Limits to Tool Life – Preventative Maintenance

by Peter Standring

"It's a bad workman who blames his tools", is a proverb which will be found in almost every language. It can be interpreted in a number of ways: that the workman did not possess the necessary skills; that the quality of the work was poor; that the time taken was too long, etc.. As a youngster, I often recalled the quotation when I struggled repairing the car or around the home to fix something when I didn't have the correct tools. This often resulted in skinned knuckles or some such inconvenience.

For the Fastener Manufacturer, the term "incorrect tooling" should refer only to tooling which has the wrong dimensions or has been incorrectly manufactured/heat treated. With appropriate inspection, such tool failures should not reach the press and if they did, would be expected not to be used in production.

This article is not concerned with tooling misadventures or how tools should be made. It is only concerned with the enhancement of efficient tool life through tool control, care and preventative maintenance.

Limits to Tool Life

All fastener manufacturers are keenly aware of the impossibility to generalise tool life. The number of variables involved: hot/cold forming; single/multi station forming; work/tool materials used; product geometry; batch sizes produced; and so many other factors demand knowledge, competence and consistency to be successful. Happenstance and serendipity are words rarely used in competitive volume manufacture.

As in all life, the only sure thing is death. For tooling, this comes either catastrophically as in breakage, or through dimensional changes by wear. Where multi-station tooling is employed, the amount of work done at each stage coupled with the geometric shape change produced will subject individual tools to different types of stress of varying degrees of intensity.

Examination of a fractured tool surface can reveal the nature of loading and failure mode. A tool having a hardened surface and a tough core will behave in a more ductile manner than one which is through hardened and only lightly tempered back. Where compressive loading is applied, catastrophic failure would normally result from a surface defect caused in manufacture or handling. Tool misalignment during setting causing tool bending would exacerbate this and hasten the failure. Where excessive loading is applied and early failure occurs, the fracture surface would be entirely crystalline. However, where significant cyclic loading takes place prior to failure, the failure mode would be one of fatigue.

As shown in **Figure One**, this is identified by the crack initiation site being bounded by a series of equally spaced lines which progress into the body of the tool. The fewer the boundary lines (striations or beach markings – as indicated by the ridges left by the tide of the sea on a sandy shoreline) the higher the loading and/or the harder the tool material. Large numbers of striations indicate a slower progress in the tool fatigue prior to ultimate failure suggesting a lower load and/or a tougher material. Final failure is identified by the crystalline structure. It should be noted that where a tool is subjected to shear/torsional loading, brittle tools will fail in a spiral or 3D manner and those displaying ductility show a planer fracture surface as predicted by classical stress theory.

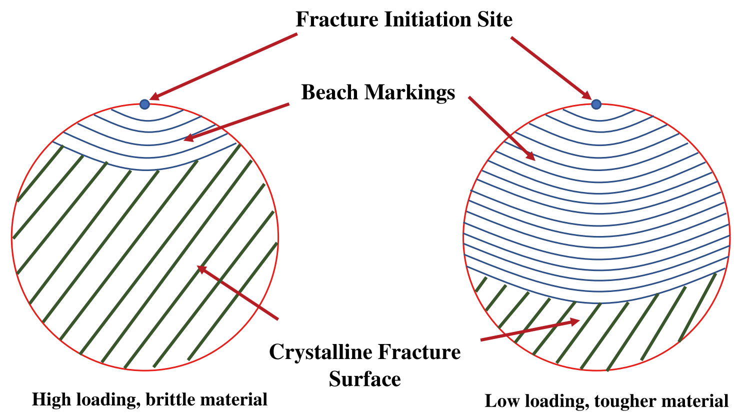

Figure One Illustration of a Typical Fatigue Failure Fracture Surface

Where the tool loading is below the stress level which will cause catastrophic breakage, the failure method becomes one of wear. In this case, the part being produced fails to meet one or more of the required dimensions and is then replaced.

