DFMA and Product Design:

Less Is More …

… Or Getting More Out Of the Same Resources

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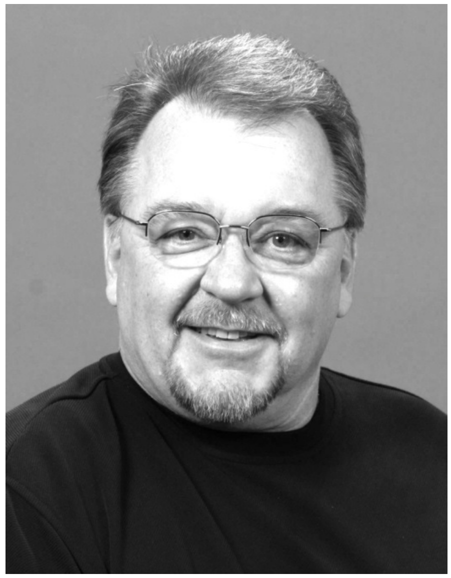

About the author:

David Vranson has been involved with engineering and manufacturing for over 35 years, specializing in Design for Assembly as a manufacturing engineer. His training as a lean master as well as his implementation of concurrent engineering programs has provided a realistic look at both the design pre-release and post-release processes. His product associations have been with the medical device industry, air defense & air traffic control radar, and aerospace industry-related products including the Boeing 777 commercial aircraft. Dave's current assignment is with ITT Aerospace Controls in Southern California.

Less is More…

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Where we have been

Since 2008, the year of the U.S. economic "meltdown," many of us have seen changes we had never seen in years past. As time moved forward, we continually sought out signs that access to money was beginning to brighten a grim outlook, only to hear of more gas being thrown on the fire of economic desperation. To this day we are experiencing only sporadic, small episodes that point toward signs of a forthcoming stability.

An unprepared manufacturing sector combined with an irritatingly weak US economy has continued to drive a shift in business operations. Down-sizing, an easy quick-fix survival tactic happened in large numbers and forced companies to operate competitively with fewer resources. "Globalization" became easier, opening up an enormous pool of workers (billions) who work for much less than Americans. This, in turn, resulted in companies shifting formerly middle-wage-paying jobs overseas. Now, in 2013 we are living the effects of what many are calling a "jobless" recovery…remaining lean and trying to exist on fewer resources.

Effect of design features on the business

The time has come for new business tactics to remain successful. It's time for design-focused thinking. The effect of product design features is far more monumental than most companies realize. A first order of efficiency should be to analyze the product design to find features that suck the efficiency out of a manufacturing enterprise. For the most part, a business improvement effort should begin with product design improvement. Otherwise, you may be revising details and support in processing that are not even needed. Just as it should have been done in the beginning, a concurrent engineering (CE) team should be assembled and the first step would be to identify the cost and difficulties in the product being manufactured. A design for assembly (DFA) analysis can quickly highlight this and the use of DFMA[1] will facilitate the effort and provide reports using <u>quantified</u> data on where the cost and challenges are. The results can then provide the justification to proceed before any further expense is incurred. Not only that, you can now establish a solid plan on how you are going to achieve your product efficiency goals.

Sometimes it's not necessary to change the complete product design to realize a significant improvement. Run a DFA analysis to help find where the real cost targets are at and work on those design points. A while back, I posted a question on a professional blog site that asked: "When considering a product improvement project, which is your primary focus or motivation: Reduced cost, or ease of manufacturability?" Or something along that line. What came back to me was not what I was expecting. I think all but one reply stated their focus was on customer

[1] DFMA; Design for Manufacture and Assembly / product trademark of Boothroyd Dewhurst, inc.

value. Making sure the product is perfect in the customer's perception. Having the customer see value in the product and that it fits well with their needs. Well guess what: you are Fired.

First and foremost, your answer should be related to the product being produced at a profit. Whether it's reduced cost-related, or being able to make more of it efficiently should be the focus. The reason you are in business is what? To make money. The whole basis for the business existing is to trade. Trade something you have that the customer sees value in for some form of consideration like…money. When the business was first conceived, was the idea ever considered to produce products or services for free? Probably not.

