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# Re-design on Vehicle Front Support Structure Using DFMA

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## Abstract

In this article, we introduced our understanding to DFMA and its technical methods. Furthermore, we demonstrated the case related to BAIC vehicle parts improvement project. In this case, in order to simplify manufacturing and assembling process, we used the DFMA theory, techniques and tools to analyze the product design and related cost, identify cost optimization opportunities. In order to reduce cost and raise profit, we redesigned related parts for massive production vehicle model. At the same time, the redesign was applied to all existing models under the same platform, as well as new model development. Therefore, the benefit from this project was extended to the early stage of development of all products, to achieve the best design with optimal cost, and realize the highest product value.

## Case study: redesign Middle pole structure of front end of BIW

Number of parts: reduced by 66%
Manufacture time: reduced by 76%
Manufacture cost: reduced by 30%
Weight reduction: replace steel with plastic to reduce weight by 24%
Platform standardization: realize the platform standardization among different vehicle models to reduce the number of new development products

## The understanding to DFMA

DFMA （Design for Manufacture and Assembly）- in the stage of product design, with the full consideration of the requirements from the manufacture and assembly of the product, design product to have good manufacturability and assemblability,so that the quality problems in manufacture and assembly in the later stage of product development are fundamentally avoided. DFMA techniques can be used in the early design stage of the product design to make qualitative analysis and quantitative evaluation on various factors affecting the cycle time, cost and quality of the product development, and optimize product design. The basic idea of implementing DFMA is to reduce the processing time of single part and the total assembly time by reducing the number of parts and simplifying the structure of the product, therefore reduce the total cost of production. DFMA emphasizes on the idea of "**make things right the first time**", other than rushing into tooling design and manufacturing, and "modify repeatedly to make things right" after the products are made. Comparing with the traditional design, DFMA design has the advantages of shortening the cycle time of product development and launching, reducing the design change and manufacturing cost, reducing the cost of assembly and improving the quality of the product.

## Technical approach of DFMA

DFMA design usually adopts the following technical approach: (1) Establish concurrent engineering team and adopt design and manufacturing integrated development mode. Through the establishment of the concurrent engineering team, the design of the product is completed jointly by the design and manufacturing engineers, and material selection, processing technology, assembly process, inspection method, repair and maintenance procedure of the product are overall analyzed. (2) The design rules of DFMA are established. While doing product design, R &D people are guided by DFMA manual and related standards; (3) Establish the KPI system and evaluation criteria of DFMA -- an important task of implementing DFMA is to establish KPI system and evaluation criteria of DFMA suitable to the company's product and manufacturing characteristics, which are based on big amount of data from statistical analysis on existing products. (4) Analyze part shape & dimension, assembly process and manufacturing cost using computer aided analysis tools, compare and optimize various design proposals. At present, BAIC is using the DFMA software from BDI company.

DFMA software includes two modules - DFA (Design for Assembly) and DFM (Design for Manufacture). By analyzing the full assembly process and individual part manufacturing, the software helps engineers "see" the design waste, and it is a tool for "finding waste" and realizing Lean Design. By evaluating assembly time and cost, the DFA module judges the existence value of each part and the complexity of the assembly process, and compares different design proposals, simplifies the design structure and obtains the best design proposal. The DFM module guides engineers to make reasonable selection of different materials and processes when designing parts by evaluating the process time and cost of individual part. Considering the actual manufacturing conditions of suppliers, we communicated constructively with suppliers to achieve the best manufacturing cost.

