Product Definition and Concept Development Using DFMA

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Abstract

This paper chronicles the Design for Manufacturing and Assembly (DFMA) process as it applies to the early product definition and concept development of the Outdoor Bench Seat Attachment: A product in the brainstorm phase of the engineering design process at the time of DFMA implementation. The result was a relatively simple design, easily adapted to accommodate a variety of manufacturing materials and processes, with the added benefit of cross-generational compatibility with the item it was designed to be paired with.

Introduction

The Outdoor Bench Seat Attachment, conceived as an accessory to the 2010 Jeep Wrangler, is intended to be a durable, portable, and easily employed product for use in a wide range of recreational applications. To achieve this goal, it was determined that the ideal product would:

- Be of a size and weight suited to accompany the average customer's camping supplies, given the cargo space of the intended vehicle;
- Require no more than two persons to deploy;
- Provide a reasonable amount of ground clearance to enable its use on moderately rocky, muddy, or snow covered terrain;
- Be offered at an initial price not to exceed $60.

For this project, the DFMA approach to product refinement was mated with the design process in a proactive manner, with the intention of minimizing startup costs related to manufacture, while lowering the projected cost of production over the lifetime of the product. The effectiveness of this approach is depicted with the use of project root cause analysis diagrams (Fishbone graphical representations)*, along with data from various DFMA analysis tools* designed to compare aspects of the optimized design against that of the baseline. The conceptual design resulting from the first iteration of the brainstorm phase was used in this case as the baseline product to be improved upon.

Baseline

Initial brainstorming of possible solutions to the problem yielded the concept depicted in Figure 3.1: Baseline Product Design. This concept utilized two, identical platforms upon which the bench seat could be mounted, and carried by four individuals. Deployment of the system could be achieved by two persons, however, the ideal four person carry aspect of this design was counter to the spirit of the initial criteria. It was also apparent that the structure, as conceived, would require the strength and durability of metal as the primary material for its fabrication.

†Provided upon request.

While a good starting point, it was deemed that regardless of alloy choice, the weight and bulk of such a system would be prohibitive to realization of the outlined criteria. It is of merit to note that though the goal of this phase of development was to achieve a baseline for refinement, DFMA methodology was already proving useful, as concepts involving separate left and right components were immediately identified as manufacturing cost multipliers, and thus cataloged for last resort use only.