So while it's noble to create or improve products with the intention to increase customer value, it had better be done at a profit or it won't be done for long. What, then, would your customer see value in? Quite possibly your nearest competitor.

Ask what effects those design features will have on my business

"How many things are there which I do not want."[2]

The smallest of features…not size-wise…but the seemingly benign features can have hidden cost traps that aren't transparent enough for a designer to recognize immediately – they need your attention early on. Why? Because before you know it, the design is released. It could be the curing time for a sealant. It might be the anodizing where a portion of the surface has a requirement to be electrically conductive. Maybe it's that small 7-pin connector that has a lead time of 26 weeks. It all has to be looked at from every single processing angle…beginning with the acquisition of materials.

I always enjoy introducing an "aha moment" during the design phase. That never gets old. One of my personal favorites: elimination of tooling! Yes…it isn't immediately recognizable that tooling can be eliminated, but have a member of your design team focus on being the process checker to recognize when a tool is required. Watch those second ops. They are always loaded with tools. Eliminate the second operations within fabrication. Maybe the piece part will become a bit more expensive in doing so, but analyze what happens to the overall cost when you design a part to be fabricated and/or assembled without special tools. Tools & fixtures have to be designed and fabricated. Then there is the wear that necessitates downtime and repair. When you design with the need for a tool, do you fabricate two? Plan for the unexpected? Then there is possibly some set-up time required before beginning the work. Load…unload. More time. Elimination of the requirement for second operations is simply elegant and innovative.

[2] *Socrates, c. 469 BC – 399 BC*

At ITT Aerospace Controls, there is a strong drive at the design phase to focus on material cost…first. Materials are typically the biggest piece of the pie. Talk about "design-to-cost" and the focus is on materials. And it starts that way at the very beginning, early-on in the design phase. If we could have a rolling dashboard of data and metrics to gage the effects, overall, on how the design affects the enterprise, designing would account for a lot more responsibility. As well it should.

To begin to understand product cost better, we'll take a brief look at *recurring* product cost distribution; the example in *FIGURE 1* displays a typical distribution example:

FIGURE 1 – Typical Cost-to-Produce at Final Assembly

Data Source: Boothroyd Dewhurst, Inc., Wakefield, RI

Surprising to most is the slight amount that represents the assembly labor. This distribution is based on research and typical industry examples. If you are disbelieving of this graphical representation, calculate what it is within your own manufacturing enterprise.

There is little that can vary with materials and labor. Only if you can change the design or shop for lower cost resources, will you somehow offset the 72% & 4% ratios. Hopefully that work was done prior to design release. But the overhead piece of the pie is driven by how the materials and labor components relate to the overhead values. Lower the part count or material values, and the labor requirement to put the assembly together, and then the overhead supporting them will follow…yet consistent to the ratio and depending on your current overhead structure. The components of the overhead structure are most often hidden costs that do not get evaluated early in the design phase.

Efficiency, like cost, is a by-product of innovation

The proportion or percentage value of the overhead will not likely change unless there is an increase of efficiency within the enterprise operation. Now how are you going to do that? It seems like overhead is kind of trapped between materials and labor. In reality, overhead can be looked at as where waste resides. This is why there tends to be so much confusion about what Lean methodologies can cure in a manufacturing environment. Overhead is non-value added and the worth of it all can be subjective. Waste in many forms can hide in both the fixed and variable manufacturing overhead costs. Lean methodologies can put a stop to over-spending, misuse of resources and useless support functions begs to be done as soon as possible. The first clue for the necessity for Lean will be an inflated overhead portion of the pie. For example a 30% overhead ratio instead of a more-normal 24% or 25%. But it will end short of preventing excess cost that is design driven. It's been said over and over again: No amount of Lean will fix a design that is inefficient to manufacture once the design is released.

