Where Does Cold Heading Wire & Rod Come From?

— Part 3: Wire Processing

by:
Laurence Claus, President
NNI Training and Consulting Inc.
14645 Old Rockland Road
Green Oaks, IL 60048
www.NNITraining.com

In recent years, there has been a strong resurgence of interest in the wine and spirits industry. One of the advantageous traits of many wines and other spirits is their ability, or in some cases necessity, to age in the bottle or a wooden barrel. This "aging" time transforms the wine or spirit from a drink that may be initially quite nondescript or even "nasty" to one that is of fine quality and enjoyed by the consuming practitioner.

In much the same way, hot rolled rod looks to all but the trained eye like a product ready to go into a cold header and be made into bolts. Like wine though, at this stage looks can be deceiving and a variety of unpleasant surprises may be in store for fastener manufacturers that would consider using hot rolled rod straight from the mill. This is why most companies turn to wire finishers to transform the hot rolled rod into a more usable or quality product. In this final installment of a three-part series about where cold heading wire and rod comes from, we will explore the details of wire and rod finishing and see what it takes to complete the material's journey to the cold header.

First let's briefly review the process to this point. In the first part of this series, steel making, we learned how iron and recycled steel are melted, refined and continuously cast into an intermediate product, most often steel billets. In the second part, hot rolling, we learned how these billets are transformed in the hot rolling mill to coiled steel rod and bar. In the third part, we will now explore the final phase of transformation, size, strength and surface conditioning.

Wire processors fall into two general categories, those that are an integral part of the mill and those that simply purchase and finish hot rolled rod. The first category consists of a couple of major players who have the capability and resources to melt, hot roll and finish all in one integrated or several satellite facilities. The second category contains companies that simply purchase hot rolled product from a mill and then finish it themselves. Most cold headers will source their purchasing from some combination of both types of companies or distributors who purchase from both types of companies.

When material is finished in hot rolling mills, it looks like cold heading material, but has three significant issues that likely require attention. These are size variation, surface condition and mechanical performance.

Size Control:

Rod off the hot rolling mill may look to the casual observer like it is round, but closer inspection would reveal that both its dimensional consistency and roundness are not particularly good. **Table 1** shows the allowable size tolerances for hot rolled rod and bar per *ASTM F2282*. Taking rod as an example, one can see that it may vary ±0.012" in diameter size and have a maximum 0.018" out-of-roundness. By comparison, depending on its size, cold drawn wire ranges in size tolerance from ±0.001" to 0.002" and maximum 0.001" to 0.002" out-of round (see **Table 2**). The process of cold drawing the hot rolled rod through precision tooling nets an almost ten-fold improvement in size variation. To the cold heading process, which fundamentally relies on volume control, this reduction in the resulting blank size variation can have a dramatically positive impact.

Table 1. Rod and Bar Tolerances.

Type	Diameter	Size Tolerance (in)	Out of Round (max) (in)
Rod	7/32 (0.219)-47/64 (0.734)	+/- 0.012	0.018
Bar	7/16 (0.438)- 5/8 (0.625)	+/- 0.006	0.009
Bar	>5/8 (0.625)- 7/8 (0.875)	+/- 0.007	0.011
Bar	>7/8 (0.875)-1.0	+/- 0.008	0.012
Bar	>1.0- 1 1/8 (1.125)	+/- 0.009	0.014
Bar	>1 1/8 (1.125)- 1 ¼ (1.250)	+/-0.010	0.015
Bar	>1 ¼ (1.250)- 1 3/8 (1.375)	+/-0.011	0.017
Bar	>1 3/8 (1.375)- 1 ½ (1.50)	+/- 0.013	0.020

Table 2. Wire Tolerances.

