Product Reliability Through Design Process

Product reliability is becoming increasingly important as a wide range industries face the day-to-day prospect of operating in extreme conditions and doing it in a safe and environmentally responsible way. This is true whether it's a butterfly valve for a cryogenic application, a knife gate valve for slurry transport, a ball valve for refinery application or a high torque actuator in an Oil & Gas application. Reliability is not a perception, although many dollars are spent on giving the buyer confidence and a positive perception of product reliability. Reliability is observable and measureable. The purpose of this report is to highlight the importance of product reliability within the product development process which includes design and manufacturing validation and continuous improvement initiatives.

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The concept of product reliability is often misunderstood and misrepresented. For example, during the very important step of defining the required reliability of a product, a loosely comparative approach is sometimes taken - "As good as, or better than…" Or, it becomes natural to think of a high standard, like a BMW Series 1 or Apple Mac Pro, and point to that level. However, comparisons do not always define your need and may include perceptions based on marketing. Alternatively, when tired of subpar experiences, we may simply say, "Just make it reliable…." However, that expression does not quantify our need nor does it guide the product development experts towards the right trade-offs.

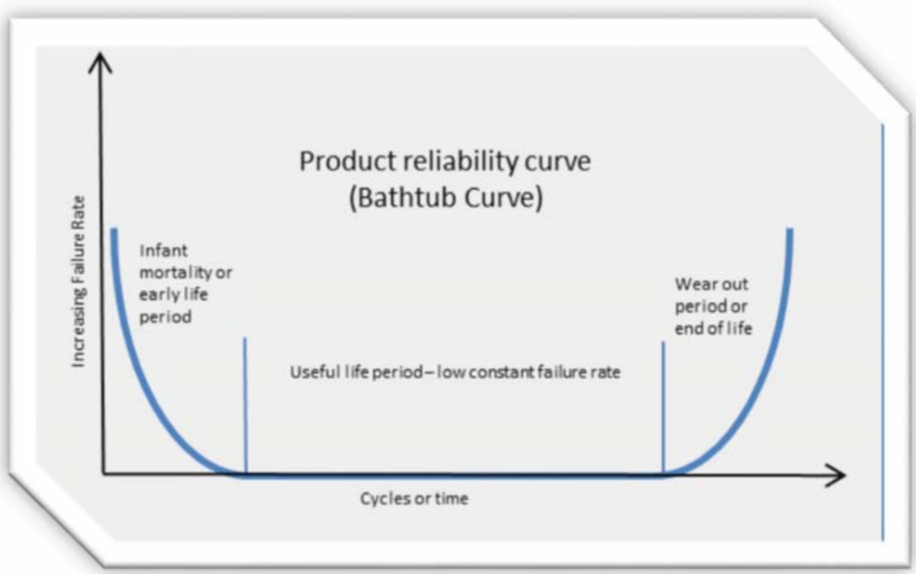
When it comes to high-tier products that are targeted for harsh applications, where there can be an enormous cost of unreliability, it is critical to have a good definition and a clear target for product reliability. This article is not an exercise to recount the full discipline of *Design for Reliability*, rather, the intent is to have a more pragmatic discussion on the emphasis on product reliability throughout a product development process.

An accepted definition of *reliability* is the probability of a product performing without failure, a specified function, under given conditions, for a given period of time (Ref. 1). This definition addresses risk, function, conditions, and duration – all aspects of performance that are important to the end-user. In addition, it establishes clearly stated, measurable and meaningful reliability goals that can be converted into reliability activities in product development, manufacturing and installation/operation processes and drive the appropriate behavior across the product team. A clearly established reliability target is the first step.