Beyond the Obvious – The Hidden Traps

The material supply chain, for reasons illustrated in the chart in Figure 1, usually contains the largest share of hidden variable-cost overhead. Part count alone within a product design can contribute a significant amount. Elements of the supply chain may involve:

- Material Planning
- Material Acquisition (procurement and expediting)
- Supplier Support (Engineering, Quality Assurance, Mfg. Engineering)
- Material Receiving
- Quality Assurance / Inspection
- Material Handling
- Stockroom or Material Staging
- Work Order Material Fulfillment (kitting)
- Fabrication Tooling

And let's not forget the chaotic, variable, hidden second effort that occurs as a result of part shortages, material expediting and material discrepancies that are unplanned and un-budgeted. Try as hard as we may to account for all of this, at best we are guessing at it. We're assuming things will be based on history. And depending on the product variety flowing through the enterprise, it varies from manufacturer to manufacturer; and that is why there is no magic formula to apply to the product cost distribution model.

The labor component is usually fixed enough, at least for a short-term, where the lion's share of manufacturing overhead is applied to. It's typical to tie our fixed facility costs and some non-fixed costs as overhead to our standard labor hours. Again, the methods of accounting used vary from manufacturer to manufacturer, but the standard labor rate is amplified, creating our manufacturing rate we use for pricing, and we're pretty-much stuck with that.

So now stand back, look at the big picture, and try to imagine how product designers will be concerned with the elements of overhead while designing.

When Less is More…

When considering reduction of overhead and hidden cost, care needs to be taken about where it goes to and how it may become re-distributed. Stop right here and go make friends with your company accountant or financial person. Fixed overhead costs, for simplicity sake, should be thought of as always being there and cost value-per-product will go up and down *depending on the quantity of product* produced and how the system applies those cost values. Fixed cost per product value will improve with an increase in material velocity. The variable overhead cost values, those tied directly to materials and labor being supported *by design* (like water and electricity used to process materials).

Let's look at a small sub-assembly of a product and how a design improvement will alter the hidden costs being applied. For this scenario, a DFA analysis was run on a small butterfly valve assembly used for aerospace applications. There is a subassembly of the valve that incorporates a safety pressure relief feature and has a part count of 15 individual pieces. The elements of a cost-to-produce are exhibited in Figure 2 below. Notice the overhead value of 23% and how this example closely mimics the industry-typical example shown in Figure 1 above.

