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DFMA: An overview and a design story

Abstract:

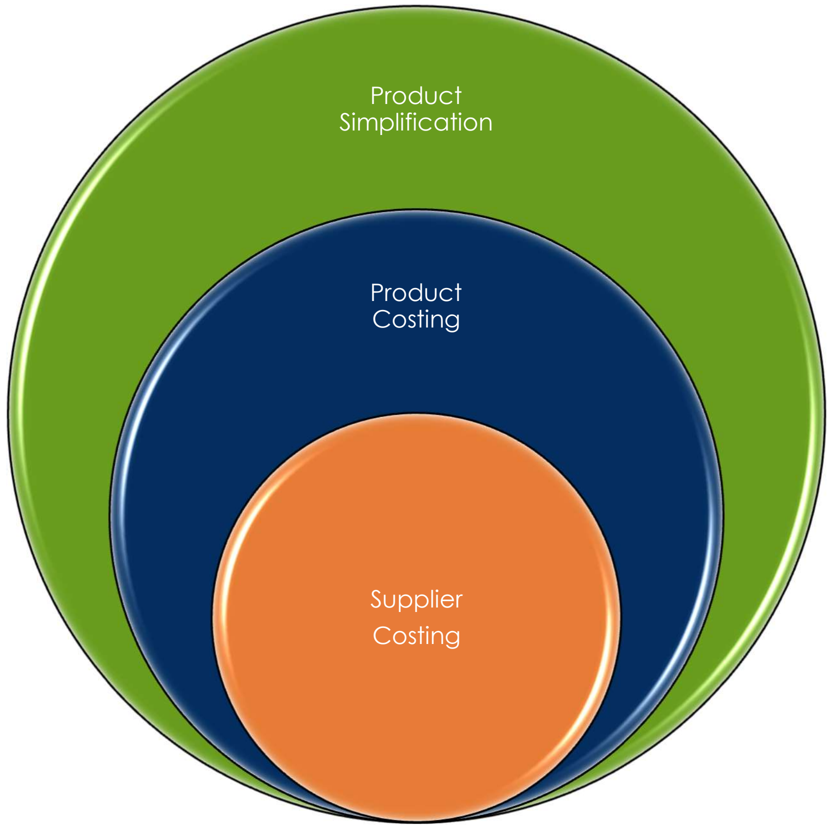
This paper will provide an overview of DFMA and will discuss common ways DFMA is used in industry today. The implementation of DFMA into an organizations product development process has well documented successes. However, many companies struggle with how to take that first step and get started. Through an overview of DFMA, a little of its history, and a discussion of how it's being used today this paper will give both individuals and organizations ideas on how to get started and where benefits can be derived most quickly. Additionally, the application of DFMA in a pseudo benchmarking role on a small sample product will be discussed.

Introduction:

Boothroyd Dewhurst, Inc. was formed in 1983 by Dr's Geoffrey Boothroyd and Peter Dewhurst. After several years of academic research, industry sponsored research, and feedback from their user community the DFMA software began to mature. Today DFMA is a sophisticated set of manufacturing process cost models, databases of machine rates and material costs, and a flexible set of operations libraries allowing full customization to a specific organization. Additionally, and true to its roots, DFMA contains a comprehensive design analysis process, Design for Assembly, that has allowed companies to save Billions of dollars over the last few decades.

