5 Common Manufacturing Defects
How They Occur and Ways to Improve

In February of 2017, a Ford employee was working on his 2015 MKC and discovered that one of the seatbelt anchor bolts in the second row had fractured. He brought this to the attention of his colleagues in Quality and they began an investigation. Their Central Labs would investigate and found that the surface hardness was higher than the specification resulting in a brittle screw. They also determined that the failure initiated from a thread lap.

As they now had a solid lead on this failure, they began digging into the manufacturing history and learned that the second-tier heat treating vendor experienced a power outage as they were processing a portion of the manufacturing lot. The power outage produced an improper temper and, thus, brittle parts.

As a result of these faults and because this bolt is safety critical, Ford elected to recall all the vehicles that contained screws from this lot. Although the actions taken in this specific case were extreme, to assure the safety of the owners of these vehicles, fastener manufacturers and users are confronted daily with choices related to parts with manufacturing defects. The reality is that all manufacturing processes are exposed to variation and occasionally external factors which can result in manufacturing defects. Although there are many different defects, this article will explore five common fastener manufacturing defects and how they can be identified, sorted out of suspect manufacturing lots, and addressed so that they do not occur again.

Head Cracks

There are several distinct types of head cracks, each derived from different origins. **One of the most common types are those that exhibit a crack or burst aligned with the axis of the part. A reasonable definition for this type of defect is an open break in the metal, aligned with the part axis, resulting from a flaw or surface discontinuity opening up during forming.**

These types of cracks can be characterized by several common traits:

1. They occur most frequently at the periphery of the head or axially along the body of the part. They may be a mostly closed crack where the non-conformity is obvious, but the depth is unknown (See ***Figure 1***) or fully burst open clearly exposing the depth of the fissure (See ***Figure 2***).

Figure 1: “Closed” Head Cracks

Figure 2: “Open” Head Cracks

2. **These cracks are almost always the result of a pre-existing axial defect in the raw material that generates a localized stress riser.** During the forming process these flaws produce vulnerable locations to overload conditions on part areas exposed to high degrees of cold working, such as the head or a collar. Typical pre-existing flaws in the raw material include seams, laps, and scratches. Seams, which are an artifact of voids being “drawn out” during hot rolling of billets to rod, are usually the most extreme of these three conditions and, thus, will most likely result in the most extreme cracks. Cracks that are the result of a seam are usually obvious because it is easy to trace the path of the seam along the entire length of the part (See ***Figure 3***). Although laps and scratches can display similar appearances along the length of the part, their extent is often less distinguishable than seams because they are not as deep. Seams and laps come exclusively from the mill that is hot rolling the rod. Scratches may be introduced at any time that the wire is sliding past an object that can scratch it. This could be at the mill that processes rod to wire or during manufacturing as the wire is fed into the cold header or in the cold header as the part interfaces with tooling.

Figure 3:
Example of Head Crack Due to Wire Seam
(Note seam running through the threads.)

In addition to the pre-existing wire defects there are other potential causes that will generate head cracks of this nature. **Any interaction with tooling that generates high friction and galling or any close to the surface stress riser can trigger the formation of such a crack.** A list of common causes for these types of cracks includes:

- Wire Seams
- Wire Laps
- Scratches and Scoring (from tools)
- Worn-out Tooling (especially the punches used to form the head)
- Large Inclusions Near the Surface
- Head Markings
- Any Flaw, Defect, or Surface Discontinuity that Generates Localized Stress Concentrations

Some measures that might be employed to reduce or eliminate such problems include:

1. **Use seam free wire.** In many cases this would be considered an extreme fix because the cost to produce seam free wire is significant over normal wire processing methods.

2. **Replace the wire.** If a seam or defect in the wire is discovered, it is likely far more cost effective to replace the suspect wire with a new coil. Swapping or scrapping a coil of wire is less costly overall than running suspect parts and having to carefully screen them 100% after the fact.

3. **Replace the tooling.** If the tools that form the head are wearing out or intermittently producing cracked heads, a tool change or machine set-up adjustment might solve the problem.