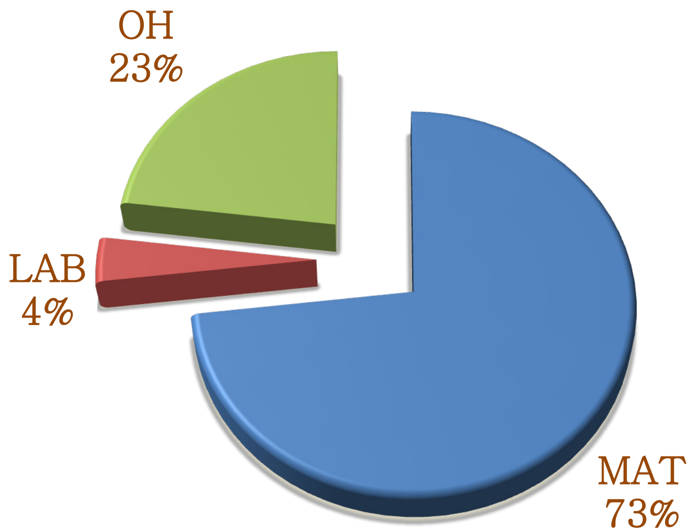

FIGURE 2 – Cost Distribution of the Valve Sub-Assembly

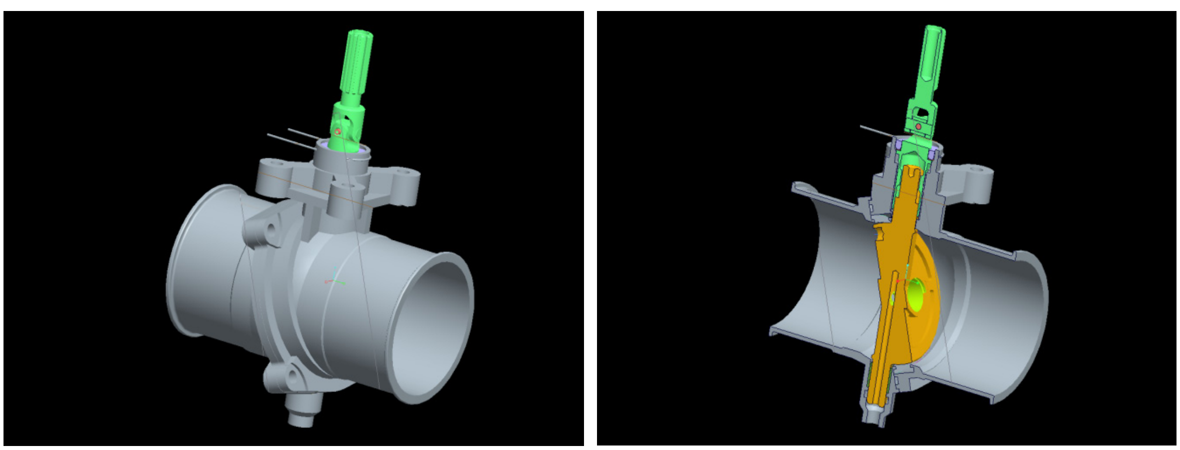

FIGURE 3 – End Item Valve Assembly

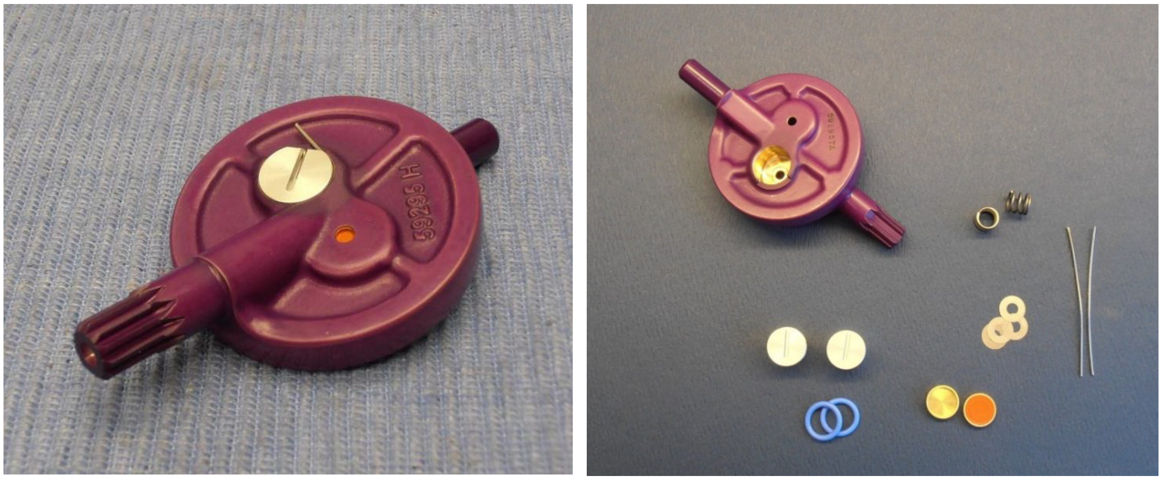

FIGURE 4 – Valve Sub-Assembly and It's Parts

Figure 4 shows photos of the assembled item and the parts it contains. The sub-assembly on the left is shown nearly completed with all 15 parts inserted, just prior to its initial poppet pressure test. The (4) flat washers are .003" thick and are used as shims to effect the correct cracking pressure, or the point where the poppet plug releases due to its specified over-pressure. It may require a dis-assembly to achieve the correct cracking pressure. There is one on each side of the valve disc to protect both inlet and outlet pressures. The wire is fed around the poppet body during insertion and retains the poppet in the valve disc bore. Total assembly time involves approximately 3 minutes while the test time involves about 13 minutes. The DFA analysis shows this sub-assembly as a bottle-neck and provides suggested redesign options to improve the manufacturability.

