How Cold Headed Parts are Made
The Operations and the Tools Used to Do It
冷鍛頭零件製造概論—相關程序及使用工具

by Laurence Claus

I was twenty years old and taking a tour for the first time of the cold heading factory that would become my world for the next twenty-six years. I was enthralled by the activity going on all around me, the noise, the vibration, the smoke in the air, and the parts flying out of the headers like popcorn out of a popcorn popper. I vividly remember walking through the thread rolling department and simply being amazed at the thread rolling process- I had never imagined that you could put a thread onto a screw that way.

Making fasteners, especially the cold heading part of the process is an exquisite and finely tuned dance that must all come together in just the right way for success. I would learn this after hundreds of hours invested with our header and roller operators working to make new, often very challenging parts go from our customer's paper concept to three-dimensional reality. During this time with our manufacturing experts I would learn much about the process of finessing a part into production, how the process worked, and the tools that made it happen. Although my job required me to be a bridge between our production operations, the rest of our "office" staff, and our customer, so that I had to learn these things, I was surprised by the lack of others showing the same interest in learning how the product was made. I don't think that has changed much and I must sadly say that it is highly likely we have many individuals in our industry that don't really understand even the basics of how a part comes together.

This article is dedicated to those individuals that have always been curious but unable to really learn how coiled wire goes into the machine on one end and comes out the other the size and shape of a nearly finished screw, bolt, or nut. This article will look at the basics of what operations we do in a cold header, the basics of how the machine works, and the tools we use to pull it all off. I am hopeful that this will be a simple enough explanation that it will help those who have always wondered how a screw, bolt, or nut is made to fill the gaps in their knowledge and really come to appreciate the engineering marvel in cold heading fasteners.

What Can We Do in Cold Heading?

How would you answer the question, "What is Cold Heading?" I often ask that in the training sessions that I do and, of course, there is always one engineer in the crowd that starts to describe it something like this, "it's a high speed adiabatic forming process where…". Although they may have a truly brilliant engineering definition, when I ask the question I am simply trying to tease out a simple explanation like we "we hit a piece of metal really hard so that it starts to take the shape defined by the tools…" And in reality, that explanation is pretty much right on target and can be understood by just about anyone.

As a metaphor, consider the child's game of playing with Playdough. Many of us may recall hours of fun spent by us or our children modelling creations from this soft clay-like material. Often the Playdough set came with a device like a garlic press that you loaded the Playdough into, pressed, and squeezed out "ropes" through a shaped hole (See **Figure 1**) or the set had little "molds" you could press the Playdough into to make new shapes and play items. By comparison, at its core the cold heading processes are not very different.

Cold heading has a number of advantages over other manufacturing techniques that we could use to make fasteners. First and foremost, it is fast. That makes it more economical and considering the sheer number of fasteners consumed every year, more practical than any of the other competing manufacturing processes, which are all much slower. Unlike machining, it has very little or no waste and parts emerge from the process stronger than the raw material that went in.


Figure 1: Play Dough Being Extruded

Clearly there are some real advantages to utilizing this process, but just what exactly can one do? Cold heading allows us to accomplish three different operations. We are able to upset, extrude, and trim or pierce parts. In fact, most parts will combine two or all three of these processes to complete the finished part. So what are these three processes?

Upsetting:

Upsetting is pretty much what cold heading derives its name from. It is the process used to form a head on a screw or bolt. At its simplest, upsetting is a process which accumulates material into a localized area of the part, like the head or a collar. In other words, in the areas that we are upsetting the diameter is getting larger. In cold heading lingo, we talk about the "number of diameters" that we can upset. Although that might sound pretty complex, it is really a relatively simple idea. Consider the shape that every part starts in. It is simple a cylinder cut from the long, continuous coil of wire being fed into the machine. For externally threaded parts (those that will become screws and bolts), this cylinder is long compared to its diameter. It is possible, therefore, to break this cylinder up into sections where each individual section is equal in height and diameter (See **Figure 2**). Each of these sections is called a "diameter". Again, with parts that are long and skinny (bolts and screws) each starting piece of wire will be comprised of multiple diameter sections. Engineers have learned over the years that you can only squeeze (or move) a limited amount of material at one time before it begins to crack or burst. In the cold heading world, the limitation is about 2 ¼ diameters per strike. Most screw or bolt heads have more than 2 ¼ diameters of material in them, so that they must be hit more than once to achieve the desired end result. On most parts it takes at least two strikes, so that we talk about a "first upset blow" and a

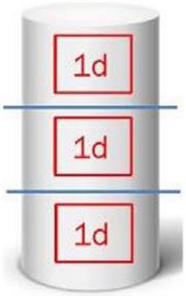

Figure 2: Pictorial Representation of the Term "Diameter"

"finish (or second) upset blow" to complete the head (See **Figure 3**). We will discuss the tooling in a little bit, but both the first and finish upset blows require different tools.