Case background

As the connection between the internet and the automobile manufacturing industry is dramatically increasing, and market competition is getting increasingly fierce, all major automotive companies are facing the same problems when they want to ensure the core competitiveness, these problems include how to design a good product that really meets the needs of the consumer, and control the cost of the vehicle effectively, while still have enough profitability. As a large domestic automotive corporation, BAIC proposed the goal of " make low cost and good car " in 2015, and put forward the use of Internet mode to build a lean cost system that runs through the whole product value chain in 3-5 years to improve the core competitiveness. In 2016, the lean design concept was introduced. Through the form of theory training, vehicle teardown and cost analysis, the redesign optimization of the BAIC off-road vehicle has been executed, the cost optimization work was carried out to achieve the cost reduction and efficiency improvement, and the cost database had been gradually established. Since design determines more than 70% of the life cycle cost of the product, the cost control can be carried out effectively only when the design and the cost are optimized at the stage of product conceptual design. In 2017,

the leaders of the R&D center of the BAIC off-road vehicle strongly supported the work of cost control in design phase, and set up a design cost engineering department to carry out the cost control at the early stage of product design and the cost optimization in the later stage. In order to ensure the best technical proposal at the early stage of the design, the design cost engineering department set up an expert team to review the cost analysis of the new product design proposal in the early stage considering the value cost related to the product function at the conceptual design stage based on DFMA.

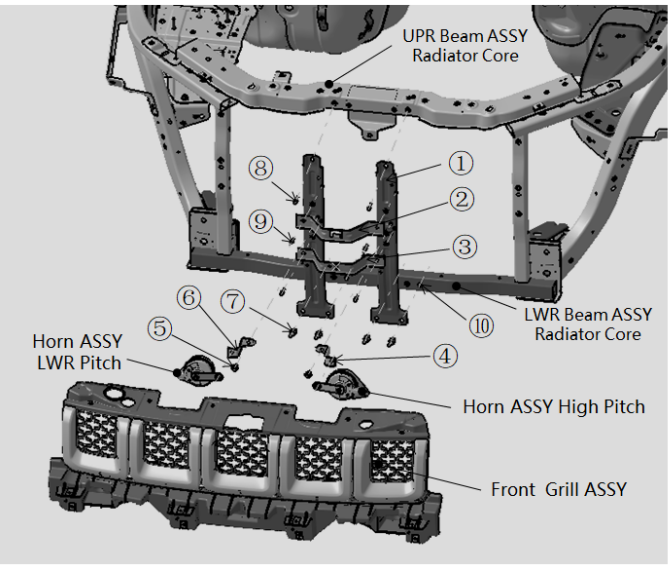
## The problem of the original design and the general analysis process

In April 2017, when one engineer of the design cost engineering department used DFMA software to analyze the front bumper system of a new model vehicle, she found that the mounting structure for the front grille onto the body was not designed well, the strength of the mounting points was weak, which could result in breakage. At the same time, the locations of the mounting points were far from the grille center of gravity, so the assembly stability was not good. The root cause of this problem was the adoption of old body structure and the location of the assembly points. "But is the old body structure a good design?"; "What if there are design defects in the old technical proposal which bring in design risks or complicated design structure and high cost to new products, what will we do?". The cost engineer had a lot of questions in her mind. She did DFMA analysis by importing the 3D models of the Middle pole of front end of BIW and other fittings. Based on the actual manufacturing and assembly process, she did detailed study on the structure, function, quality and cost of each part. It was concluded that there were big problems in the original design, both from manufacturing and assembling point of view. The actual design structure is shown in Figure 1, and the proposal is described as follows:

1. The main function of Middle pole of the front end is to provide the mounting points for the front grille and the compound horn. At the same time, it needs to have enough stiffness to meet the impact force requirements during the closure of the cover.
2. There are 2 Middle pole assemblies①, which are assembled with the upper and lower beams of the water tank through 1 bolt ⑧ and 2 bolts ⑦ respectively.
3. The bracket MID Up Radiator Grill② and bracket MID LWR Radiator Grill ③ are respectively connected with the Middle pole ASSY① by two M6 bolts⑨.
4. The bracket ORN ASSY-high-pitch④ and bracket ORN ASSY-lower-pitch⑥ are respectively connected to the Middle Pole ASSY through one M8 bolt⑤.
5. The middle pole, the bracket MID Up Radiator Grill, bracket MID LWR Radiator Grill and compound horn are all metal materials, which are relative heavy.
6. There were too many fasteners, the total number was 24, including 12 bolts, 6 welding nuts, 2 rivet nuts and 4 machined Fix Nut LWR Carling ⑩;
7. The assembly process was tedious: all parts are self positioned through the circular assembly holes, and they needed to be hand-held during assembly. There

was no error-proof and pre-positioning structure, so the assembly cycle time and precision were affected.