So, what exactly is DFMA. Well its best thought of as two different things that happen to work quite nicely together. Design for Assembly of DFA is our product simplification tool. It's used to challenge a design team to come up with a simpler product design. We accomplish this through a question and answer approach to analyze the design focusing on the difficulties of handling and inserting the parts into the assembly. Additionally, a critical part of the Design for Assembly analysis, the minimum part criteria, are also evaluated. This forces critical thinking by the team about which parts truly are required in the design of the product generally leading to significant reductions in the number of parts which leads to significant cost savings. The number one driver of cost reduction in products is the reduction of parts. Design for Manufacture or DFM is a method of evaluation the likely manufacturing cost of an individual part. DFM was developed as a result needing to know what new part geometries will likely cost that result from a Design for Assembly analysis. When questioning the need for parts in DFA the design will undoubtedly need to change. Changes resulting in part count reduction are things that will almost always result in cost savings but exactly how much will be saved? In order to answer that question, you could complete a design of the part or parts. Produce detailed drawings for them that procurement can then send out to one or more suppliers to hopefully get quotes back within several weeks. The other option is DFM. Using DFM you don't need detailed drawings, CAD models, or even details of the manufacturing processes involved. Just the envelope dimensions of the part and a material and process by which it will be made. Using that information DFM will use a combination of library values, industry best practices, default and calculated inputs to calculate costs. DFM will develop a manufacturing process flow and more importantly a cost. This could possibly give the team the answers they need but DFM allows for the user to edit any of the responses to develop a more 'accurate' cost if required. In combination DFMA will allow a team to analyze a design, uncover opportunities to reduce complexity and cost, and roll up a total cost to manufacture the reduced part count design. A powerful set of tools to have in the hands of design teams. Understanding likely product costs from the very earliest stages of a products development.

In industry today DFMA has three main uses, we have termed them Supplier Costing, Product Costing, and Product Simplification. The graphic below represents the likely bottom-line cost impact associated with each of these activities.



Supplier Costing:

Supplier costing focuses on single piece parts and understanding their cost of manufacture. The idea is to get a detailed breakdown, with all the accompanying backup data, of the manufacturing should cost of a part. Using supplier costing will allow you to engage in more meaningful ways with your suppliers by having rational discussions about data rather than emotional discussions about price. Supplier costing is easy to do and with DFM Concurrent Costing everything you need to start analyzing costs is built right into the software. However, the data is customizable so that a user can start to input their own known values if they want to improve the accuracy of their results. Supplier costing requires very little investment. Perhaps some cost databases are setup and some resources assigned to do the work but once it's all setup there is little to no risk in doing Supplier Costing. You are buying the same parts made from the same materials by the same processes and likely from the same suppliers. You simply have data in your hands now that will allow you to push back on what you're being told. This activity is given the smallest circle in the diagram above because it likely has the least impact from a cost perspective. There will be parts with significant savings associated with them, but likely Supplier Costing will yield low single digit percentage cost savings. However, these results can be obtained quickly and with no engineering redesign efforts required.

Product Costing:

For product costing we move outward on the diagram to the middle circle. Here we are still really focused on individual parts, but we are starting to investigate what might happen if things changed. What would happen if you were to change a material or a manufacturing process or both to the bottom-line cost of a part? Product costing is a way to begin to understand the tradeoffs in cost between different manufacturing methods and potentially different materials. First the cost of a part is determined basically along the same lines as conducting a supplier costing exercise. We are simply attempting to establish a baseline cost for the part that we can then compare other materials and processes to it. Once the initial cost is understood and we are confident that the result represents the likely manufacturing cost we can then change processes (or materials or both) and see what the impact on the piece part cost would be. Tradeoffs between processes like forging with finish machining versus investment casting to a more near net shape. Looking at the difference between additional investment in tooling for increased numbers of cavities compared to the potential reduction in piece part cost as a result of making more parts per cycle. All of these sorts of activities can be quickly and easily established under the product costing umbrella. The result of this activity is knowing that you have chosen the best manufacturing process from a cost perspective for the production of a particular part geometry.

Product Simplification:

When we move to the outermost circle on the diagram two things happen. First, we transition from looking at individual parts to looking at the product. Second, we no long focus on cost (although that is of course the reason we are doing the work we are here) but rather we focus on the opportunity to simplify the design of the product. Through asking the minimum part criteria questions about each of the parts in the product we can uncover opportunities to reduce the number of parts in the product and therefore ultimately reduce the products cost. Some training on the fundamentals of Design for Assembly analysis is obviously required but once understood this methodology of product simplification can be applied to any electromechanical product to unlock cost savings.

