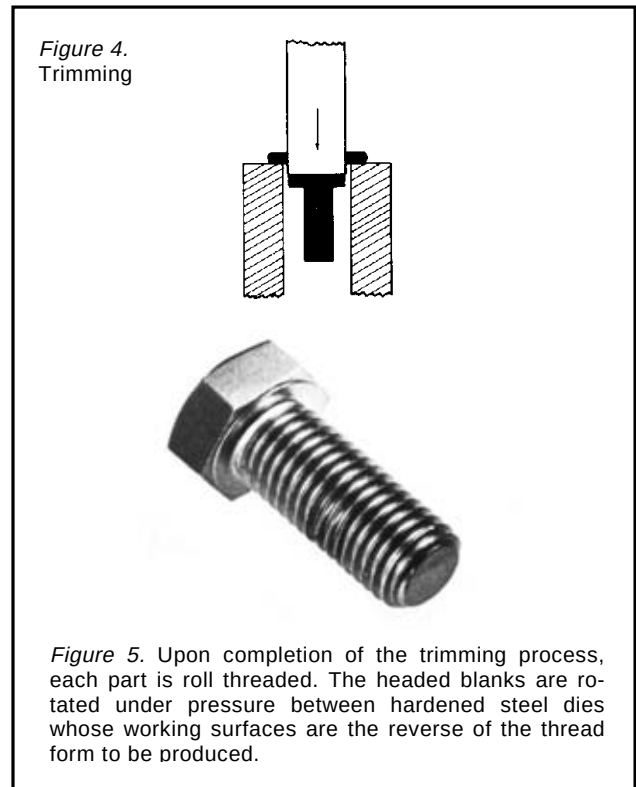
Figure 3. This illustrates method by which head may be increased to $6 \frac{1}{2}$ diameters of shaft. Shaft is extruded to smaller size while head is upset from original wire diameter.

For more complex shapes, multiple blows may be struck, with the blank moving through a sequence of dies. The high production rates and "no chips" concept of cold heading led to its becoming the principal process for producing nuts, bolts, screws, rivets, and other fasteners, a position cold heading has enjoyed for about 100 years.

More complex shapes also can be made, including some that are not in the fastener or shaft categories, such as spark plug shells. Additional operations enhance cold heading versatility: trimming, piercing, extrusion, and warm heading.

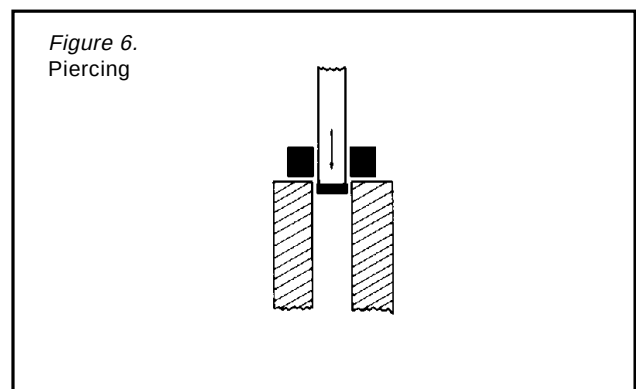
Trimming

For parts having other than round heads, an additional heading operation called trimming (Figure 4) is performed. A typical application is cold forming hex-head cap screws, such as the one shown in Figure 5.



Piercing

A final operation in the heading sequence for making nuts is piercing (Figure 6) in which the hole is punched out as a step prior to threading.



Extrusion

Extrusion, as it applies to cold heading, is the forcing of the metal into a die smaller in diameter than that of the original wire stock, which increases its length, as illustrated in Figure 7. This is an efficient and highly economical method for creating two or more diameters in the part being formed. Also, increasing the ratio of head-to-shank size beyond the normal cold heading capability is possible, as shown in the examples in Figures 8 and 9.

Figure 7.
Forward Extrusion

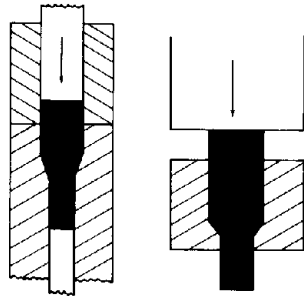


Figure 8. Shank of this part was extruded, and the head upset, to produce the exaggerated head to shank



Figure 9. The shoulder on this part is the same size as the wire diameter, while the shank was extruded and the head upset.

Warm Heading

Exceptionally good results are obtained when heading stainless steels that are first heated to a temperature between 200 and 750°F (93 and 399°C). Warming decreases the work hardening character of the metal, particularly the austenitic 300 Series stainless steels, thus improving headability.



Figure 10. Indented hex head screw warm headed from Type 305 stainless steel.



Figure 11. Another warm headed fastener . . . this one a truss square shoulder bolt of Type 384 stainless. By using warm heading, less forming pressure was required on the die, resulting in increased tool life.