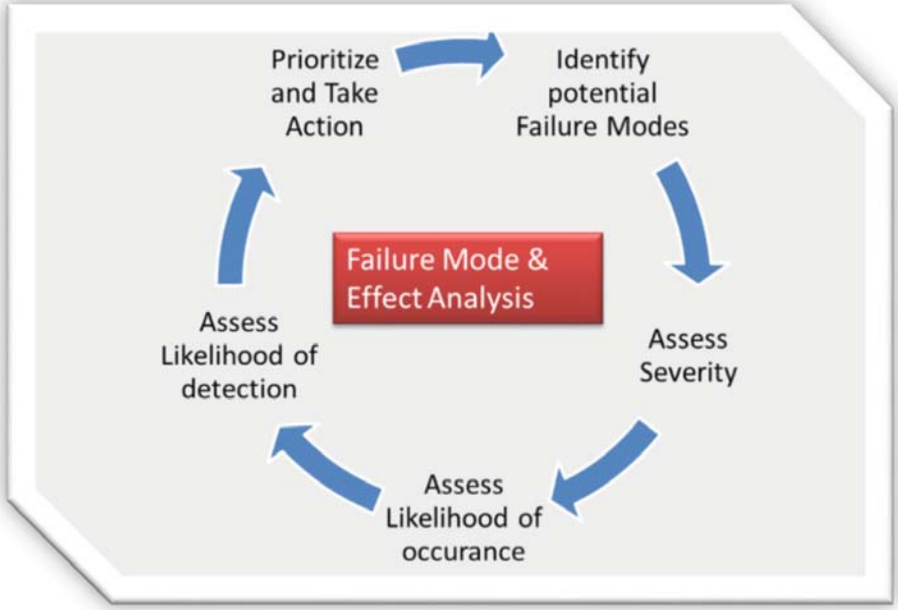
The Product Reliability Curve (Ref 2.), or the so-called "bathtub curve", provides a reasonable depiction and highlights some key points in terms of product failures throughout the product lifecycle. The curve shows failure rate versus time and provides important distinction between early life, useful life and end of life of a product.

The early life period is characterized by a decreasing failure rate, often referred to as infant mortality. Numerous factors contribute to high failure rates throughout the product lifecycle. For example, incorrect installation & operation can contribute to the early failure rate; poor maintenance or unanticipated stresses could lead to a product failing during its useful life; or high corrosion can run a product to the end of its life. There are, however, important elements that are ubiquitous in arriving at a highly reliable product – throughout its lifecycle. These essentials are: 1) solid product development process, 2) good design choices, 3) rigorous product validation, and 4) continuous improvement.

The product development process for valves, pumps, and almost any mechanical equipment begins with correctly identifying



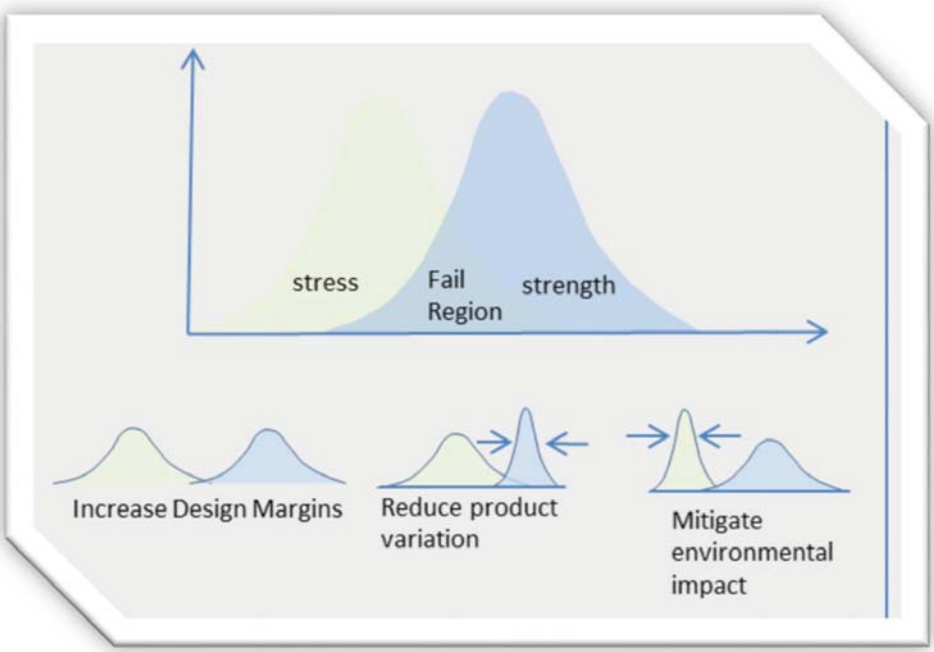
product requirements – design input. For products where reliability is an important deliverable, it is critical at this stage to define a reliability target. A reliability goal is to be clearly stated, meaningful and measurable, and can be converted into specific reliability activities during the product development, manufacturing, and even the installation and operation process. The reliability goal must drive the appropriate behavior from the beginning of design to the actual operation and maintenance of the product. The reliability goal should be a reflection of customer specifications and environmental conditions for the product.