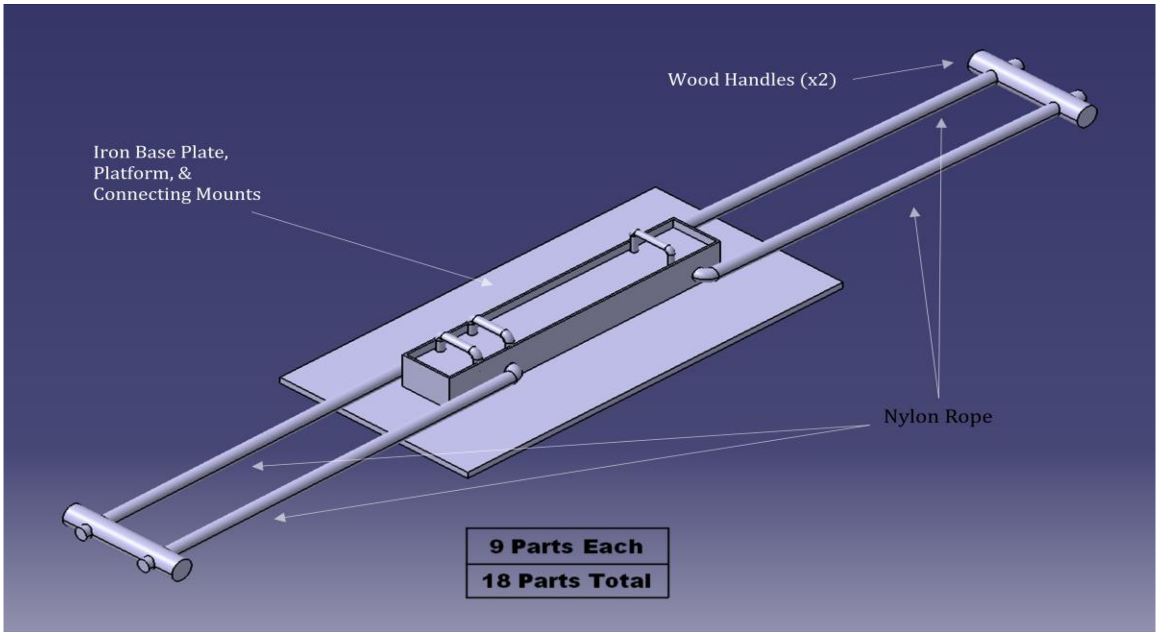

Figure 3.1: Baseline Product Design.

While more thought was being put into overcoming the design flaws of the initial concept, a pool of manufacturing materials were considered. This step was seen as a possible means of homing in on a viable solution for the next design iteration, as it was determined that the mechanical properties of materials of interest could influence, or inspire design parameters. The search for manufacturing materials was limited to the category of metals, due to the vast expanse of engineering materials currently on the market, and the structural requirements of the initial concept. The CES EduPack materials database was consulted, and proved invaluable for this task. In Figure 3.2: Logarithmic Plot of Metal Density vs. Price Per Unit Volume of Material, it can be seen that cast irons and low alloy steel were the metals of lowest cost among the selected pool of materials. Applying the material density properties of these iron based metals to the baseline computer aided design (CAD) model yielded weights well in excess of 100lb per platform, so the decision was made to investigate the aluminum alloys, in lieu of the less expensive material. Platform weights of around 70lb were observed with these alloys. While this weight was still prohibitive, it was deemed that the manufacturing and design capabilities associated with aluminum alloys made it a strong candidate for the design iteration to follow.

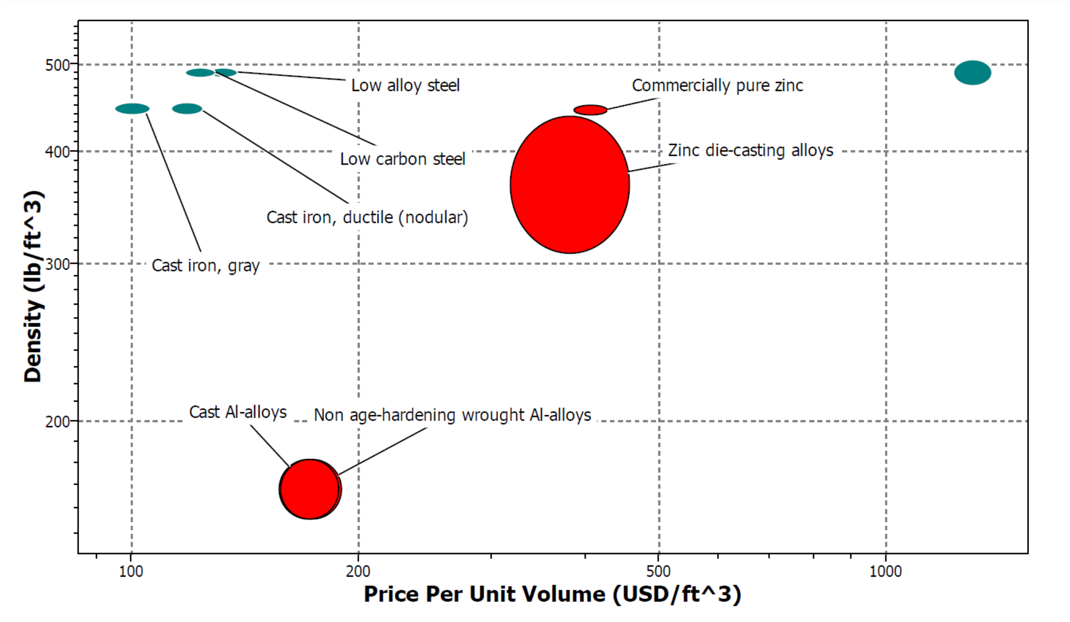

Figure 3.2: Logarithmic Plot of Metal Density vs. Price per Unit Volume of Material.

