The Price of Failure

by Peter Standring

"For the sake of a nail a shoe was lost
For the sake of a shoe the horse was lost
For the sake of a horse the message was lost
For the sake of a message the battle was lost
All for the sake of a horse shoe nail!"

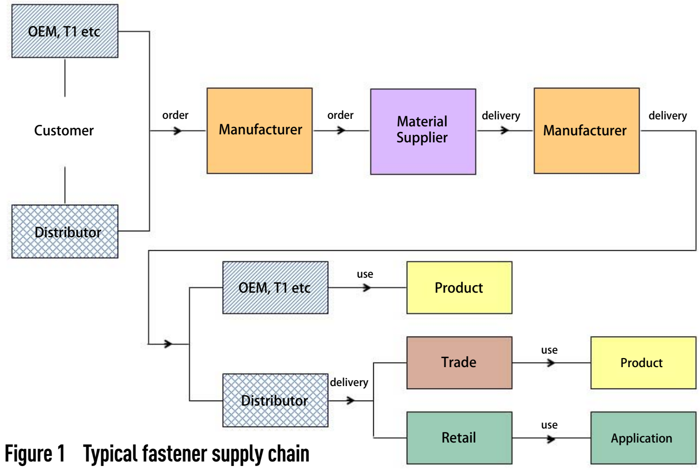

Figure 1 Typical fastener supply chain

So rhymes the verse which as a boy I learnt and I dare say the same storyline, although using a different metaphor, can be found in regions and cultures around the globe. It is a salutary tale about the importance of what may at first glance appear to be trivial but which is in fact crucial to success. And the centrepiece of the story is a humble fastener.

The simple yet imaginative example of significance crossed this Author's mind in recent months when he was asked to advise on a series of failed bolts. Of course through commercial interests, the circumstances of the failures cannot be revealed in this article but the relative views of such failure as perceived by the various parties involved is I believe universal and worthy of consideration.

In his mind's eye, Einstein contemplated objects in terms of their 'relative' velocities. Famously, a person travelling in a rail carriage sees the world differently to another person stood watching the carriage roll by. Figure 1 is a view of the fastener supply chain and the various players in it.

At the start of the chain is the Customer who has a need and places an order with the Manufacturer. The activation of that need triggers a demand for material which when delivered to a Manufacturer results in the desired product being produced. Fulfilment of the order to the Customer allows the product to be employed which during its in-service life should give satisfaction to the end user. It is only when something goes wrong in the chain that scrutiny follows and it is the different views of the various players during this activity which is the topic of this article.

The Blame Game

In manufacturing terms, nothing begins until the stock material is delivered along with the documentation stating its compliance to the initial order. At this stage and using Einstein's analogy, as seen in Figure 2, the Customer views the Material Supplier and Manufacturer as if they are riding in the same carriage unified by their desire to deliver a satisfactory product and then to be paid.

The Material Supplier's view is somewhat different in that they consider themselves to be independent within the supply chain, a view based on the specialisation they possess. As shown in Figure 3, looking up the chain to the Manufacturer, once the order has been delivered and paid for the only follow up the Material Supplier seeks are further orders.

The Manufacturer also considers their position to be 'special' but, as indicated in Figure 4, recognise that to carry out the business requires not only contributions and involvement from the material supplier but also those of: equipment, tooling, lubrication, etc.

The Manufacturer however resents the squeeze they experience from the cost of material and the knock down price they charge the Customer in order to win the business. So, inevitably, they seek to make their process as efficient as it can be and in doing so, often push the technical boundaries of success/failure.

In truth, all success is treated as being commonplace because that is what the Customer always expects and is what they are paying for. Zero parts per million defects is today's accepted standard for aerospace, automotive and many medical products. So, if an accredited part fails in-service, particularly where there is a 'safety critical' aspect involved in its use, an audit trail will be followed and the unwanted finger of blame pointed somewhere. From the Einstein perspective, a failure which has catastrophic consequences involving perhaps multiple fatalities, will attract Public Interest toward the end product supplier (particularly an OEM).

