Application of design for manufacture and assembly (DFMA) method to passenger car door design

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ABSTRACT – Design for manufacture and assembly (DFMA) guidelines aim to reduce part count, number of welds and number of operations. In this paper, the effectiveness of DFMA method is shown in passenger car design. Using Boothroyd and Dewhurst analysis, it employs a quantitative analysis of the design. Each part of the design is rated with a numerical value depending on its assembly requirements. The product is then redesigned, using the numerical values as a goal to be minimized. The outcome is a new design that has a shorter assembly time.

1. INTRODUCTION

The automotive body is perhaps the most important vehicle system in terms of impact, time, cost and customer satisfaction. For the car impact, the body defines the vehicle platform, which has many model variants. Models are often redesigned, often requiring completely new bodies. The time taken for the body is always on the critical vehicle development path, as obtaining and installing the tooling to stated quality requirements in an organized fashion always seems to take more time than is available. Often tooling is reworked until the project schedule dictates that it be finished. The cost for the body is arguably the most costly vehicle system, second only to the power train. When introducing a new vehicle model, costs associated with changes in the body are usually dominant.

For over 500 companies worldwide, DFMA has become a vital design tool in their effort to compete in domestic and world markets. The data collected from published literature on over 50 case studies conducted by McDonnell Douglas, an aerospace manufacturing company at its St. Louis plant, outlines the power of the DFMA methodology. Some of the results are reduction in manufacturing cycle time, part count reduction, part cost reduction, time-to-market improvements, quality and reliability improvements and reduction in assembly time. According to Geoffrey Boothroyd, Professor of Industrial and Manufacturing at the University of Rhode Island, the practices now known as Design for Assembly (DFA) and Design for Manufacture (DFM) had their start in the late 1970's at the University of Massachusetts [1]. Of all the issues to consider, industry was most interested in Design for Assembly.

Many has pointed out the advantages of using DFMA. Some recent application include the application of DFA and DMA in washing machine design where the authors concluded the study as achieving acceptable cost estimation [2]. Silva et al. [3] mentioned that DFMA enabled finding opportunities for improvement as they applied for electronic voting machine printer. Barbosa and Carvalho [4], who applied DFMA on aircraft electrical system design listed the advantages as allowing low cost, high quality and best optimized condition. Yuan et al. [5] mentioned good manufacturability and assemblability when applied in construction industry. Tasallato et al. [6] shows application with welding as an independent design module while Kim et al. [7] applied in bridge design. In automotive industry, Suresh et al. [8] studied the environmental impact of a charge alternator pulley designed using DFMA. Ardayfio [9] applied DFMA in automotive electrical and electronic system.

This paper extends the applicability of DFMA to passenger car door. It begins with a reverse engineering approach to a chosen car model and followed by design analysis.

2. METHODOLOGY

The study was carried out using a DFMA software based on Boothroyd and Dewhurst analysis. Several stages are carried out when implementing DFMA and the implementation is represented as in Figure 1 [10].

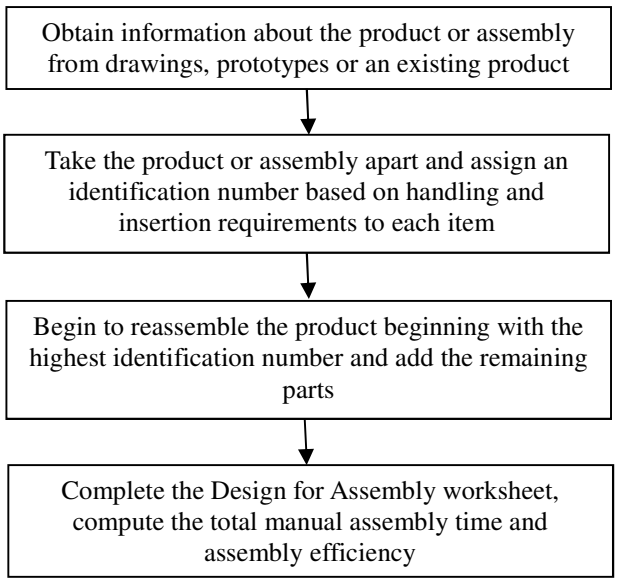

Figure 1 Stages of DFMA application

In the third stage, when beginning to reassemble the product, at each stage of assembly:

- A row of the DFA worksheet is completed for each part

- Never to assume that parts are grasped one in each hand and then assembled together before placing them in a partially-completed assembly.

The study was focused on manual assembly where it can be divided naturally into two separate areas - handling (acquiring, orienting and moving the parts) and insertion and fastening (mating a part to another part or group of parts).

The assembly efficiency a.k.a DFA index (E_{ma}) is calculated based on [10]:

$$E_{ma} = \frac{3 \times N_{\min}}{t_{ma}}$$

$N_{\min}$: theoretical minimum number of part

t_{ma} : total assembly time

4. RESULTS AND DISCUSSION

Shown in Figure 2 is one among many components of car door that has been disassembled and given identification number.

Figure 2 Component of Car Door

Nineteen different components were identified. Other than a variety of fasteners, these components are door frame, door board, internal and external door handle, window bar, glass window etc.

Table 1 shows the result of a new design developed after implementation of DFMA. Based on the criteria provided in Boothroyd and Dewhurst analysis, the theoretical minimum number of part is set as 9.

Table 1 Comparison of before and after DFMA application on passenger car door design

	Old design	New design	% Change
Number of parts	41	33	19.50 % reduction
Assembly time (second)	304.60	247.80	18.65 % reduction
Assembly efficiency (%)	9	11	22.2 % increment

By using DFMA, as many as 8 parts were identified as suitable to be taken out from assembly. No component was completely removed but the quantity is reduced. Such reductions are as follows:

- Flat head srew from 4 to 2 parts
- Pan head screw from 4 to 2 parts
- Round head screw from 12 to 6 parts
- Indented hexagon washer head screw from 6 to 4 parts

5. CONCLUSION

The study showed that further improvement may be made to the chosen car door. A calculated increment of 22.2 % efficiency may be achieved if the new design is adopted. DFMA has been shown to have another area for design improvement towards concurrent engineering, particularly in automotive industry.

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