Product Simplification Using DFMA

33rd Annual International Forum on DFMA
Providence, RI
September 11-12, 2018

"Nine-tenths confidence and one-tenth common sense equals a successful aviator."
John B Moisant

AUTHOR:

KOHLER CO.

Bill Devenish Global DFx Principal Engineer, Global DFMA Leader

INTRODUCTION

What is DFMA, and how is it accomplished? DFMA, Design for Manufacture and Assembly, is a methodology used to enhance product assembly efficiency and cost. The process starts with an initial design concept and results in an optimized product design.

DFMA should be conducted at a time when the design is flexible.

DFMA activities are ideally conducted as soon as a product development team begins brainstorming early design concepts. DFMA should be conducted at a time when the design is flexible and allows for the investigation of multiple alternative ideas. Don't wait until the design is considered good enough to share, because usually by this time, the team has invested too much time and effort into one specific concept and will be hesitant to make improvement changes. Sometimes the initial idea is just a napkin sketch or preliminary CAD model.

DFMA METHODOLOGY

One of the first DFMA steps is to list the parts of the early design concept after it has been chosen. Sometimes a parts list from a similar product can be used as the baseline. While composing the parts list it can be helpful to concurrently identify the envelope shape (block or cylindrical), along with the size and symmetry of the parts. If available, it can be useful to include estimated part costs in an effort to establish a total cost for the baseline concept.

The next step is to organize the parts in the expected order of assembly. List any reorientations of the parts or product while visualizing the assembly of the parts. Additionally, identify any necessary operations, such as: adjustments, securing of parts, tightening, material applications, testing and inspections.

Once the assembly order has been determined, each part needs to be evaluated for handling and insertion difficulties. Assess each part for the need to use one or two hands during handling. Furthermore, evaluate whether the parts are flexible, slippery, susceptible to nesting and tangling, or require careful handling. Insertion difficulties that need to be identified include obstructed access, restricted visibility, resistance, hang-up and the inability for the part to be self-located.

Each part in the list then needs to have the Minimum Part Criteria applied. The Minimum Part Criteria is a part categorization technique that facilitates part combination and reduction. It increases understanding of product functionality and then assists in the effort to combine parts that meet required functions. It also provides justification for parts to exist as separate components in the design.

The primary purpose of the Minimum Part Criteria is to examine each part for the possibility of elimination or combination with other parts in the product.

The Minimum Part Criteria consists of four categories; Base Part, Movement, Material and Assembly. Parts that meet these criteria are considered theoretically necessary. A part that doesn't meet one of these criteria is considered a candidate for elimination, including fasteners and connectors. Fasteners and Connectors never meet the Minimum Part Criteria

A part that meets the criteria for Base Part is usually the first part in an assembly, and is considered the one that most all other parts are attached to. There can only be one base part in an assembly, therefore, it is typically found in the top level of a parts list. Lower level subassemblies generally will not have parts that meet the criteria for Base Part. Some common Base Parts might include Body, Housing, Frame, Chassis, Enclosure or Main Plate.

A part that meets the criteria for Movement is one that must move relative to the parts already assembled. During operation of the product, significant movement must take place between the part and the other assembled parts. Part movement that could theoretically be obtained by integral elastic elements, such as a living hinge or spring, does not meet the criteria for Movement. Some common examples of parts that meet the criteria for Movement include a piston in a cylinder, a wheel rotating on an axle shaft, or a handle on a faucet. Usually the entire part moves relative to the others.

A part that meets the criteria for Material must be made from a different material than the parts already assembled. It is important to only consider fundamental material properties, such as light permeability, sealing, applied force, life cycles or electrical conductivity. Some common examples of parts that meet the criteria for Material include a window, O-ring or electrical insulator. Sometimes there might be multiple parts made of the same material in an assembly that could theoretically be consolidated into a single part, and in this instance the first part meets the criteria for Material but subsequent parts do not meet the criteria. There may also be times when a collection of multiple materials grouped together are treated as one part, such as a valve in a faucet, and these meet the Material criteria.

Finally, a part that allows for the assembly of previous parts is theoretically necessary, and so it meets the assembly criteria. This is usually a cover, or the part that holds all the other parts together.

If a part is not a fastener or connector, and it doesn't meet any of the four Minimum Part Criteria (Base Part, Movement, Material, or Assembly), then there is no fundamental reason for it to exist. It is a candidate for elimination or combination.

Fasteners and Connectors never meet the Minimum Part Criteria.