4. **Check the draw die, any rollers,** and the cutter mechanism to make sure they are not scratching the wire. If they are or it is suspected that they might be, either polish the tool/component or replace it.

Head cracks are reasonably easy to discriminate using simple visual inspection. However, with large production lots the prospect that thousands of parts might need visual inspection is quite onerous. Therefore, automated methods are preferred. As recently as ten years ago, head cracks, especially closed cracks, were hard to sort out on automated sorting equipment. **Today, optical sorting technology has gotten so much better that head cracks, even the hard to identify ones, can be accurately recognized and culled from suspect lots with a high degree of precision** (See ***Figure 4***).

Figure 4: High Definition Optical Sorting Camera

Shear Bursts

Another type of common crack is a shear burst. These are easily distinguished from other cracks because of their characteristic 45° angle crack interface (See ***Figure 5***). A shear burst is an open break located at an approximate 45° angle to the product axis which results from the material being incapable of withstanding the stresses or strain exerted upon it. Shear bursts pretty much occur only during cold working of the head, flange, or collar.

Figure 5:
Example of a Shear Burst

These types of cracks are characterized by the following common traits:

1. They occur at the periphery of the head, flange, or collar.

2. They may also occur on the side of a hex shaped part (See ***Figure 6***).

3. They will always exhibit the 45° angled fracture surface.

4. They may be open or closed, although they are mostly partially or totally open.

Figure 6: Example of Shear Burst in Hex Flat

The cause of a shear burst is fundamentally because the material is overloaded. Unfortunately, that opens the door to many root cause possibilities. It also means that cracks such as these cannot be conveniently attributed to material flaws. In fact, organizations experiencing shear bursts should look first at what they are doing before casting blame on the raw material. Some potential causes of shear bursts include:

- Poor tool design, especially the first blow upset
- Overworking the material prior to upsetting
- Poor ductility due to "hard wire" or coarse grain size
- Poor or insufficient lubrication
- Rough wire surface
- Cold drawing the wire with too steep an approach angle (The steeper the approach angle of the draw die, the more concentrated the cold work is on the surface of the wire.)
- Surface defects and flaws

Some measures that can be employed to prevent this type of failure include the following:

- Often this is a tool design issue, so that reworking the upset to move less material or redistribute the material differently may solve the problem.

- Reducing the draw percentage on the wire prior to heading.

- Replace the wire if obvious surface defects or localized hard spots are detected.

- Increase or redirect the lubrication.

- Check the draw die to make sure the approach angle is correct for the material being drawn and repolish the die if there is any evidence of scoring the wire.

Shear bursts are generally much more noticeable than many of the axial head cracks. Today, sorting them with high-definition cameras is effective.

Folds

A fold is a lap, folding over, or doubling of metal that occurs during the forming process because of mismatched features or localized buckling. Folds normally occur at the intersection of two features and are commonly evident on

the top and bottom faces of flanges and collars. Sometimes folds are nearly invisible before plating and many folds do not pose any safety risk to the part, although if the plating highlights their presence, they may be considered unsightly and unacceptable. Folds are most commonly seen on hex flange heads and parts with similar geometry (See ***Figure 7***). Usually, the cause is a small misalignment between forming blows. In the example illustrated by Figure 7, the centerline of the tool that created the first upset blow and the centerline of the tool providing the finishing blow are just slightly off from one another. The result is the finish blow shears a small section of material from the first blow, deposits and presses it into the surface at the bottom of the tool, in this case the flange. Cold heading exerts extreme pressure to provide the necessary energy to get material to flow, so this excess material is pressed into the surface of the part. In many cases the surface appears continuous and uninterrupted but, in reality, that sliver of material is just laminated onto the top surface of the flange. **Folds are preventable and when detected can be corrected by repairing the tools or reworking the set-up.**