Type	Diameter (in)	Size Tolerance (in)	Out of Round (max) (in)
Wire	<0.076	+/- 0.001	0.001
Wire	0.076<0.500	+/- 0.0015	0.0015
Wire	>=0.500	+/- 0.0020	0.0020

This is accomplished by cold drawing the rod through precision draw dies. In many cases, the desired draw can be accomplished in one pass and utilizes the most basic drawing equipment, a one-hole wire drawer. This is basically accomplished by spooling the wire on a rotating capstan, which provides the necessary drawing power to pull the wire through the die. When wire must be reduced to smaller diameters than one pass will allow, the wire may be formed by cold working the wire through multiple drawing passes. This may be done through multiple iterations on a one-hole wire drawer or by utilizing a multiple-hole drawer. A multiple- hole drawer works in exactly the same manner as a one-hole drawer except that there are multiple capstans and drawing boxes arranged in series so that the wire can move from one to the next and be progressively reduced in size. The draw dies are closely monitored and maintained as they directly impact the precision of the wire size and geometry.

Performance:

Most cold heading raw material is desired in its most workable and predictable state. For steels, that is in the spheroidized annealed condition. Annealing processes are designed to improve the material's ability to plastically deform without fracturing, or more simply stated to make it more ductile and to improve its forming capabilities. In spheroidized annealing, coils remain in the annealing furnace for prolonged periods of time just below the critical eutectoid temperature producing a uniform microstructure of spheroidized cementite. This microstructure provides the best formability possible, which makes it especially attractive for cold heading.

Wire coils can be annealed in continuous furnaces that are capable of moving the coils from one end to the other along a mesh belt, although because of the time needed for spheroidization, the more common practice is to anneal in batch furnaces where multiple coils of material are processed at one time. In both cases, the furnace atmosphere is protected so that the wire or rod is not decarburized.

Although not common with carbon and alloy steel wire and rod, some nonferrous materials are often strain hardened prior to cold heading. There can be a number of reasons for this practice. Take for example, A286 (iron-nickel-based alloy), to maximize the mechanical strength that can be achieved in finish parts, it is a common practice to purchase prestrained wire and combine it with solution hardening and aging to achieve the final part strength requirements. In other cases, very low-strength materials like aluminum and some brasses, form much better when the raw material possesses some stiffness. In these cases, it is not uncommon to purchase prestrained wire in perhaps the ½ hard condition. Therefore, in some instances the wire finisher is drawing the rod or wire not only for size, but to establish a specified "prestrained" or tensile strength condition.

Surface Condition:

Perhaps the most important function performed by the wire finisher is improving the surface condition. Because of the rigorous treatment that cold headed parts endure during forming, the conditions on the surface are critical. During the hot rolling process, the rod will generally form some scale on the surface. Depending on length of time and conditions in storage, the rod may also have a build-up of oxides and dirt. These conditions would be very deleterious to cold heading wreaking havoc on the cold heading tooling. For this reason, the coils are cleaned, perhaps several times in the process, but always after arriving from hot rolling. In particular it is critical to remove any scale or oxides that have formed on the wire surface.

Some industries demand excellent surface conditions, free of defects and decarburization. These wires are usually referred to as "seam and decarb free" or "aerospace quality". There are several ways to achieve this condition, but all require material removal. Perhaps the most common method is to "shave" the wire which entails passing the wire through a rotating knife, which machines (or shaves) away the desired thickness of stock. Passing the wire past grinding heads is another method. The final method is known as "peeling" where the wire is drawn through what amounts to a draw die turned backwards. The sharp interface with the tool shears (or peels) away the desired amount of material. Although "shaved" wire provides a superior surface to regular wire, it comes at a steep price premium. For this reason there are many industries that never use it.