A less intense public examination but equally as potentially commercially damaging will take place if the failure occurs within the supply chain. Such internal assessments are not normally open to public scrutiny (unless regulatory legal action is taken) but will involve detailed examination of every aspect of the supply procedure.

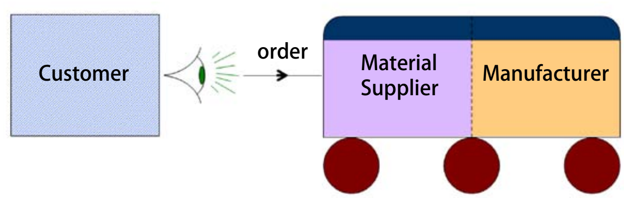

Figure 2 Customer view of supply chain

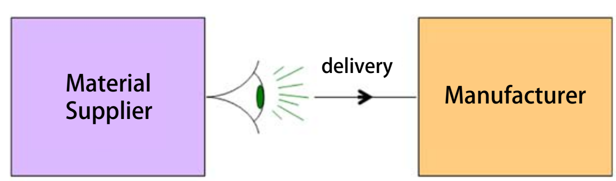

Figure 3 Material Supplier's view

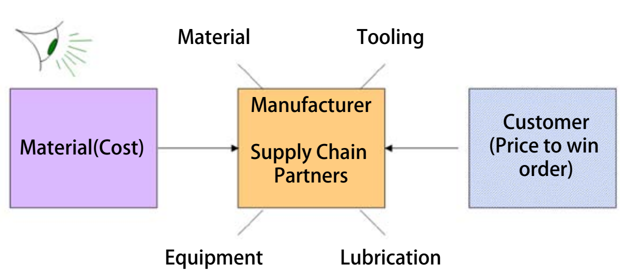

Figure 4 Manufacturer's view

In short, when an investigation into product failure occurs, no one wants to be in the position as in the children's game Musical Chairs, where they find, when the music stops, they don't have a chair to sit on.

Acting on Failure

It may appear to be a strange statement but a failure is the most important information an engineer can have. If a part never fails in service it suggests it may be over designed and therefore inefficient in the use of resources. A failed part allows an engineer to examine the failure and to hopefully determine its cause with a view to designing it out. All too often, failed parts are tossed aside without consideration and yet, if their message can be read, they hold the key to what took place. The price of success can be estimated by the cost involved in trying to piece together a crashed aeroplane to identify what went wrong or the carefully controlled and monitored vehicle crash tests which may involve many hundreds of thousands of US dollars to stage.

Creating failure is not easy so when one occurs any engineer worthy of the name will thankfully grab it with both hands and attempt to find its cause.

A product failure which takes place internally within the manufacturing organisation presents a much easier route to determining its cause. Assuming this has no health and safety issues, which would often bring in external involvement, the matter can be dealt with by systematically examining each stage in the process. More importantly, all aspects of the manufacturing method belonging to the organisation can be accessed with full process understanding and without commercial sensitivities. Basically, this means that people can knowledgably discuss matters at issue and conduct studies, tests and examinations at a level which would not be available to an outside source.

For an OEM like Toyota where vertical integration still dominates the supply chain, any assessment of internal failure could be dealt with in this way. But for virtually all other automotive OEM's where outsourcing of parts (horizontal integration) can be in excess of 80%, then any failure would require the setting up of a task force to include all elements of the supply chain. Naturally, proprietary processing information and subject knowledge would/could seriously impede a successful resolution of the issue particularly where, like in the children's game of Musical Chairs, no one will want to be left standing to take the blame.

To successfully manufacture anything in high volume (including fasteners) demands high investment which of course is fine when things are running well. However, when the high cost equipment doesn't run, either through lack of business or a failure to make it work, then it becomes a serious debt.