To ensure efficient quality of production, all fastener manufacturers must have and maintain full process consistency. In reality this can only be obtained by having all performance data captured, recorded and analysed at every stage of manufacture. The purpose of this information gathering is quite simply to gain a measure of 'predictability' over the production process. Given so many variables exist in the system, the unanticipated will always occur. In this way, by being able to recognise and identify the 'how' part of the problem, it should be possible to include the new information into the data base to help ensure that the 'when' and 'where' rarely occur in the future.

Tool Loading

Intuitively, we all know much more about the behaviour of materials than we think. Most children at an early age are aware that crockery and glassware often breaks when dropped on to a hard surface. That metal is hard and heavy. That rubber is elastic unless overstretched when it breaks and that wood can be bent when loaded normal to the grain or split along it.

Figure Two shows a simple stress strain graph for a material in tension. Stress is the applied load acting over a given area. Strain is extension over the original length. Of course, different materials will behave in different ways. For example, nylon would undergo a very large strain at a low level of stress whereas a brittle material would fail catastrophically with very little strain. Interestingly, the nature of the plotted results for a brittle material would be the same as that of an elastic band if it were extended to failure although with very different values.

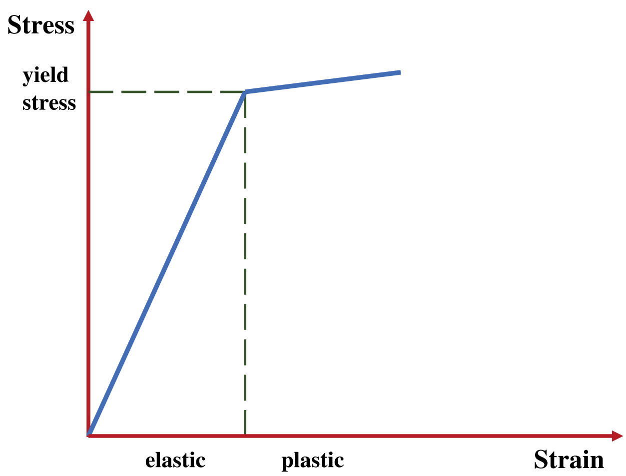

Figure Two Stress/Strain Graph for a Material in Tension

In both cases, the resulting curve would be a straight line indicating the relationship between stress and strain. This initial portion of a stress/strain graph is the 'elastic' region since when the loading is removed, the material will return to its original geometry.

If a metal does not behave in a brittle manner and is loaded beyond the 'elastic limit', then to do so without failure, it must 'yield'. The stress at which this occurs is termed the 'yield stress'. In a brittle material where yield does not occur, it would be the fracture stress.

Further application of load in a material with some ductility will take the material into a 'plastic' phase where the resulting strain becomes permanent. When forming metals, failure of a workpiece to exceed the yield stress will not produce the desired deformation. In the case of tooling, loading beyond the elastic limit will permanently reshape the tool. Hence, the material the tools are made from must have significantly enhanced properties relative to the materials they are forming.

Figure Two shows the loading situation in tension which in compression would be a mirror image. However, a shear or lateral loading would reduce the stress at which yielding occurs in tension or compression by around one half. This shows that any off-centre loading by either design or incorrect setting/location, could have dramatic results.

Stresses due to bending, torsion (twisting) and impact may cause direct tool failure but if not, could provide a major contribution to failure by fatigue. Invariably, as indicated in **Figure One**, such breakages are the result of stress raisers in the tooling. These could be score marks, sharp corners, tooling constraints etc., and their effects will be exacerbated by the cyclic nature of the deformation process. Even the nature, degree and direction of tool polishing can be identified as a cause of fatigue failure.

It is only through the dedicated, continuous and methodical collection of tooling data and its analysis that any fastener manufacturer can hope to understand the tooling situation. Change suppliers, invest in new equipment and/or techniques then, without previous performance data, on what basis could any assessment be made to determine if the change was worthwhile?