In addition to cleaning the wire, one of the most important functions provided in finishing is to coat the wire. This is very important because the high pressure exerted by the parts in the tooling during cold heading would, if unassisted, quickly gall and break the tools down. Coating however, provides lubricity to prevent this from happening. Today there are many different coating options available. However, most cold headers tend to have formed their own preferences years ago on what works best for them, and generally don't experiment much with other techniques. On steel wire, the coating is almost always zinc phosphate with some form of topcoat treatment. The three most common scenarios are phos and lube, phos and lime and phos and polymer. Of these three, phos and lube is probably favored by the highest percentage of cold headers for its cost effectiveness and because it is cleaner than phos and lime. Coatings become even more critical when heading some of the more difficult-to-form materials such as stainless steels, nickel alloys or steel parts with extreme upsets or extrusions.

Wire & Rod Processing Conditions:

Every manufacturer has a mixture of different parts with different needs. The manufacture of some parts may only be feasible with wire or rod processed in a certain way. Therefore, a manufacturer may purchase and use wire or rod in several different process conditions. **Table 3** shows the more common conditions that cold heading steel wire and rod may be purchased in.

Table 3. Common CHQ Processing Conditions.

Process Condition	SAIP	DFSAR	SAFS	DD	CC
Key	Spheroidized Annealed In-Process	Drawn from Spheroidized Annealed Rod	Spheroidized Annealed at Finish Size	Direct Drawn Wire	Clean Coat Rod
Starting Point	Hot Rolled Rod	Hot Rolled Rod	Hot Rolled Rod	Hot Rolled Rod	Hot Rolled Rod
Process 1	Clean	Clean	Clean	Clean	Clean
Process 2	Coat	Coat	Coat	Coat	Coat
Process 3	Draw	Anneal	Draw	Draw	
Process 4	Anneal	Clean	Anneal		
Process 5	Clean	Coat	Clean		
Process 6	Coat	Draw	Coat		
Process 7	Draw				

Naturally, as the processor adds more steps, the coil takes on a more premium designation and the cost goes up. Most North American fastener manufacturers likely purchase and use SAFS or SAIP. However, each of the five categories shown in **Table 3** has a market and purpose.

Storage & Handling:

Ironically, today mills and finishers take great care to handle and store coils of material carefully only to have their customers handle them poorly. Any surface damage as a result of poor handling practices can become a problem once that damaged area is exposed to the rigors of cold heading. Therefore, careful handling and prudent storage practices throughout the entire production chain will likely be a practice with significant payback.

It is common to have the mill or finisher take extra care in packaging. This may include wrapping the coil in a plastic or paper covering, placing protectors underneath the bands to eliminate band-on-coil contact, placing cardboard or plastic rings between the coil and the base of the carrier and to place plastic or cardboard protectors on the carrier uprights to prevent coil contact.

Besides protecting the coil itself, users should employ prudent and practical handling and storage practices. Finished wire coils should never be stored outside or in a location where they might be exposed to a corrosive or wet environment. Although this is a common practice to save space, coils should not be stacked on one another. This practice has a number of pitfalls, but primarily exposes the lower coils to potential contamination and damage from the upper coil carriers. Designated areas with rubber or other padding on the ground should be employed when coils are stored off of carriers. Finally, care should be taken in moving coils from one location to another so that they are not bumped, dragged or contacted with the forks on a lift truck.

As has been illustrated in this three-part series, bringing high-quality cold heading quality materials to the manufacturer is no small undertaking. There are many steps that occur between the introduction of a steel/iron source to a melt furnace all the way at the beginning until the final wire and rod processing is done. For many reasons, it is wise for the user to understand these processes and how they interrelate with the cold heading process. Armed with this understanding, the user can better customize the process and react when material-related problems in forming arise. *www.NNITraining.com* FTI

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NNI Training and Consulting Inc. *is a dynamic, entrepreneurial 'knowledge provider' offering training/consulting services to small and medium-sized firms. NNI's specific expertise is in cold heading, fasteners, fastener and application engineering, and automotive, industrial and aerospace parts supply. NNI provides training based on a strong foundation of theoretical knowledge, combined with practical understanding and applied skills. NNI provides consulting services on fasteners, fastener engineering and fastener quality; quality management systems and certifications; and business and sales development and strategy.* ***www.NNITraining.com***