Thread Laps

One of the most common of all manufacturing flaws are thread laps. **A thread lap is similar to a fold but in the threads. Most threads are produced by rolling, a cold-working process where the material is repositioned into threads by rolling and squeezing parts between two opposing die faces.** There are several different process methods, but the majority of threads are rolled using flat dies. In flat die rolling the thread is generated by rolling an unthreaded blank though a set of paired flat dies. The dies themselves have the thread profile and characteristics milled into the face and as the blank rotates between them, increasing pressure causes the material to be squeezed into the groove and develop the desired thread profile. With flat dies in particular because parts are being rolled between two parallel plates, the dies must be carefully aligned with one another during set-up. If the dies are even a small bit out of alignment, the tip of the thread root formed on one side will not perfectly align with the tip of the thread root from the other side. On the next rolling pass the part will be squeezed further into the die opening the thread and breaking through any web present from misalignment in the first pass. This web of material is like a fold and is subsequently laminated onto the nearby thread flank. Like a fold a lap is normally not visible by eye but evident when the part is cross sectioned or etched (See ***Figure 8***). Thread laps are particularly "dangerous" on parts that are exposed to fatigue loading since they create an origin for crack formation.

The most prevalent cause of thread laps is poor set-up resulting in the misalignment described above. However, there are other causes for laps, which include:

Figure 7:
Example of Folds in Hex Flange Head

Figure 8:
Example of Thread Lap at Thread Root

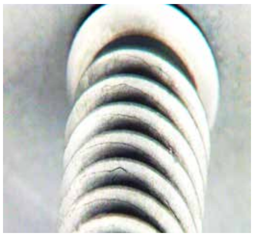

Figure 9:
Example of Etched Part Exposing Thread Laps

- Poor Blank Quality
- Improper Die Design
- Tilting of Blank
- Slippage of Blank
- Die Starting Features (particularly cross nicks placed in the die perpendicular to the thread grooves in the die)
- Poor Machine Condition

Figure 10: Example of "Slider"

Thread laps are not readily discernable by visual inspection, however, can be easily detected by etching parts in warm acid (See ***Figure 9***). For this reason, manufacturers who have customers with no thread lap requirements will often have an acid etching station available to thread rollermen where they can quickly verify the absence of thread laps. Another way to detect thread laps is to mount parts in a phenolic disc, grind, polish, and look at them under magnification. Although this method is conclusive, it is time-consuming and is usually reserved for final inspection or when arbitration is required.

"Sliders"

When a thread rolling process is employed to develop the threads, it is imperative that the blank rotates freely between the dies. It does not matter which rolling process is employed, flat die, cylindrical, or planetary, they all require the blank to turn. The tricky part is to accomplish this at the start when the blank is most loosely gripped by the dies. Roll die manufacturers, therefore, usually blast the start of the die to rough it up just a little and encourage the parts to rotate. If the part does not rotate and begins to slide through the die it does not properly form the thread. In fact, it produces a flattened, mangled thread. In addition, parts that slide through the die often do not have enough momentum to exit the dies and are drawn back in, further damaging them. ***Figure 10*** illustrates a slider. **The j-shape is indicative of a part that has been drawn back into the die as it exited. The primary cause of sliders is not gaining sufficient traction at the start and sliding instead of rotating.** A couple of other causes, however, can also trigger this defect. Amongst them are the blank being tipped at the start, improperly set-up dies that apply inadequate pressure, or too much lubricant. Although Figure 10 is a pretty extreme example, sliders are always mangled and to some degree unusable. If sliders are discovered in a lot of parts, it will either need to be entirely scrapped or 100% sorted. Fortunately, it is such a pronounced condition that **today's high-definition camera sorting machines can easily identify and remove these parts.**

Summary

Manufacturing fasteners share something in common with all other manufacturing processes, there is always variation acting on the process. The influence of both expected and unexpected variation sometimes results in defects. There are many potential defects that emerge from time to time on fasteners. Five of the more common ones have been addressed in this article. These are common to all manufacturers of cold-headed and rolled fasteners and the savvy ones are able to learn from their mistakes and prevent similar events in the future. ■