The redesign involved rethinking how the poppet plug parts needed to work together to provide the same reliable function without all the touch labor and to hasten the assembly process to completion. Nearly all the parts were necessary for it to work correctly. But what resulted was a significant improvement on the assembly floor. The new redesigned poppet plug will be a small pre-adjusted, pre-tested and self-contained assembly purchased from a contract manufacturer involved with the redesign project. They will come as a set of two with the O-rings lubricated and installed on the plug body and sealed in a poly bag ready to be installed into the valve disc.

The view in Figure 5 shows what is assembled along with the rest of the butterfly valve assembly and no longer requires a separate assembly and test station and will no longer be a bottleneck for the top assembly process. Part count dropped from 15 parts to 5 parts, there is no longer a pressure test at the disc assembly operation and the operation time dropped from 16 minutes to just about 1 ½ minutes. Material cost remained nearly the same with only a 7%

improvement, but the improvements in material velocity and waste elimination may even allow for a material cost *<u>increase</u>* to be acceptable.

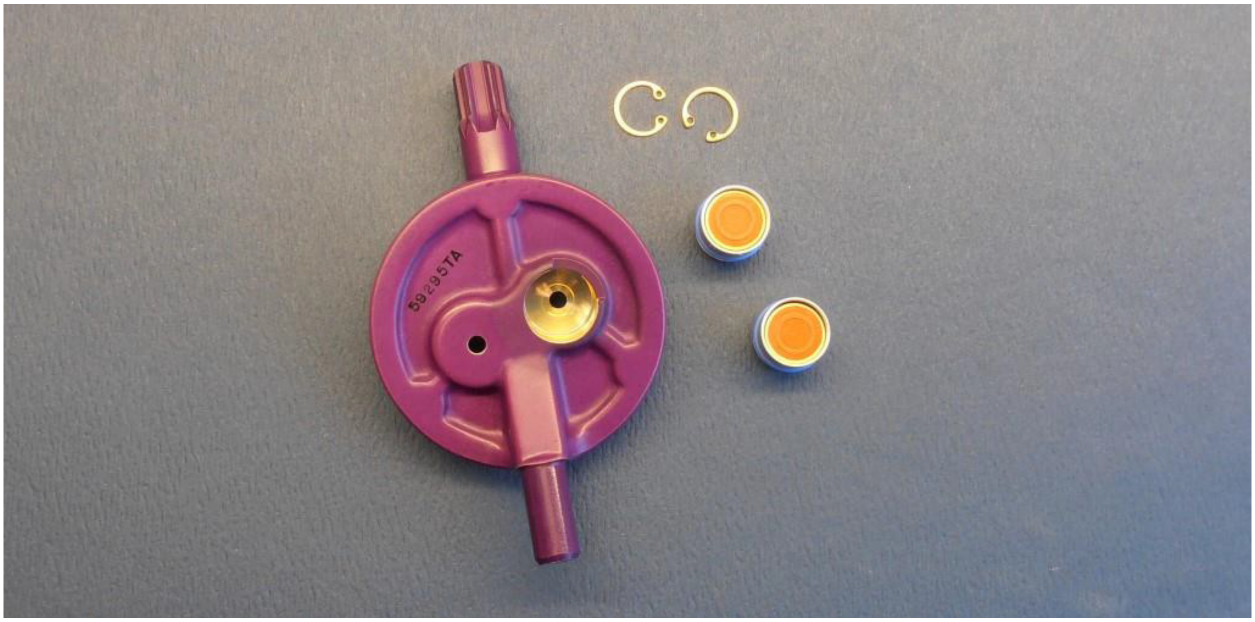

FIGURE 5 – Redesigned Sub-Assembly and It's Parts

By creating a design change such as this, the overhead drops to nearly half of what it currently is in spite of the shallow material savings: Nearly cut in half from 23% to 12%. Figure 6 displays the new cost distribution. In time, the overhead reduction required for this item will redistribute itself over the entire product line and the overall manufacturing enterprise benefits from this redesign action.