The next major decision influencing design was identified as that of die casting versus machining from stock. The pros and cons of either manufacturing method are tabulated in Table 3.1: Pros and Cons of Aluminum Alloy Machining vs. Die Casting.

Table 3.1: Pros and Cons of Aluminum Alloy Machining vs. Die Casting.

MACHINING		DIE CASTING	
✗	Significant tool wear. (Could drive production costs up)	✗	Trimming operations required for flash and overflow removal. (Added lead time)
✓	Little to no custom tooling required for start-up. (Lower initial investment)	- -	Die life limited to approximately 200k shots. (100k units of product per die set)
✓	Instantaneous implementation of design changes. (Reduced time to market)	✗	Process normally used for high-volume production. (New product. Unproven demand)
✓	Production can be outsourced. (Storage of final product: possibly only overhead)	✗	Casting equipment, tooling, and operators required for production. (High start-up costs)

Second Concept

Based on the pros and cons outlined, machining appeared to be the more desirable method of manufacture. Keeping the selected manufacturing material and method in mind, the second concept began to take shape. For this concept, the front connector assembly would be inserted into a sheath-like crevice within the platform, while the rear connector would be cradled by a depression toward the back of the platform, and mated with a connecting rod of the same diameter of the seat mount as within the vehicle. The CAD modeling of this concept was being rendered when the design engineer noticed the complexity associated with modeling the sheath and mating bar to accommodate their intended components. This complexity was identified as a manufacturing cost driver as it translated to a high dependence on tolerancing, which was considered excessive for the intended function of the product. An incomplete CAD rendering of the second concept is depicted in Figure 4.1: Incomplete CAD Rendering of Second Concept.

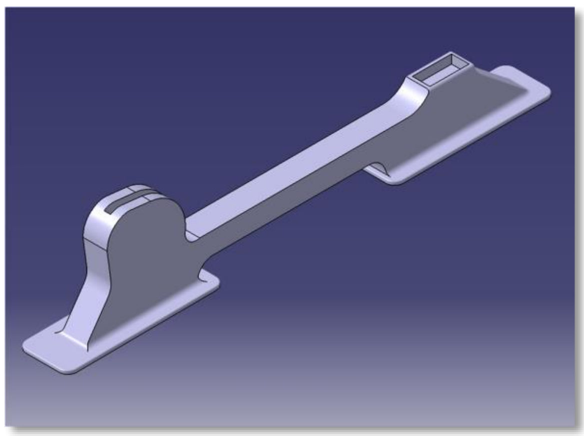

Figure 4.1: Incomplete CAD Rendering of Second Concept.

Third Concept

The brainstorming phase was revisited with the purpose of closing in on a design that was simple enough to be machined without need for custom tooling or frequent tool swapping. It was realized that by designing the product as a true, simple platform rather than an attachment, a lot less tolerancing would be required, and it would be easier to make accommodations for the previous generation of Jeep Wrangler seats (Backward compatibility). The concept arising from this bout of brainstorming is depicted in Figure 5.1: CAD Rendering of Third Concept, followed by a drafting representation of the new design in Figure 5.2: Drafting Representation of Third Concept .

The simplicity of this new concept prompted the design engineer to reconsider manufacturing materials and processes. It was determined that plastic molding became a highly attractive option, along with aluminum casting. The beauty of the design lay in the fact that it could be easily altered and optimized to be manufactured using both methods and a possible host of others. This was of particular interest, as it meant fluctuations in the cost of raw materials could be met with a large degree of flexibility. If there were to be a shortage in supply of the original material selected for manufacture, adjustments could be made with such ease as to greatly reduce, or—with keen projection—possibly eliminate losses associated with time-to-market delays.