At the other end of the fastener sector are the very small manufacturers of "specials". These produce small batches of fasteners for: hard to obtain or obsolete part replacement, selective demand and emergency supply. Considered in terms of added value based on material cost, the yield of high volume parts can be a few percent whereas specials may be priced at 100 times the price of the material required to make them. But such 'specials' do have the additional cost of generally being safety critical and are often required 'yesterday'. A failure of such parts can shut down a major global operation and if it did, the repercussions to the Manufacturer could be just as dramatic.

Causes of Failure

The inevitable cry when a fastener making machine cuts out, or has an unexpected brief tool life, or makes a 'bad' fastener is, "It's the material!" In the Einstein view of things and glaring at the material, the fastener Manufacturer surmises, "It didn't happen when we ran this part before so why has it happened now?"

The Material Supplier's view is, "We just did what we have always done. It didn't happen then, so why blame us now?"

It is interesting to note just how difficult and costly it is to obtain high purity in a single element common metal. Produce an alloy containing a multiple of different elements and it is not surprising that each composition is defined by the range (upper and lower values) of its various elements.

Since each element has its own contribution to the overall performance of the alloy and these can interact both positively and/or negatively dependent on processing, heat treatment etc., it follows that a material's mechanical properties can and will vary between and within melts/batches. This is the reason why 'material characterisation' is so important when any numerical modelling of a process is to be carried out.

It also follows that materials having wide elemental bands in their compositions will respond less uniformly than those where selective elemental control and remelting has been employed. The 'cleanliness' of triple melted bearing steels for example has dramatically improved the power density of such products by three times since vacuum arc remelting (VAR) was introduced as standard.

In brief, the material provided by the supplier at all levels, naturally conforms to the standards by which it was made. Refinement is costly and in truth, you get what you pay for.

Wire/rod for fastener production can be coiled or for smaller quantities of larger diameter, obtained in bright drawn bar form. This will arrive from the supplier with a form of Certification analysing the material i.e., what it is (including heat treatment), its chemistry and mechanical properties (tensile, yield, elongation, hardness, impact strength etc.). For a metalformer, the ability for the material to be cold formed can be assessed by considering the difference between the values of tensile and yield stress i.e. a measure of the material's work hardenability and from the figures for elongation provided. A spherodised annealed condition would be a preferred option for a cold working steel prior to use.

Free cutting steels should be avoided where forming is required since the low shear strength designed to produce 'chips' dramatically reduces ductility.

Assuming what was ordered was received, then any observeable material faults can only occur on the outside (surface defects) or on the inside (segregation, inclusions, cracks). Other 'property' (differences) which may affect fastener production could occur due to local straining by coiling and uncoiling, non uniform heat treatment, etc. These would not be evident by any visual examination but their results could be seen in the machine output/performance.

So, for the fastener Manufacturer, failure to produce a satisfactory part could be due to many factors, machine set up, tooling, lubrication and variability of the material. The targeted "window of success" is defined initially when all variables in the system are set at green for go! Any departure from the optimum will undoubtedly decrease the window size. Just as with 'tolerance build up' interacting variables of material properties, tool quality, machine status, setter skills will interact to increase, or if lucky, decrease the opportunities for failure. Ignorance of the existence of such factors or their interaction leads inevitably to there being a number of levers to pull with no one knowing quite what to do.

And so?

Investment in equipment without the knowledge to make it work is a sure recipe for disaster. Similarly, paralysis by analysis will achieve the same goal. It is for these reasons that to be a welcome member of a supply chain, a partner should acquire and maintain not only a complete knowledge of their own business but must also obtain a 'relative' understanding of the views of others. From a technological standpoint, this is often/always couched in a jargon filled, acronym loaded language, known and understood by those who use it to differentiate their business from outsiders. The legal, medical and financial services 'businesses' are prime examples of such jargon speakers.

A Material Supplier who can understand the Customer's needs/issues can offer real Customer Service. Likewise, when a Fastener Manufacturer appreciates the factors which are involved in material manufacture and can recognise the 'real world' value of the limited data printed on a Certificate of Analysis then, the two business partners can share the same carriage envisioned by Einstein and together fulfil the Customer's perception of them travelling in unison to achieve the same goal. If they do, the journey should be both worthwhile and profitable.