Thread Rolling Machines

by Laurence Claus

I started my career in the fastener industry between my third and fourth year of university. Although it's been thirty-four years now, I can remember almost like yesterday the first time I got to walk around a fastener manufacturing plant. Of course we started in the heading department and seeing headers paying off wire and spitting out parts was very exciting, but it was the rolling operation that really left a lasting impression on me. I guess it was because the operation was so very different than what I anticipated. Up to that point the only method I knew for developing threads on parts was to use a die set and cut each thread. In hindsight I should have realized that such a method would not be practical for the wide array of thread styles and sheer quantity of fasteners made every day, but having no experience with fasteners I didn't know any better. For this reason, I was fascinated, no actually a better description would be astounded, by the high speed rolling process used to form threads of all styles, sizes, and shapes.

These days, when I am teaching my "Fastener 101" class and get to the section on manufacturing, I like to describe the thread rolling process in these simple terms, "It is all about the number of times you can rotate the part." In other words, thread rolling is a process which moves material around rather than removes or cuts material away. Like the preceding cold heading process, for most materials this is accomplished at room temperature, and must be done in incremental steps. The materials these fasteners are made of must be moved gradually, as too much plastic strain could result in overloading and fracturing the developing threads. Therefore, only a little material should be moved at a time. To accomplish this, each time the screw fully rotates a little more of the thread is developed, so that after a number of rotations the thread is completed.

On externally threaded components rolled threads are advantageous to cut threads for several different reasons.

- Rolling threads is faster than cutting them. This article will explore several different thread forming methods, but they are all significantly faster than if the thread were being cut.
- There is generally no waste. Like cold heading, the thread rolling process moves material that was already present. Therefore, there is no waste. There are a couple of notable exceptions, where a point, such as a gimlet or piercing point, is created during the rolling process by squeezing down the tip. This results in a small "cut-off" that separates from the end and becomes scrap.
- There are no chips. Once again, with the exception of the designs where the tip is rolled off, no waste is generated so that no chips have to be separated or handled.
- The threads are stronger. Rolled threads are stronger than cut threads because the metal displacement forms a "bent" grain alignment rather than the undisturbed "straight" grain in a cut thread (See **Figure 1**). This grain alignment makes the threads stronger. To illustrate this point picture a soft clear pine wooden board with straight grain running its length. If you orient the board in the direction the grain is running, the chances are very good that bending the board from the edges can easily break it into two pieces. Now imagine that same board except there is a small, tight knot in the center. Instead of the grain running straight up and down like the prior example, the grain in this board is swirled around the knot, making a wavy and bent grain pattern. Exerting the same bending load from the side likely does not break the board as the grain orientation is now stronger against loading and more resistant to the bending load.

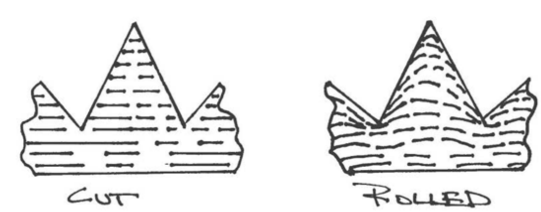

Figure 1

Rolling external threads is feasible on most fasteners when the right equipment and method are used. For very small fasteners (1mm or less in diameter) all the way up to about 25mm (1 inch), thread rolling is the predominant, if not exclusive method of developing the threads. However, once parts start to get larger than 25mm (1 inch), the size of machine and force they have to exert to form the threads begins to exponentially increase and reach a point of diminishing returns where cutting the threads may become more practical. However, since most fasteners produced globally are smaller than this inflection point, it is safe to conclude that most externally threaded fasteners possess rolled threads.

There are three different thread rolling methods; flat die thread rolling, cylindrical die thread rolling, and planetary die thread rolling. Each method has its advantages and disadvantages so that manufacturers, if they have the equipment available, can customize their manufacturing process to employ the best method for each part they make. Of course, although manufacturers have these three methods available to them, it is not uncommon for a manufacturer to only use one or two of the methods. This is largely a function of producing a narrow range of products that favor one method or simply having preferences developed over time.

Flat Die Thread Rolling:

Of the three methods, Flat Die Thread Rolling is the most predominant. This method works very well for very small parts all the way up to about 20mm (3/4 inch) in diameter. Compared with the other methods, it is relatively easy to set up and maintain. The dies are relatively inexpensive and if the set-up is done properly, the dies will last for a long time. Additionally, often the dies can be purchased with two faces. These are called "Duplex Dies" and can simply be flipped over when one side wears outs, often doubling the lifespan of the roll die.

The operation of a Flat Die Thread Rolling machine is pretty straight forward. Each die comes as a set with one die a little longer than the other. Flats dies are aptly named because they are flat plates of steel or carbide which have parallel grooves with the thread profile ground into the face of the die set at a slight incline to the long sides of the die (See **Figure 2**). This incline is the helix angle of the thread which is the feature that allows the threads to advance forward or backward. The machine is arranged so that the shorter die is placed in a stationary pocket and the longer die in a pocket on a moving ram. Unthreaded blanks are loaded into a feeder which progressively feeds parts into a rail. Parts slide down the rail until they reach an Escapement. The cycle begins with the ram extending all the way to the back of its stroke. As it begins to come forward, the Escapement opens and a Pusher Finger pushes a single blank into the gap between the stationary die and the leading edge of the moving die that is stroking forward (See **Figure 3**). If properly inserted and set-up there is pressure exerted on the blank by the two die faces and as the moving die strokes forward, the blank begins to rotate. The pressure being exerted between the die faces causes material to gently flow into the grooves in the die and begin developing the threads. With each rotation more of the thread is developed until it is complete and the part rolls off the trailing edge of the die.