The result is that less pressure is required to fill the die cavity, sharper corners and shoulders are achieved, and the possibility of cracking is minimized. The accompanying illustrations in Figures 10 and 11 show examples of the improved forming made possible by warm heading techniques.



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Qualifications for Cold Heading

There are several basic conditions that justify cold heading:

Volume—In general, cold heading jobs run in excess of 5,000 pieces, most often over 25,000 pieces for economical production. The actual quantities are predicated in part by the relative complexities of header dies and the type material being formed.

Sizes—The largest size stainless steel slug that can be cold formed on standard one- or two-blow headers is about 1 inch (25.4 mm) in diameter, with a $\frac{3}{4}$ inch (19.05 mm) shank diameter.

Material—Various AISI stainless steel types especially suited to cold heading operations are available, such as AISI Types UNS-S30430*, 305, and 384, which are discussed in greater detail beginning on page 14. Other stainless steels are also available as cold heading wire, among them including Types 303, 410, 430, 440C, UNS-S17400, and a number of proprietary stainless steels.

*Type UNS-S30430 is a copper-bearing stainless steel often referred to as Alloy 302 HQ, which is a proprietary trade name. Type UNS-S30430 is described on page 17.



Disc spindle for water meter (formerly screw machined)—
Type S30430



Type AB self-tapping screw—
Type 410



Dishwasher pump blade screw—
Type 430



Cold heading Design Considerations

Before discussing the specifics of designing a product to be cold headed, a brief review of cold heading equipment is appropriate.

Single-Blow Headers—Although seldom used now, single-blow headers are the simplest and fastest. They can produce hundreds of pieces per minute but are limited to minor shank extrusion and simple head shapes. In single-stroke machines, wire is sheared to length, transferred to a die, struck one blow, and ejected. Single-blow headers are adequate when head diameters or volume is relatively small, and the material lends itself easily to upsetting. The straight-chromium stainless steels, such as Types 410 and 430 are quite often processed on such machines. (Figure 12).

Double-Blow Headers—The most commonly used cold heading machine for the chromium-nickel stainless steels such as Types UNS-S30430, 304, 384, and 305 is the double-stroke header.

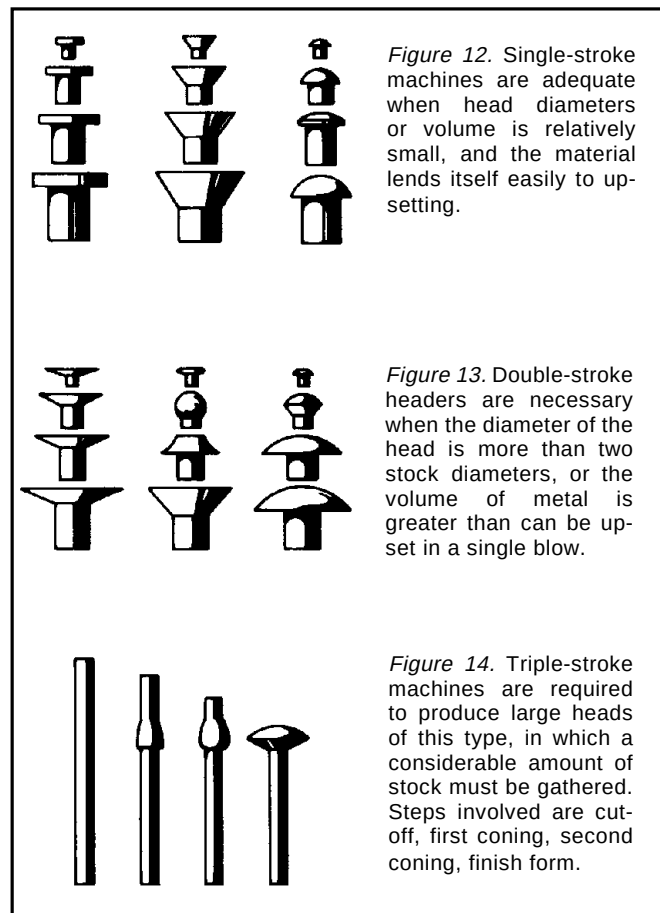


Figure 12. Single-stroke machines are adequate when head diameters or volume is relatively small, and the material lends itself easily to upsetting.

Figure 13. Double-stroke headers are necessary when the diameter of the head is more than two stock diameters, or the volume of metal is greater than can be upset in a single blow.

Figure 14. Triple-stroke machines are required to produce large heads of this type, in which a considerable amount of stock must be gathered. Steps involved are cut-off, first coning, second coning, finish form.



When two blows are used to form the shape, the first punch starts the metal flow in a given direction so the desired shape can be completed with the second blow, as shown in Figure 13. The punches oscillate between blows to one die so that a finished part is produced with every other stroke.

Multiple-Die Machines—Where additional strokes are required for more intricate contours, multi-station or progressive headers are used. On such machines, parts are mechanically transferred from one die to the next, and all stations work simultaneously so that a part is finished and ejected at each stroke. These machines may have as many as six stations or dies. (Figure 14).