8. The two Middle Pole assemblies and the upper and lower beams of the water tank were assembled, then received electrophoretic treatment together with the whole vehicle. They would be delivered to assembly line afterward. After the two Middle Pole assemblies would need to be removed with the upper beam assembly, in order for front engine room to be assembled. The assembly process was too complicated.



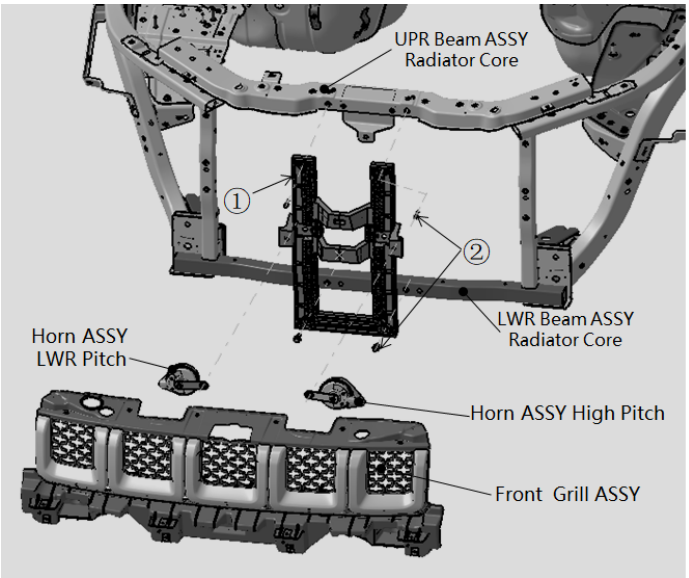

| NO | Part Name | Part Count |
|---|---|---|
| 1 | Middle Pole ASSY(2 Nuts) | 2 |
| 2 | Bracket MID Up Radiator Grill | 1 |
| 3 | Bracket MID LWR Radiator Grill | 1 |
| 4 | Bracket ORN ASSY-High-Pitch | 1 |
| 5 | Bolt (M8) | 2 |
| 6 | Bracket ORN ASSY-Lower-Pitch | 1 |
| 7 | Hex Flange Bolt W/Teeth (M8) | 4 |
| 8 | Hex Flange Bolt W/Teeth (M6) | 2 |
| 9 | Hex Flange Bolt (M6) | 4 |
| 10 | Fix Nut LWR Carling | 4 |

Figure 1. The original design proposal

Through the analysis above, the original design was too complex for both manufacturing and assembly. It is necessary to optimize the design from the two aspects of DFM and DFA. According to the minimum part design criteria of the DFMA, the bracket MID Up Radiator Grill, bracket MID LWR Radiator Grill, the bracket ORN ASSY-high-pitch and bracket ORN ASSY-low-pitch can be all removed. They provide mounting points for the front grille assembly and the compound horn assembly, so they can be merged into the Middle Pole structure. Through integrated design, the product structure and assembly process can be simplified. Considering the need for a platform which allows the new and old models to co-exist in the market, the mounting points of the original front grille were retained in the optimized front end Middle Pole structure. At the same time, the positions of the mounting points and structure are redesigned based on the latest shape of the new grille to ensure that the design structure of front grille of new model is optimal and the cost is the lowest. Moreover, in order to ensure the reliability of assembly, the number and type of assembly bolts for Middle Pole and body are reduced.

After the redesign proposal was carried out, the experts from various R & D departments were organized for the project evaluation and risk assessment. The conclusion of the evaluation was that the overall proposal was feasible. After several rounds of data structure optimization and material selection, the engineers finally

meet the requirement of performance indicators. The redesign structure is shown in figure 3.