The Jewel in the Crown

In the current Covid 19 crisis, everyone is struggling. None more so than the TV News people. Normally, they have such slick studio presentation skills and now, with interviews, discussions and talk shows linked to home working using a range of different on-line systems, the whole thing often looks and sounds quite amateuristic. This is because we have become conditioned to certain standards and when they are unavailable, it becomes very noticeable.

So it is with the very best metal forming companies working in fastener manufacture, cold/warm forging and powder metallurgy. They are all aware that the materials, equipment and technologies they purchase are readily available to their competitors. However, what is different and recognised by all as the Jewel in their respective Crown, is the toolmaking skills they require to give them a competitive edge.

Such skills are never acquired overnight nor can the tool quality demanded be obtained using worn out, ineffective machines and practices. Wherever quality metal formed products are produced the core competency is always to be found in the toolroom. Recognising the fundamental importance of these attributes to the success of the business, individual enterprises (very often family owned) jealously guard the personnel and techniques they have spent such efforts to create and nurture.

Successful fastener companies can be acquired and successfully continued if the new owners are themselves appreciative of what provided the success in the first place. Anyone contemplating setting up a competitive company to manufacture fasteners from a zero knowledge base would find it tantamount to pouring water into sand.

Tooling Database

Only a few millennia ago, people measured time in years. Then, in seasons, months, weeks, days, hours, minutes and seconds. Today, we use the oscillations of a caesium atom (just over 9 billion make one second). At all stages of human development it has been the awareness of the time which has allowed the regulation of everything else. Travel times, work times, leisure times, etc.

In manufacturing, predictability is the key to all planning. We can predict with some certainty that the factory will be available and open for business tomorrow (or whenever). We can predict that employees will be available to work (despite recent shutdowns!). We can predict that machines will run and that work can take place but can we predict the tool life?

In a low loading situation where only wear is a likely problem and using methods of statistical process control (SPC) to monitor product dimensions, it should be relatively easy to recognise when a tool change is necessary. Continuous monitoring of when tools require to be changed can be used to produce a Tool Life Diagram.

Such information will provide opportunities to investigate and evaluate methods to improve existing tool life and to assess their effectiveness. Tool Life Registration Cards which are used to capture the data must be an integral part of developing a Tooling Database.

Things become much more difficult if tool breakage is the failure norm. By definition, such failure will be unpredicted and therefore significantly more damaging to manufacturing production schedules. Again, by the use of Tool Registration Cards, it will be possible to obtain definite data as to the timing of the failure and by examination and analysis provide an understanding of the likely cause(s) of that failure. Continuous data capture of these stochastic events will allow a timeline diagram of failures to be plotted showing the nature and frequency of occurrence.

Such information, hopefully shared across many different products/applications, should provide a genuine opportunity for tooling gurus to: identify sensible tool change schedules prior to failure occurring; introduce knowledge based programmes for tool development and improvement; have a marked and very positive influence on the company's tooling issues.

Tool Maintenance

In any volume production process, down time is a hit on efficiency. Automotive suppliers are terrified of stopping an assembly line and the costs that may involve.

In the case of tooling, this is often expensive to produce and unless it is used appropriately, will be unable to carry out its function as designed. So, tool setters are key to ensuring that tooling is able to perform to its optimum. When it has produced the batch quantity required, the tooling should be: inspected, cleaned, its condition documented, its refurbish implemented, inspected, the Registration Card updated and then suitably stored ready for further use.

The undoubted key to good tool usage is in its management. As stated earlier, the background needed to have the tooling necessary for any successful fastener manufacturer cannot be obtained off the shelf. As in most of life, you get what you pay for. Only in this case, the payment is in time, effort and knowledge gained and maintained; in some cases through more than one lifetime.

The International Cold Forging Group (ICFG) has published twenty years of study by its Tooling Sub Group. These documents, Tool Life & Tool Quality in Cold Forging (parts 1 to 5) are available for purchase from Meisenbach Verlag Bamberg and are very definitely recommended reading.