Design for Manufacturing and Assembly of a BAJA Steering Knuckle

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Abstract: *This study aims to demonstrate the application of Design for Manufacturing and Assembly (DFMA) principles to the steering knuckle of the all-terrain Baja vehicle developed by the UFPR Baja SAE team. The steering knuckle typically presents challenges in manufacturing and assembly, often resulting in parts with incorrect dimensions and higher rate of scrap. To address these issues, DFMA concepts from the literature that are most applicable to the design of this component were selected and implemented in the redesign of the steering knuckle. As a result, a 33% reduction in the number of parts and a 6.49% reduction in part costs were achieved, leading to significant improvements in the assembly process, as well as in the subsequent mechanical adjustments and maintenance of the knuckle.*

Keywords: DFMA, steering knuckle, BAJA

1. INTRODUCTION

The Baja SAE BRASIL program presents a challenge to engineering students, providing them the opportunity to apply classroom knowledge obtained in a practical envorinment, thereby enhancing their preparation for the job market. (SAEBRASIL, 2022)

In this context, the design of components used in the Baja vehicle prototype must consider criteria such as efficiency for competitiveness, cost-effectiveness, manufacturing and assembly feasability, among other desired characteristics typical of competition and series production vehicles. To achieve this, methodologies such as Design for Manufacturing and Assembly (DFMA) are particulary relevant, as they are used to optimize designs focusing on manufacturing and assembly processes. This methodology is grounded in concepts and criteria at streamlining, simplifying, and reducing costs in product development. (BERTIN, 2019)

1.1 Steering knuckle

The steering knuckle was selected for the application of DFMA in the Baja project due to its relative complexity in manufacturing and assembly. The steering knuckle is a key component that connects the suspension to the vehicle's wheel. Figure 1 ilustrates the assembly of the Double A-arm suspension system used by the UFPR Baja SAE team, highlighting the steering knuckle along with some other components of the suspension.

a) b)

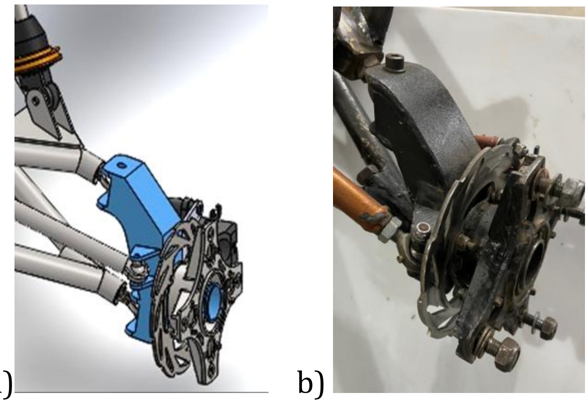

Figure 1: Steering knuckle a) project; b) as built

Figure 1 presents: a) the current design of the steering knuckle for the UFPR Baja SAE prototype, and b) the manufactured version. The project encountered manufacturing and assembly difficulties, as reported by the manufacturing team. Several parts had to be discarded due to manufacturing non-conformities, wich rendered them incompatible for assembly.

2. DESIGN FOR MANUFACTURING AND ASSEMBLY

DFMA is a methodology applied in product design to optimize manufacturing and assembly processes. (BOOTHROYD, DEWHURST, KNIGHT, 2011). It is primarly divided into three main applications: supplier costing, product costing, and product simplification (Figure 2).

The focus of product simplification shifts from individual componentes to the product as a whole. By simplifying the overall design, the number of parts is reduced, leading to a decrease in overall costs. (DEWHURST, 2019)

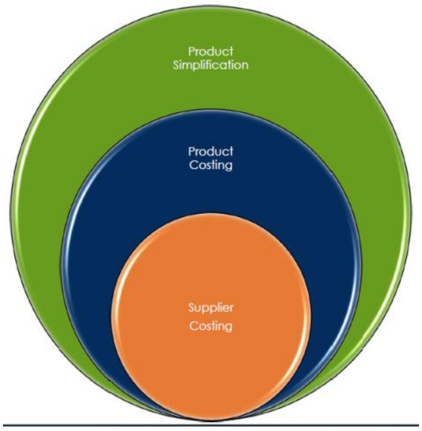

Figure 2: Design For Manufacturing and Assembly

The main principles of DFMA are:

Minimization of Parts: Reducing the number of unique parts in a product simplifies manufacturing and assembly processes. It lowers inventory costs, reduces the likelihood of assembly errors, and decreases the overall complexity of the product.

Design for Manufacturing (DFM): This principle focuses on designing products considering the capabilities and limitations of the manufacturing processes involved. Engineers can avoid features that are difficult or costly to produce when considering manufacturing constraints early in the design process.