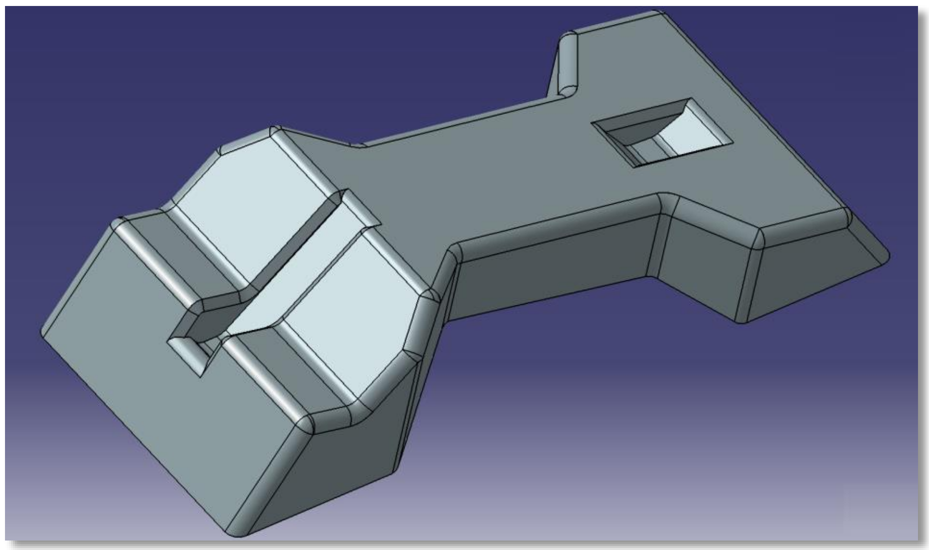

Figure 5.1: CAD Rendering of Third Concept.

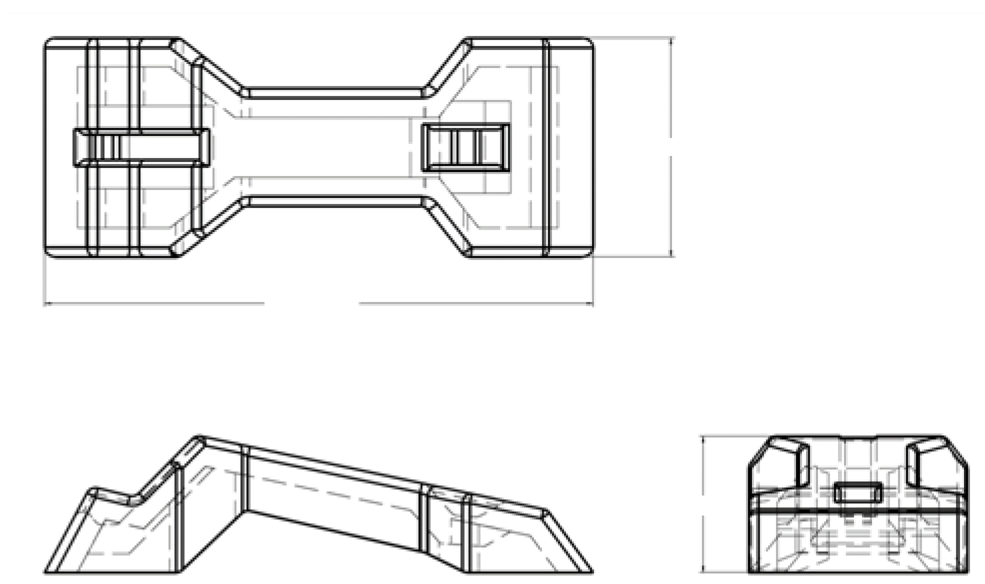

Figure 5.2: Drafting Representation of Third Concept.