So, while DFMA and its three main uses have been discussed here going from simple part cost analysis to perhaps more complex design analysis an ideal implementation of DFMA would happen in the reverse order. First a design team (at the earliest stages of a products development) would conduct a Design for Assembly Product Simplification analysis. This would uncover part count reduction opportunities that would lead to some potential redesign of the product. In order to achieve that redesign changes in the geometry of the parts that remain would likely be required. Next we would apply that product costing techniques to discover the lowest cost method of manufacture along with the best choice of material from a cost perspective. Then finally we could transition this information to a supply chain management group so that they could then go out and buy these parts for the lowest possible cost. This would obviously follow on the supplier costing discussion from earlier.

It's also important to note that while what has been discussed is an ideal implementation of DFMA there are many people and organizations that simply choose to do one or two of these activities independent of the others.

DFMA: A design study.

One of the struggles we face at Boothroyd Dewhurst, Inc. is finding examples we can use to showcase our DFMA software. Ideally a product we use as an example needs to be fairly small, have between 15 and 30 parts, be made of parts that we have manufacturing process cost models for, and have at first glance some opportunity for part count reduction. Not that we prejudge things ever but sometimes potentials for redesign are more obvious than others. So, we are constantly looking for parts or products that we can use in our sales literature, webinars, customer demonstrations, and various other things. Almost 10 years ago now we came across the Off Clip on product. It fit most of our criteria and made a pretty good example for some training classes and some demonstrations. It then sat on the shelf until about five years later when the company, SC Johnson, released a redesign of the product. We purchased a couple of them and took a look at the changes but honestly never really did anything with it. It wasn't until a trip to a local CVS that we discovered that the company had yet again redesigned the product. Now things could be interesting. We had a product that met our criteria and had a story we could potentially tell about the evolution of the design of the product. A story that spanned nearly 10 years! The products are seen below.

Released in 2008

Released in 2013

Released in 2017

In order to start the process, we gathered some initial high-level information about each of the products. Additionally, we simply observed them, looked at what was interesting and tried to understand why things were the way they were. This information doesn't require any analysis but could also be an interesting set of things to compare.

For what we will call the Original Design we note the following:

- Made in 2008
- Weighs 7.1 oz (Packaged weight)
- Measures 7.4” x 5.5” x 2.25” (Packaged dimensions)
- Uses two AA batteries
- Purchase price $8.94

Additionally, we note the following comments:

- Unit feels heavy
- All one color
- Plastic feels thick and substantial
- Packaging is complex
    - Several inserts
    - Large multi color printed cardboard
    - Relatively large clam shell package
- Simple, intuitive operation
- Simple to replace batteries
- Belt clip is fixed and does not rotate

For what we will call the Redesign A we note the following:

- Made in 2013
- Weighs 4.3 oz (Packaged weight)
- Measures 5.75” x 4.75” x 1.75” (Packaged dimensions)
- Uses two AAA batteries
- Purchase price $8.20

We also make the following observations:

- Smaller lighter weight unit
- Now in two colors
- Plastic feels less thick but still substantial
- Packaging is smaller and more simple
    - No inserts
    - Smaller cardboard inserts but still two and with color printing
    - Smaller clam shell plastic package
- Simple, intuitive operation
- Simple to replace batteries
- Belt clip now rotates
- Uses AAA batteries rather than AA in original

Finally, for what we will refer to as Redesign B we note the following:

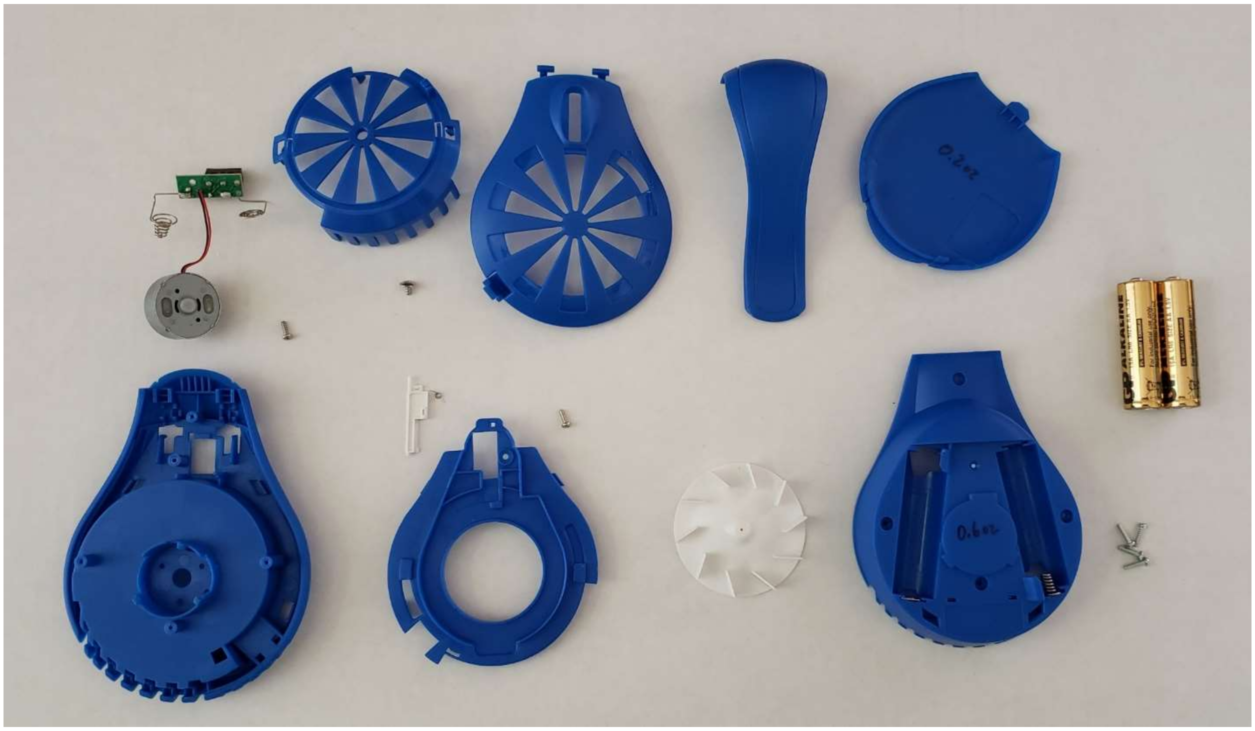
- Made in 2017
- Weighs 4.0 oz (Packaged weight)
- Measures 5.5" x 4.625" x 2.00" (Packaged dimensions)
- Uses two AAA batteries
- Purchase price $7.94

We also make the following observations:

- Unit is smaller still
- Now in three colors
- Plastic feels less thin, almost too thin
- Packaging is smaller and even more simple
    - Cardboard outside is part of the package
    - Two color printing on outside packaging still
    - Smaller simple thermoformed cup stuck to plastic
- Operation is simple but seems a little less intuitive
- Simple to replace batteries
- Belt clip still rotates
- Unit now incorporates an LED to show its on / low battery
- Still uses AAA batteries

Each of the units were then completely disassembled and a DFMA analysis of each of the products was then completed. Ultimately this was done so that the results could be compared to one another and discussions about the designs could be held. Using the disassembled units, a DFA analysis was conducted as they were put back together. This allowed us to see any handling or insertion difficulties that might be present and answer the DFA questions appropriately. Once the assembly analysis was complete each of the plastic parts in all three designs of the product had DFM analysis completed to understand the manufacturing costs and tooling investments associated with the parts. Assumptions were made about the costs of off the shelf parts. They were kept consistent through all three analyses.