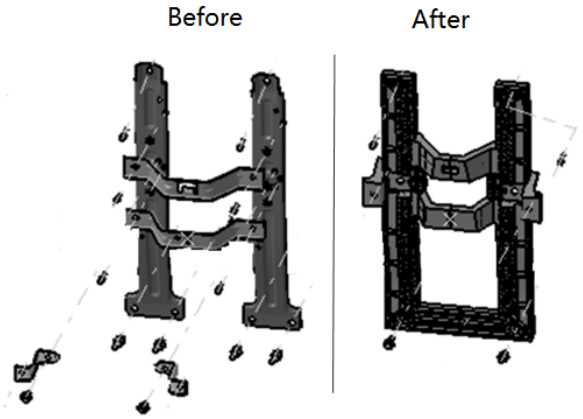

| NO | Part Name | Part Count |
|---|---|---|
| 1 | Middle Pole ASSY(2 Nuts) | 1 |
| 2 | Hex Flange Bolt W/Teeth | 4 |

Figure 2. The redesign proposal

The specific redesign proposal is described as follows:

1. Integrate 6 metal stamping parts into 1 plastic injection part①, and reduce 4 pairs of bolt and nut at the same time.
2. Unify 2 types of bolts connecting the upper and lower beams of water tank from Q1800616 and Q1800816 to Q1800625; and reduce the number of mounting points - changing the assembly points from 4 to 2 for the lower beam of the water tank.
3. Part material is changed to PP-GF30 which replaced steel, so that the effect of light weight is remarkable.
4. In addition to retaining the mounting points of the front grille from original design, the new plastic Middle Pole design has combined the design of the new grille with optimized mounting points and structure which are based on the center of gravity for the grille, to ensure assembly reliability of the front grille and the strength of the mounting points, and the platform standard application between the different models is realized.

## The comparison between original design and redesign




| DFMA Savings | | | |
|---|---|---|---|
| Item | Original design | Redesign | Savings |
| Parts | 30 | 10 | 20 |
| Fasteners | 20 | 6 | 14 |
| Actual time(s) | 552 | 131 | 421 |
| manufacturing costs (RMB) | 42.41 | 29.62 | 12.79 |
| Total Weight (Kg) | 1.28 | 0.97 | 0.31 |

Figure 3. Comparison between original design and redesign

The redesign improves the assembly of original design, mainly by removing a lot of bolt fasteners, unifying bolt and nut types, integrating all metal mounting brackets into one. And the redesign of the self positioning structure for assembly guidance is easy for assembling, avoided no error proof structure issue in original design. Through the results analysis of the original design and redesign, we can see that the number of independent parts has been reduced from 35 to 12, and 20 parts were removed; the assembly efficiency has increased by 70%; the assembly dimension chain has been shortened, the assembly precision has increased and the quality of the product has improved.

## Conclusion and lessons learned

DFMA breaks the wall between "I design, you make" in the traditional design procedure, combines various technical requirements such as market, performance, specialty, modeling, quality, technical process, supplier, procurement, cost and others, and designs the product with "simplest structure" to meet consumer needs in the process of product concurrent development. It ensures that the input and output ratio of products is the highest and the value is the highest. In the process of product design using DFMA technology, the product engineers analyze the manufacturing process and assembly process of the whole product, measuring the cost of each step from four aspects of material, labor, equipment and quality, to evaluate whether each design element is necessary and optimal. Through this " design based on cost " method, the design thinking of "pay attention to function and ignore cost" has been gradually changed in the minds of R & D engineers, and the design cost awareness of the R & D engineers is improved. From the source of the product design, the cost of the product life cycle (70~80)% is controlled to the optimal. And finally we achieve real lean production through lean design.

DFMA is a must-go road for product lean research and development. It is a necessary basic skill for product engineers. As an excellent designer, it is necessary to judge the necessity and rationality of each design, starting from the necessity of performance and function definition, then to the rationality of material and process

selection, and then to the leaning of manufacturing and assembly production. In the end,we can present perfect product to customers which can meet market needs. In order to achieve this ultimate goal, all companies are looking for the best way. The efficiency brings cost saving. DFMA methodology is shortcut route to realize conceptual design to functional embodiment.