When conducting a DFA analysis, all parts in the assembly must be assigned a Minimum Part Criteria category. The Minimum Part Criteria is used to examine each part for the possibility of elimination or combination with other parts in the product. When assigning parts their respective category it is important to proceed in the order of the actual assembly process. This provides the opportunity to compare the current part against the parts that have already been assembled and not those expected to come later in the assembly. When applying the Minimum Part Criteria, it is also imperative to keep in mind what is theoretically possible, ignoring practical, economic and technical limitations for the moment. While evaluating parts for Minimum Part Criteria, think of them in the context of a theoretical redesign of the product. In other words, determine if the parts need to be separate, or can be combined, considering the theoretical alternatives. There is no need to have expert knowledge of the alternatives, just an awareness of the possibility. It can be helpful to repeatedly ask the question, “Theoretically, can I accomplish the design objective without this part?” or “Theoretically, can I combine this part with another?” This leads to creative solutions for optimizing the design.

Handling and insertion difficulties, along with process operations, add time penalties to the total product assembly time.

The next step is to calculate the total assembly time for the proposed product. The estimated assembly time is the sum of handling, insertion and operation times. Make note of all the time penalties for each difficulty and operation that have been identified. This will help spur ideas for improving the efficiency of the design.

A simple way to measure Assembly Efficiency is to use a number known as the DFA Index, which is an essential ingredient in the DFMA analysis process. It is a ratio of the theoretically ideal assembly time over the actual assembly time. The range is from 0 to 100, with a higher number representing a more efficient design. It can be used to compare alternate design concepts that have been created to meet the same functional requirements. The DFA Index can also help make data driven decisions, instead of relying on instinct, gut-feel, or intuition.

The formula for calculating the DFA Index is shown below.

$$\boxed{E_{ma} = 100(N_{min} T_a / T_{ma})}$$

E_{ma} = DFA Index (represents the value for the DFA Index)

N_{min} = Theoretical minimum number of parts

T_a = Ideal assembly time for one part (~2.93 sec.)

T_{ma} = Total estimated assembly time

The numerator in the equation is defined by the theoretically ideal assembly time, where N_{min} is the theoretical minimum number of parts multiplied by T_a, the ideal assembly time for a given part, which is equivalent to ~2.93 seconds. The ideal assembly time can vary slightly depending on the size, weight and shape of the part.

The Denominator is defined by the estimated assembly time, T_{ma}, which includes penalties for handling and insertion difficulties, along with time penalties for parts that don't meet the Minimum Part Criteria.

The DFA Index can be used as a quantitative metric to track the progress of product development. It also encourages Product Simplification by facilitating creativity.

When the DFA Index has been calculated for the initial design concept, the baseline DFA analysis can be considered complete. The observations and results from the baseline analysis can now be used to brainstorm alternate and improved design concepts. When generating new ideas, it is important to remember some of the basic rules for brainstorming. First, there are no bad ideas, second, reserve judgment on all ideas until later, and third, focus on the quantity of ideas and not the quality. A tip to help generate ideas is to concentrate on the parts that don't meet the Minimum Part Criteria. Focus on eliminating and/or combining those parts that don't meet the criteria, as well as the fasteners and connectors. Additionally, review the handling and insertion difficulties, along with the time-consuming operations, to create ideas for improving the assembly.

Compile the improvement ideas into logical concept groupings, such as Safe, Reach and Stretch, or into different design concept options. Copy and paste the baseline DFA analysis for each of the unique improvement ideas. Make the changes to DFA analysis for each new concept identified.

Now it is time to conduct DFM analysis on targeted parts in the assembly. For example, one idea from brainstorming might be to combine the function of two separate parts into one single part. The question usually arises, will the combined part cost more, or less than, the two separate parts and their associated assembly time? Conducting a DFM analysis on the two individual parts, in addition to the combined part, will provide data to help answer the question. Complete the DFM analysis for all parts requiring cost data. Consider alternate materials and processes for creating the parts. Sometimes this develops into an iterative process where the DFM details that emerge lead to changes in the assembly concepts. Other times, as the different concepts are analyzed, some of them will merge and morph as new and better ideas are developed.

Once the various design concept options have been quantified using DFA and DFM, it is time to evaluate them. Several criteria metrics can be used for comparing the options. The DFA Index can be a prime indicator, with a higher index number pointing to an assembly that is more efficient. Similar metric comparisons include assembly time and number of parts. One of the most common metrics for comparing options is cost, and this should include the material part cost as well as the cost to assemble the product. When comparing part costs, it can be helpful to also look at the total cost of the parts over the lifetime of their production, which includes amortization of any associated tooling costs. The tooling investment should also be a consideration. Finally, it is important to evaluate and compare the risks for each design option. These criteria are evaluated together to select an optimum design option.

CONCLUSION

Following the DFMA methodology during product development provides a structured approach to optimizing the final design of the product. It unleashes creativity and facilitates the use a data in the decision-making process. Ultimately, it leads to a world-class product design.

The DFMA methodology leads to optimized designs.