For the Original design its exploded view and DFMA results are shown:



Entries including repeats	Original
Parts meet minimum part criteria	11
Parts are candidates for elimination	13
Analyzed subassemblies	3
Separate assembly operations	9
Total entries	36

Assembly labor time, s	
Parts meet minimum part criteria	60.44
Parts are candidates for elimination	92.69
Insertion of analyzed subassemblies	27.26
Separate assembly operations	60.75
Total assembly labor time	241.14

Design efficiency	
DFA Index	16.52

Per product costs, $	Original
Assembly process	0.48
Manufacturing piece part	3.70
Total cost without tooling	4.18
Total tooling cost	0.10
Total cost	4.28

Total tooling investment, $	
Assembly tools and fixtures	0
Manufacturing tooling	101,101
Total investment	101,101

Production life data and weight	
Life volume	1,000,000
Total production life cost, $	4,278,624
Total weight, lb	0.17

For Redesign A its exploded view and DFMA results are shown:

Entries including repeats	Redesign A
Parts meet minimum part criteria	11
Parts are candidates for elimination	7
Analyzed subassemblies	3
Separate assembly operations	12
Total entries	33

Assembly labor time, s	
Parts meet minimum part criteria	69.53
Parts are candidates for elimination	46.20
Insertion of analyzed subassemblies	32.73
Separate assembly operations	69.29
Total assembly labor time	217.75

Design efficiency	
DFA Index	18.29

Per product costs, $	Redesign A
Assembly process	0.43
Manufacturing piece part	3.23
Total cost without tooling	3.67
Total tooling cost	0.09
Total cost	3.76

Total tooling investment, $	
Assembly tools and fixtures	0
Manufacturing tooling	91,026
Total investment	91,026

Production life data and weight	
Life volume	1,000,000
Total production life cost, $	3,756,731
Total weight, lb	0.13

For Redesign A its exploded view and DFMA results are shown:

Entries including repeats	Redesign B
Parts meet minimum part criteria	11
Parts are candidates for elimination	20
Analyzed subassemblies	1
Separate assembly operations	19
Total entries	51

Assembly labor time, s	
Parts meet minimum part criteria	65.92
Parts are candidates for elimination	153.90
Insertion of analyzed subassemblies	3.54
Separate assembly operations	116.31
Total assembly labor time	339.68

Design efficiency	
DFA Index	11.73

Per product costs, $	Redesign B
Assembly process	0.67
Manufacturing piece part	3.73
Total cost without tooling	4.40
Total tooling cost	0.07
Total cost	4.47

Total tooling investment, $	
Assembly tools and fixtures	0
Manufacturing tooling	74,787
Total investment	74,787

Production life data and weight	
Life volume	1,000,000
Total production life cost, $	4,473,815
Total weight, lb	0.07

Once all of the analysis work was complete, we were able to then make comparisons between the different iterations of the design. These comparisons are shown in the table below.

Entries including repeats	Original	Redesign A	Redesign B
Parts meet minimum part criteria	11	11	11
Parts are candidates for elimination	13	7	20
Analyzed subassemblies	3	3	1
Separate assembly operations	9	12	19
Total entries	36	33	51
Assembly labor time, s			
Parts meet minimum part criteria	60.44	69.53	65.92
Parts are candidates for elimination	92.69	46.20	153.90
Insertion of analyzed subassemblies	27.26	32.73	3.54
Separate assembly operations	60.75	69.29	116.31
Total assembly labor time	241.14	217.75	339.68
Design efficiency			
DFA Index	16.52	18.29	11.73

Per product costs, $	Original	Redesign A	Redesign B
Assembly process	0.48	0.43	0.67
Manufacturing piece part	3.70	3.23	3.73
Total cost without tooling	4.18	3.67	4.40
Total tooling cost	0.10	0.09	0.07
Total cost	4.28	3.76	4.47
Total tooling investment, $			
Assembly tools and fixtures	0	0	0
Manufacturing tooling	101,101	91,026	74,787
Total investment	101,101	91,026	74,787
Production life data and weight			
Life volume	1,000,000	1,000,000	1,000,000
Total production life cost, $	4,278,624	3,756,731	4,473,815
Total weight, lb	0.17	0.13	0.07

Seeing this data now allows us to make comparisons about the designs themselves, their manufacturing costs, and the labor content. However, it still doesn't really show the total cost of the products because none of the packaging information is included. This was added in a DFM assembly fabrication analysis and added to all three products so we can truly make statements about the total manufacturing costs of each product. Shipping costs and import taxes and duties from China were also included in this analysis.