Figure 3: Example of a First and Finish Upset Blows

Extrusion:

Extruding is a general term because relative to cold heading there are three distinctly different types of extruding processes. There are two forms of forward extrusion; Open and Trapped extrusion, where the material is being pushed out in front (or forward) of the tool. The third form of extrusion is Reverse Extrusion where the material is flowing backward against the direction that the tool is moving. Let's consider each in a little greater detail.

Open Extrusion:

Open extrusion gets its name from the fact that the majority of the part is not confined by any of the tools before entering the part of the tool where the extrusion happens. This allows the extruding portion of the tool to be located near the top of the die which maximizes the length we can extrude the part. The downside is that it takes pressure to push the part through the extruding part of the tool. If we push too hard, since the part is not being supported much by the tools it will buckle resulting in a catastrophic failure of the process. Therefore, open extrusions are limited to reducing the area by no more than about 35% (See **Figure 4**).

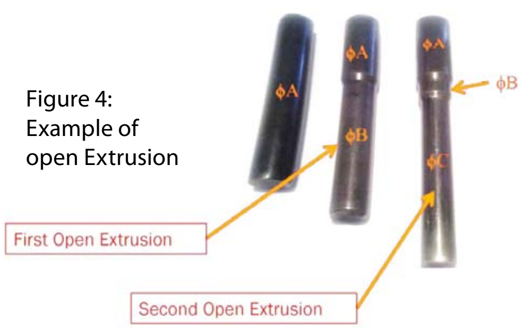

Figure 4: Example of open Extrusion

Trapped Extrusion:

Trapped extrusions are pretty much the complete opposite of an open extrusion because the part must be completely confined in the tool before it begins to get pushed through the extruding part of the tool. This confinement allows us to push much harder so that we can now reduce the diameter by about 75% (See **Figure 5**). The drawback is that much of the tool gets consumed in making room for the part before extruding so that the length of the extrusion is much shorter and more limited than what can be achieved in an open extrusion.

Figure 5: Example of Trapped Extrusion

Reverse Extrusion:

Reverse extrusion is the primary process used in forming hollow parts such as nuts or bushings. In this case a pin is pushed into the part which is confined inside the die. There is clearance between the outside diameter of the pin and the walls of the die allowing material to flow backwards up along the pin. The result is an outside form beginning to take shape and the beginning of an internal hole or channel (See **Figure 6**). Reverse extrusion is also incorporated to form internal drive recesses in screw heads.

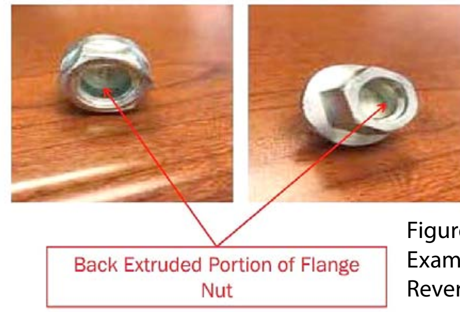

Figure 6: Example of Reverse Extrusion

The final operations that can be accomplished in cold heading are trimming and piercing. Not every part will be trimmed or pierced. In fact, the majority of externally threaded screws do not receive a trimming operation. Both trimming and piercing are shearing operations. The speed, force, and design of the tools simply shear the subject area away. For externally threaded parts, we trim and the operation is almost exclusively reserved for finishing a head or collar shape. Perhaps the most common of all trimming applications is creating a trimmed hex head.

When internally threaded parts are made, most often reverse extrusion is occurring on both sides of the part. The blank, just prior to the last station, therefore, will have holes started but not going all the way through on both sides of the part. Separating the two holes is a thin web of material. The last operation in the sequence is, therefore, a piercing operation where a pin is thrust into the hole, shearing the web, and opening the hole continuously through the part.

In both cases, whether it is an external part being trimmed or an internal part being pierced, there is a small amount of offal. This is the only scrap, however, that will be experienced in cold heading and is only a small percentage of the entire amount of material that constitutes the part. Cold heading, therefore, is not a high scrap generator.

How does the Cold Header Work?

There are many different brands and designs of cold headers, so it is impossible to describe the way that one works and proclaim that this covers every possibility. However, most cold headers operate on similar principles, so that we can have a discussion here and it is likely to be relevant to many of the machines in a cold header's shop.

Cold headers are essentially horizontal mechanical presses that feed raw material into an entry point, cut a piece off, and then transfer that piece of raw material through a series of strikes (more commonly referred to as blows) before emerging out the other side of the machine as a finished blank.

Cold headers are comprised of a stationary side that houses the "Dies" and a moving side that houses the "Punches" or "Hammers". The machine comes together to strike the part in what is called a "blow". Cold headers are defined by the number of blows that they provide. The simplest machines have one die but hit the part twice. More complicated headers can hit the part many times, although few commercial machines exceed more than six dies and blows.

Headers are classified or named by the number of dies they have and the number of blows they can inflict on the part. The simplest of machines is the one-die-two-blow (also known as a single-die-double-stroke machine). This equipment has only one die but hits the part twice. For some that description may seem sort of counter-intuitive. How can the machine only have one die but hit the part twice? In the simplest explanation, this means that the machine is designed so that the part gets struck by two separate punches while never moving out of the die. These machines are reserved for simple parts where almost all the work being done is to upset the head. The first blow creates an intermediate upset and the second (or final) blow completes the head. It is highly likely that little or nothing is actually happening in the die.