Flat Die rolling allows only one part to be rolled at a time, but the machines cycle at high speeds so that production rates of several hundred parts a minute are commonplace. This method can be used on a wide variety of parts and geometric configurations, and, once again, is the most predominant method used for standard screws and bolts. This method normally requires that a head or collar be on the part to allow for feeding and loading into the die, although special feeding set-ups can be developed to feed this style of machine with headless (or collarless) products.

Figure 2

Figure 3

This equipment is most often automatically fed and loaded, although it can be hand loaded. Of course, hand loading results in much slower cycle times and less throughput. Although parts are usually threaded before heat treatment, this process works on hardened, heat treated blanks as well. Naturally die life is decreased, but thread rolling after heat treating results in parts that are more resistant to thread nicks and have significantly improved fatigue life.

To reiterate, thread rolling (or roll forming) is a first order function of the number of rotations that can be achieved. The number of rotations thus determines the length of the die and ultimately machine size. Flat Die Rollers are generally categorized by a number that is a multiple of ten. The higher the number, the larger the machine, so that a #10 roller would be used for much smaller parts than a #30 thread roller. In theory, we could keep going up in size to accommodate larger thread diameters, however, in practice few machines get larger than #60. This is most likely a practical acknowledgement that once machines get larger than this they become unwieldy and consume large footprints, so that other methods become more advantageous.

Cylindrical Die Thread Rolling:

There are two different varieties of Cylindrical Die Thread Rolling. One method uses three dies (See **Figure 4**) and one method uses two dies (See **Figure 5**). The three die method is usually reserved for smaller diameter parts and the two die version for larger diameter parts. Considering that thread rolling is a function of part rotation, the advantage of cylindrical die rolling is that, in theory, the process can be designed with an infinite number of rotations. Obviously that would not be practical but the point is clear that with this method one does not have to rely

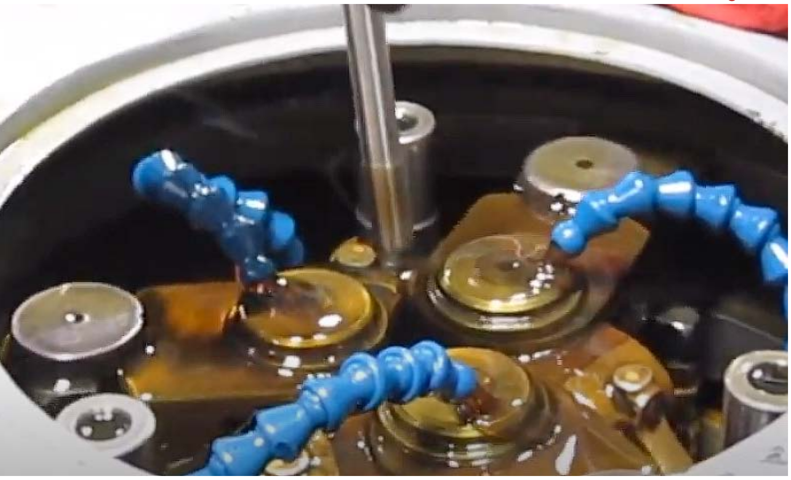

Figure 4

on progressively larger machines to get more rotations, but rather simply turning more revolutions of the cylindrical die.

Cylindrical Die Thread Rolling is often manually fed but can also be adapted for automatic feeding. Whether manually or automatically fed this method is the slowest of the three. The advantages of this method are:

- Smaller machine footprint and size - dies can be rotated as many times as needed without running out of die. This is particularly advantageous when rolling large diameter fasteners because this method can accommodate larger sizes without having to consume ever larger machine footprints.
- When concentricity or run-out are a concern- the three cylindrical die version places very even pressure on parts so that parts which must stay "straight" can benefit from this method.
- Ability to roll hollow parts- parts such as Tube Nuts which have hollow centers and a thread on the exterior surface often benefit from this method as rolling pressure is applied evenly, but, more importantly, can be applied more gently (slowly) so that parts with such hollow features don't get pressed out-of-shape.

Planetary Die Thread Rolling:

The final thread rolling method, and perhaps the least common, is Planetary Die Thread Rolling. In this method there is a stationary, semi-circular die that surrounds a fully round moving central die (See **Figure 6**). Parts enter at the leading edge and rotate through the semi-circular die until they roll off the trailing edge. In a similar vein to the cylindrical dies, the semi-circular shape of the stationary die provides more die length to gain additional rotation in a smaller package. These machines take the most amount of expertise to set-up, but once set-up they can run long runs without a great deal of additional attention.

Planetary Die Thread Rolling Has These Advantages:

- Throughput- Unlike either flat die or cylindrical thread rolling which can only produce one part in a stroke, planetary thread rolling is designed to have multiple parts in the die at all times. These machines often can run between 1000 and 2000 parts per minute. Therefore, throughput is high and makes this process especially well-suited to parts or families of similar parts with large volumes where the machine can be dedicated to them.

Figure 5

Figure 6

- Pressure Settings- Most flat roll dies have limited pressure settings- usually at the leading and trailing edges. Planetary Rollers have pressure settings evenly spaced along the entire semi-circular die length. This gives the set-up operator greater flexibility with how and when pressure is being applied. This feature, for example, makes these rollers nicely suited to the complexities of rolling the thread and groove on parts like Tension Control Bolts.

Thread Rolling is truly an elegant process. Not only is it accomplished at high speeds but it produces a product that is stronger than cut threads. Although most fastener manufacturers either gravitate towards one or two of these methods because their product dictates these choices, each method has its advantages and can be employed with great success to a manufacturer's needs. Manufacturers need only to educate themselves about these technologies to determine what the best choices for their manufacturing operations will be.