Standardization: Standardizing components and processessimplifies manufacturing and reduces costs. Using standardized parts not only streamlines procurement but also facilitates interchangeability and compatibility between different products or product variants.

Simplicity: Simplifying the design of a product reduces manufacturing complexity and production costs. It involves minimizing the number of parts, reducing the number of manufacturing operations, and utilizing standard components where possible.

Design for Assembly (DFA): DFA aims to minimize the complexity of assembling the product. This involves designing parts with features that facilitate easy and efficient assembly such as standardized interfaces, self-aligning components, and modular construction.

Material Selection: Choosing materials wisely can significantly impact manufacturing and assembly processes. Designers should consider factors such as material availability, cost, ease of machining or forming, durability, and environmental impact.

Design for Disassembly (DFD): DFD focuses on designing products considering their end-of-life. By making products easier to disassemble, components can be more readily recycled or reused, which contributes to sustainability goals and reduces waste.

3. DESIGN OF A STEERING KNUCKLE ACCORDING TO DFMA

This study focused on redesigning parts without altering the assembly itself, analyzing one component at a time. The analysis considered the potencial effects of changing the material, the manufacturing process, or both, providing an opportunity to reduce production costs for the same part.

DFMA establishes design requirements that facilitate manufacturing and assembly. Among its recommendations isminimizing the number of components in each assembly. As shown in Figure 3, the application of DFMA allowed for a reduction in the number of steering knuckle parts from a) current design - 9 pieces to b) proposed design - 6 pieces.

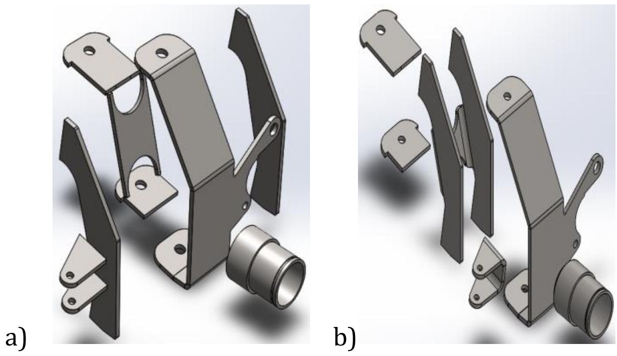

Figure 3: Steering knuckle a) current; b) proposed

Changes were proposed with consideration of the welding capabilities and the limitations outlined by DFM requirements to facilitate manufacturing. Figure 4 illustrates a) the integration of the sides and plate into a single piece, and b) the steering wheel holder. These modifications are designed to streamline the welding process.

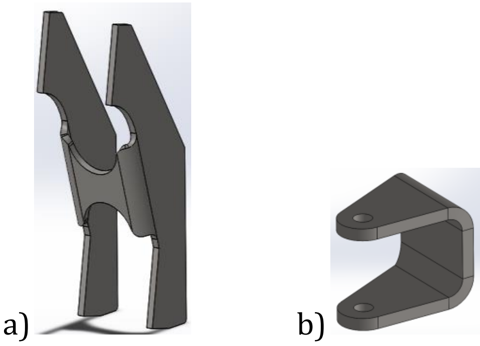

Figure 4: a) Reinforcement plate b) Steering wheel holder

The positioning features project illustrated in Figure 5 facilitates the correctly locating parts for welding.

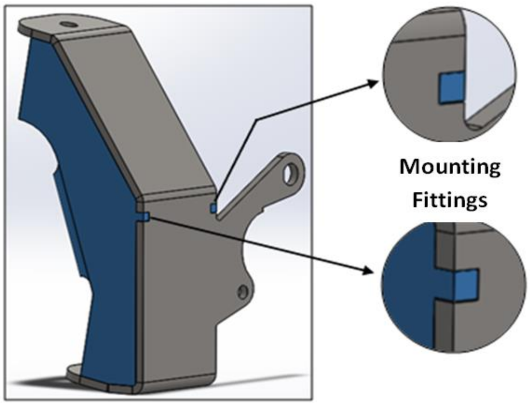

Figure 5: Positioning features

Figure 6 shows a) arm holders and b) a welding jig used to keep the right position for welding. This way, there is no need for subsequent kuckle adjustments when assembling the joint.

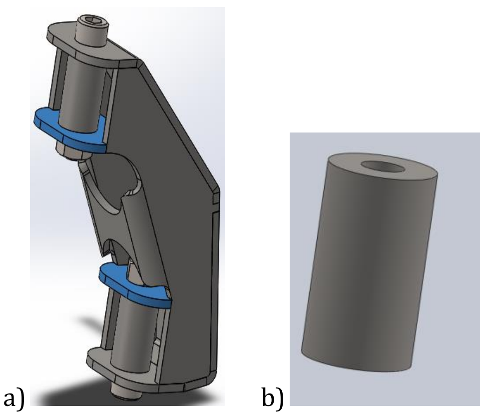

Figure 6: a) Arm holds b) welding jig

A hole was designed in the main body (Figure 7), and a chamfer in the shaft to allow welding positioning. This ensures the correct location of the shaft in the main body during the welding operation.