As parts get geometrically more complicated, this simple forming routine will no longer be successful and requires a machine with more dies and more opportunities to hit the parts. These upgraded machine types include two-die-three-blow machines (where the part gets hit three times) to multi-die parts formers and nut formers which may have as many as six dies in a line and hit the part six times. (Theoretically you can have an infinite number of dies in a line, but practically most commercial cold heading machine manufacturers don't produce machines beyond six dies.) The more you can strike the part, the more complicated or geometrically unique you can form parts.

What are the Basic Tools?

I have already mentioned the two primary tools used to make part, Dies and Punches. Each machine however, has a complete set of tools that can range from perhaps several dozen pieces to six station parts formers with several hundred tools. Let's look at the primary components:

Cut-off Tools: Every cold header has to have a way to measure out and cut-off a piece of the continuous wire coil. The method of getting wire into the cold header and actually cutting it off will vary from brand to brand. In the end though, once it gets into the machine, they all will have a cut-off knife which strikes the wire from a transverse direction shearing a piece off. This system is usually comprised of a number of parts besides just the cut-off knife.

Dies: Dies are larger than the punches because they must withstand greater loading. Dies are located on the stationary side of the cold header. Each die is actually an assembly of a few to many pieces. The working tool is usually made in segments so that there are three or four separate segments that make up the working part of the die. These are all pressed under great pressure into a much larger diameter cylindrical canister called the "casing". The inserts (working part of the die) are under extreme radial pressure with each blow. If they did not have some form of support they would quickly burst and fail. For this reason they are pressed into the casing, which is much larger and able to absorb and disperse the forming pressure providing integrity to the die for many thousands of parts (cycles). In fact, die casings can be used multiple times before they need to be retired.

All dies will have a hole central to the axis of the tool into which the part is pressed. Because of the extreme pressure being exerted on the parts, what prevents them from shooting right through the die and out the back of the machine? This is where the "knock-out pin" system comes in. There are a series of pins located at the rear of the die that perform two functions. First during the forming portion of the stroke, they prevent the part from being pushed out the back of the die. Secondly, at the end of the forming stroke, these pins are thrust forward pushing the part out of the die.

Punches: Punches are located on the moving side of the machine. The punches are smaller than the dies as they experience less pressure during the forming process. To prevent leaving the wrong impression, however, they, too, experience heavy loading and must also be contained inside punch casings. The punches usually define the shape of the head for screws where one punch will be the first blow and the second punch the final blow. They may also just support a pin that pushes the part into the die, especially in instances where the dies are facilitating open or trapped extrusions or recess pins that facilitate backward extrusion to form the drive recess in parts.

Transfer: The final tool/system that bears some discussion is the transfer mechanism. This is pretty simple on a one-die-two-blow machine, where the only transfer necessary is the sheared cut-off to the die. However, once you start stepping up to more and more dies in a multidie header, the transfer mechanism becomes an important component. The tooling piece of the transfer is usually just the "fingers" or the grips that actually grab and hold onto the parts as they move from one die to the other. These fingers are usually custom made for every part.

Transferring parts is a real art, especially as part geometry begins to play a factor. As parts begin to get top heavy from the upset head and occasionally a large shoulder, gravity takes hold and they begin to want to droop as they come out of the die. The operator, therefore, has to get the transfer timed just right so that it grabs and holds the part before it fully exits the die but doesn't begin to actually move the part until the part is fully clear of the die. It's a well-timed "dance" that often requires hours of experience and practice by the set-up technician to really hone the skill.

Recent Innovation

Like most things, cold heading machines are constantly being improved and getting better. Two tool related innovations that continue to evolve are:

1. Segmented Tooling: this is tooling that has been cut into segments and spring loaded so that the die can open up allowing parts with double collars or wasted shanks to be formed net shape and exit the die. It is impossible to form parts with this type of geometry in traditional tooling because they are unable to exit the die. There is significant interest in this innovation because it may allow the manufacturer to eliminate an expensive and time consuming secondary operation. Although quite interesting, this technology is not suited to everyday every cold header or every part. When employed the tooling is significantly complicated relative to traditional tooling and the expense of the tooling package rises dramatically.
2. Better Cut-offs: Much improvement has gone into the wire feeding and cut-off mechanisms of many machines providing wire cut-offs that are more square and tighter in tolerance. This is a real advantage because the more tightly controlled the volume is the better the end part. Additionally, the more square the ends the better condition the ends of the final part will be.

Conclusion:

Cold Heading is a unique and exceptional manufacturing process. Few people who have ever just stood for the first time next to a header and marveled at how it runs really have an appreciation for all the variables and intricacies that go into the tooling, set-up, and machine timing to arrive at a successful finish. The next time you stand next to a header I hope you can now better appreciate what a finely tuned process it really is.