		Cost per part, $							
	Life volume	Material	Setup	Process	Rejects	Piece part	Tooling	Total	Initial tooling investment
1 Original Assembly fabrication Polypropylene	1,000,000	4.6125	0.0003	1.0303	0.0021	5.6451	0.1058	5.7510	105,841
2 Redesign A Assembly fabrication Polypropylene	1,000,000	3.9036	0.0003	0.8652	0.0016	4.7708	0.0959	4.8667	95,904
3 Redesign B Assembly fabrication Polypropylene	1,000,000	4.3847	0.0003	1.0796	0.0011	5.4657	0.0794	5.5450	79,361

Comparison and discussion:

It's interesting to see the changes in the design of this product over an almost 10 year time period. Clearly efforts to reduce the cost of the product have been made as time has progressed. It's also clear from the results however that they didn't succeed. Good progress was made as the product initially evolved into Redesign A. Part counts were reduced and the total cost to manufacture was reduced. Something happened though when Redesign B was undertaken. The parts got 'cheaper' the counts of parts increased. This is likely due in part to the added functionality of the LED. Perhaps the company was willing to accept an increase in cost to add that function, we will never know. I think it would have been worth asking though at what cost would this feature have not been included. The function of the LED is to show that the unit is on, and when the batteries get low. This requires some components on the board not present in the original design and there was no PCB at all in the second design. This also led to a dramatic increase in the number of operations with all the soldering that was required to attach the wires and battery connectors to the PCB.

Its also very interesting to see the various design techniques used over time. Screws practically vanish in Redesign A and are replaced with heat staking. In redesign B heat staking, snaps, and fasteners are used to hold parts together. The manner in which the motor is secured in redesign B seems like it must have been a fix in manufacture.

The obvious question here now is what if they had adopted DFMA in 2008 when the original design was developed. Applying the DFA principles the follow changes could have been implemented. Assuming that we use the form factor of the final design we could make the following changes based on the DFA analysis:

Based on our study and applying DFA principles:

1. Use snap fits to secure all parts
2. Remove PCB and wire to battery connectors like Redesign A
3. Remove LED (controversial)
4. Since product is round belt clip rotation seems unnecessary
5. 'Orange media disc' seem to have no function other than cosmetic so remove it
6. Maintain same packaging as Redesign B

	Cost per part, $								
	Life volume	Material	Setup	Process	Rejects	Piece part	Tooling	Total	Initial tooling investment
Original Assembly fabrication Polypropylene	1,000,000	4.6125	0.0003	1.0303	0.0021	5.6451	0.1058	5.7510	105,841
Redesign NPD Assembly fabrication Polypropylene	1,000,000	3.7477	0.0003	0.6675	0.0011	4.4166	0.0691	4.4857	69,129

A difference of $1.2653 or 28.2% of $12,653,000 since 2008 with no design changes

Closing comments:

The intent of this study was to observe what happens to a design over time. We really have no details on any of the products development projects. They likely were different teams or certainly had different team members over that time period. The point here though is that you can do this work too. Sure, you could do it on some little product that seemed interesting to you and perhaps even learn things about design that you could then employ in your own designs. However, you can do this on your own products over time and you can do it on your competitors' products. Remember here we just purchased these products from a store. Now we have a detailed understanding of their designs, their manufacturing costs, the likely profit levels seen by the company. Additionally, we have a theoretical competing design at a lower cost. So, use DFMA not only to help you in your own understandings of cost and bettering your own designs but use it to understand your market and get a leg up on your competition.