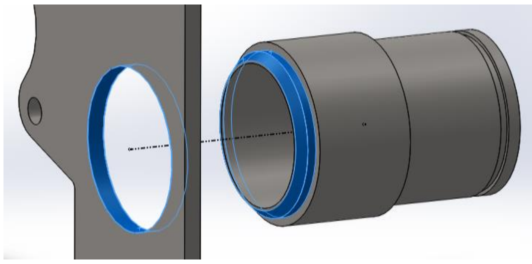

Figure 7: Self-aligning components.

The standardizing of components was achieved for 4 components. In this way, Figure 8, interchangeability and compatibility of right and left side knuckles are possible.

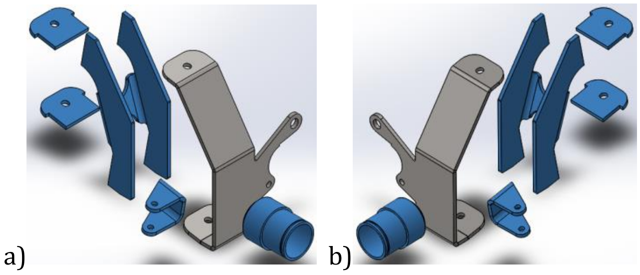

Figure 8: a) right side knuckle b) left side

DFA aims to minimize the complexity of assembling the product. This involves designing parts with features that facilitate easy and efficient assembly such as standardized interfaces, self-aligning components, and modular construction.

Figure 9 and Figure 10 show an assembly study carried out in a virtual environment. Only two tools are needed to mount all steering knuckles to the car suspension.

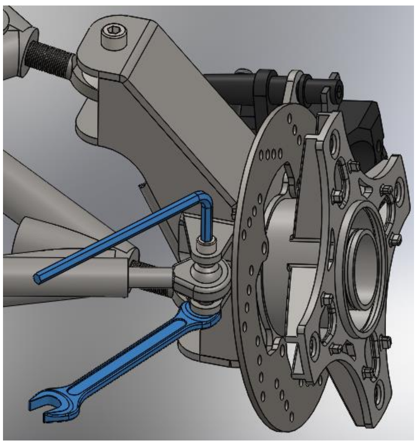

Figure 9: Steering arm assembly

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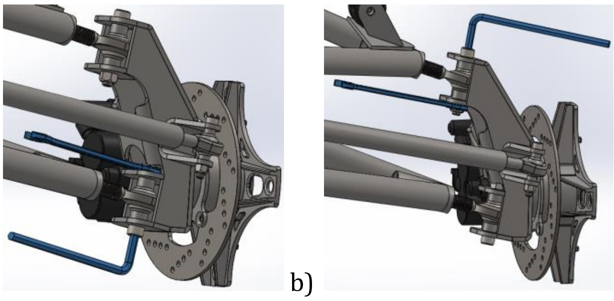

a) b)

Figure 10: Assembly a) lower arm b) upper arm

Subsequently, an analysis of the production costs for the current steering knuckle model was conducted. The results can as presented in Table 1.

Current model			
Part / Process	Quantity	Unitary Cost	Cost
Main body	1	18	18
Reinforcement plate	1	7	7
Reinforcement side	2	6	12
Steering wheel holder	2	1.50	3
Lower arm holder	1	1	1
Upper arm holder	1	1.5	1.5
Machined shaft	1	22.50	22.50
Welding	-	12	12
Total	9	-	77

Table 1: Cost analysis – current model

Similarly, an analysis of the production costs of the DFMA steering knuckle model was conducted. The results are presented in Table 2.

DFMA model			
Part / Process	Quantity	Unitary Cost	Cost
Main body	1	18	18
Reinforcement plate	1	16	16
Steering wheel holder	1	3	3
Lower arm holder	1	1	1
Upper arm holder	1	1.50	1.50
Machined shaft	1	22.50	22.50
Welding	-	10	10
Total	6	-	72

Table -2: Cost analysis – DFMA model

The application of DFMA concepts in the redesign of the current steering knuckle resulted in a 6.49% reduction in production costs.

4. CONCLUSIONS

The principles of DFMA were applied to redesign the current steering knuckle of the UFPR Baja SAE vehicle. The key outcomes included a 33% reduction in the number of parts and a 6.49% decrease in parts costs, along with significant improvements in the assembly process and subsequent mechanical adjustments and maintenance of the joint. These results demonstrate that DFMA is well suited for application in Baja projects.

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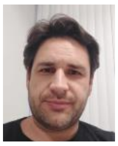

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