The next step was to evaluate the new design by comparing it to that of the baseline. A quality function deployment matrix was constructed to ensure the chosen concept and primary manufacturing method would satisfy the goal of providing a high quality product to customers while making sound manufacturing decisions. The results are tabulated in Table 5.1: Quality Function Deployment Matrix, in which the prototype is shown to be the optimum choice (Lowest value in the totals column), with an improvement over the baseline by a factor of 81%.

Table 2.2: Quality Function Deployment Matrix.

	Producibility									
Options	Recurring Cost	Non-recurring Cost	Weight	Part count reduction	Manufacturability	Deveopment time	Lead time		Total	
Baseline	5	5	8	5	7	5	9		6.45	Baseline. Steel proposed. High reliance on multiple parts suppliers.
Combine parts and design for aluminum casting	3	9	2	2	3	2	5		3.70	High cost associated with casting equipment/tools. Time between casts.
Design main body for machining from stock aluminum extrusion.	3	4	2	2	3	2	3		2.75	
Design part as pedestal rather than attachment	3	4	2	1	2	1	2		2.35	Significantly reduces need for tolerancing. Complete CNC production.
Plastic part	2	1	1	1	1	1	1		1.20	Requires no coating. Molds needed.
Weighted Factor	20%	15%	25%	10%	15%	5%	10%			

9 - High Consequence
7- Medium High Consequence
5 - Medium Consequence
3 - Medium Low Consequence
1 - Low Consequence

Next, the design parameters for both concepts were entered into design for assembly (DFA) Product Costing and Simplification software for comparison†. The design efficiency of the baseline was rated at 1.77, indicating it as a perfect candidate for redesign. The prototype was rated at a favorable 64.87, indicating a good design with room for improvement. Total labor time was also a factor highlighting the stark contrast between the baseline and the redesign. It was estimated that the baseline would require 12 minutes for assembly of each platform, while the prototype was estimated to have a 19 second assembly time. The design for manufacturing (DFM) software however, gave a more trustworthy value of 3 minutes as the prototype manufacture time, as it accounted for more details of the plastic thermoforming process chosen. This higher manufacturing time still overshadows that of the baseline by 78%, highlighting it as the far more efficient option for production. The total cost comparison also revealed that the prototype could be produced for an estimated 17$, a savings of 89% per unit manufactured over the baseline.

†Provided upon request.

Upon review of the criteria satisfaction and pros associated with the current concept, it was determined that it should serve as the prototype to be honed for product release. The wording of the previous statement is entirely inspired by DFMA methodology, as it is the concept that has proven itself, not the particular design. Further product refinement would be approached with a degree of objectiveness to encourage discovery of new pathways to optimization.

Summary

- The project started off with a product baseline that, if produced, would require a lot of outsourced components, a lot of lead time, and a host of other undesirable factors.
- The second concept would have been milled from solid blocks of material, resulting in:

  - A lot of waste;

  - A lot of retooling cost;

  - A lot of handling per item, cycling from one tool to another.

- The third concept is simple enough to manufacture in a residential garage. This is an important advantage for an unproven product, as equipment to manufacture one item at a time would be adequate for startup. As an added benefit, a large number of the companies that manufacture molds also offer the standard service of providing high volume manufacture of products, utilizing their facilities and resources from start to ship. This provides seamless expansion in the event of a large, sustained increase in demand.

Conclusion

The design for manufacturing and assembly approach to the engineering process is a highly productive and time saving method of reducing costly pursuits of less than optimum design development. Such was demonstrated in this project during the process of rendering the second platform concept. The aspect of DFMA which promotes perpetual communication among product cycle team members across departments was instrumental in preventing the design engineer from spending more time rendering a less than optimum design. For this project, the journey toward optimization still has a few unforeseen detours ahead, but the DFMA product cycle arms companies with confidence to face such inevitabilities in an agile and flexible manner.

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