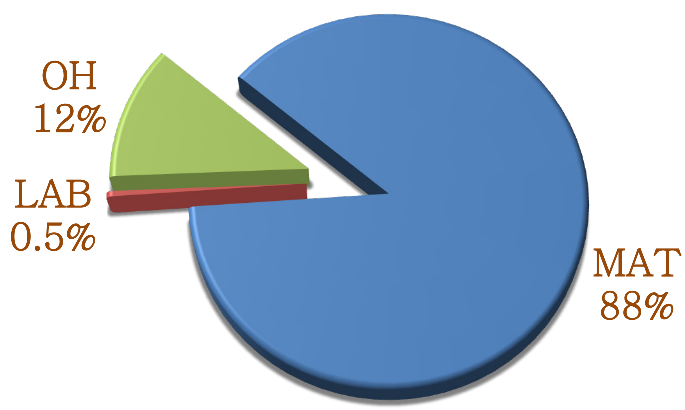

FIGURE 6 – New Cost Distribution of The Redesigned Sub-Assembly

Finding where the cost is located

The use of the DFMA calculator becomes invaluable for identifying where the cost and processing hardships are within a product design. The relatively simple redesign exercise shown in the example above is a typical result of DFMA and a design-for-assembly analysis. While the material savings were not as significant as what would usually be found using this program, the time and throughput improvement is. Throughout a product design phase, cost points become highlighted and are corrected before the design is released into the production stream and is considered to be elimination of waste that would have otherwise been introduced.

Changes such as this one example can provide subtle, yet significant improvements to the efficiency of the entire manufacturing operation. Similar improvements are often overlooked when focusing on the usual and obvious goals of product development. No matter how factory efficiency is calculated and how these values are applied to the individual products, these are true improvements-where the value can be accounted for…seemingly hidden or not.

Product quality, one of the big 3 objectives[3] in providing customer value, became greatly enhanced as well. Because of assembly simplification, there is less margin for error and improved repeatability in the specified performance, nearly eliminating the once *anticipated* second effort (rework) at both the final assembly and the contract assembly processing as well. Adjustment by disassembly, re-shim and reassembly is eliminated with the introduction of a threaded spring retainer. Any necessary adjustment to the pressure relief points can be affected with a simple operation while still mounted in the test fixture. Receiving these small subassemblies, pre-tested, provides enough reliability at the final assembly stage; only a functional ATP test at the end-item level (required anyway) assures the cracking pressure consistency. In the event of a poppet failure, the problem is fixed with a simple sub-assembly replacement without having to disassemble the entire valve. Moreover, these small sub-assemblies are field replaceable and do not require the customer to return the entire valve for repair, a HUGE quality point in the customers eyes.

Understanding where your product's cost is located is key to truly understanding your complete product. As mentioned before, a product designer's cost focus is primarily on the cost of materials and then how those materials will make a product. In today's manufacturing environment, Lean methodologies tend to be substituted as a panacea for the forgotten, often hidden support overhead that it takes to run a factory. More often than not, manufacturing operations will get the blame for an undesirable cost-to-produce. And again, Lean won't fix a product design that is inefficient to manufacture.

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[3] The "Big Three" objectives of customer value: Price, Delivery and Quality…or "PDQ"

A completely functional design sequence is to (1) lay out the product concept and define the configuration, (2) conduct a DFA analysis to identify the designed-in waste, (3) mitigate that waste through design revision and (4) release the product for production.

Following that activity, the production costs can be monitored going forward. Then track what the actual cost is and subtract the original cost, as defined by the previous DFA analysis and the difference will be your lean target to remove waste within the factory operations

Embrace your nearest competitor

Your closest competitor should be considered to be yourself. Having this mindset will keep the product line fresh with new, robust points of quality manufacturability. We need to compete with ourselves – finish a project and immediately begin a new one with the intent for it to be better than the last. Many successful product manufacturers do this. The automotive and cell phone industries are two great examples of beginning a new product development immediately following the previous release. Following this practice will help to maximize product design returns and minimize the support functions that quietly erode away profits, and allow you to see that less really is more.