Effective tools

Once an appropriate target is set for reliability of the product, this must translate into design activities and design decisions. A very effective example to illustrate is the principle of stress-strength interference. Intuitively, we know that a product fails when the stresses experienced by the product exceeds its strength, as indicated in the overlap region of the curve. Design decisions and engineering tradeoffs must be made to reduce the failure probability. In general, this is done by increasing design margins, reducing variation in product strength and reducing the effect of environmental conditions. The effect of each is also depicted. Furthermore, stress and strength distributions change over time due to wear & tear, corrosion, etc. These must be taken into account during the design and validation process.

Numerous tools are readily available to measure & predict system reliability. These include, among many, Reliability Block Diagram, Design Margin Discovery & Improvement, Reliability Characterization Testing and Design of Experiments.
For a far more thorough description the reader is referred to the broader disciplines of Design for Reliability (DfR) (Ref. 4) and Design for Six Sigma (DfSS) (Ref 5.)
One of the most effective tools to assess & control risk early in a product development process is the FMEA (Failure Mode & Effect Analysis). The FMEA enables the product development team to systematically identify failure modes, the severity and likelihood of occurance and the likelihood of detecting the failure mode. This information can be used to take prioritized corrective actions to mitigate the most serious failure modes. An effective and continuous FMEA program can reduce probability of failure and increase product reliability.
Of course, in reality, you have to rely on what you inspect, not on what you expect. A product must be proven to meet all input requirements including reliability goals prior to release to market. Design and Manufacturing Validation of a product are essential elements in reassuring Customers of their investment. The details of product validation must be included within the Design Plan and Manufacturing Plan early in a project. The validation program must incorporate industry standards, customer required tests and, if necessary, additional reliability testing.



Validation

Design validation should be conducted on a prototype(s) that is inspected against the design requirements. The validation plan should be followed to demonstrate that the designed product meets all product requirements including reliability requirements. This may (and should) include multiple prototypes and high cycle testing to establish the product performance not only during its early life (referring to reliability curve) but throughout its useful life period and, if possible, testing it to failure through the wear & tear of end-of-life period. Once the design is deemed to be robust to the

requirements and characterized through the useful life period, it can be released for manufacturing. The manufacturing validation must demonstrate that the product can be consistently produced to the product requirements using the planned production value chain – procurement, machining, assembly, etc. Here also, a number of samples must be tested, even after product release, to establish and ensure a consistent quality product, meeting the requirement, can be manufactured.

Once a product is launched, keep in mind that any change in product or changes in manufacturing process may require a repeat of selected validation testing. A different manufacturing location, a change in critical component supplier, a change in material, changes in key production personnel, and on-and-on. A tremendous amount of effort must be put into the product development process to ensure product reliability, but if the proper follow-up and efforts to continuously improve the product and process are not implemented, then reliability will suffer, and all of the effort on the front end would be diminished.

Conclusion

In summary, to achieve a reliable product requires continuous attention to product reliability from the beginning of a project through the entire lifecycle of a product – all the way to obsolescence. First, define what is considered "reliable" and develop reliability goals. Next, have a design plan with a focus on reliability. In doing so, predict reliability of the design using reliability tools readily available – including performing FMEAs. Finally, continuously characterize the reliability through design validation, manufacturing validation, continuous and period production validation to ensure the product meets the reliability targets. Continue to improve the reliability through sustaining engineering and a continuous improvement plan. It's true – the emphasis on getting the product right, and achieving a reliable product requires more upfront effort and cost. But this is what our customers rely on as their challenges increase – in fact, product reliability is what our customers expect. The costs of *unreliability* far outweigh the costs to achieve a reliable product.

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