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DESIGN, ANALYSIS AND IMPROVEMENT OF SEATBELT COMPONENTS

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Abstract: *This paper presents the design challenges form car manufacturer request to concept and concept validation, examining the customer's needs and assimilating them in the design goal document used by component suppliers for the automotive industry. The rules and regulations that apply to the to the safety systems components bought as international law, customer specifications and internal specifications. The design challenges for this are to integrate all the design goals into the product as sometimes there is a thin line between product failures and over-engineering as designers and engineers must not only build a product that is robust, but it must also be cost effective bought in used terms of materials and component design.*
Keywords: *seat belt, design, simulation, analysis*

1. INTRODUCTION

When a car crashes due to collision with an obstacle, the seatbelt is there to protect your body from severe injury. NTF states that seatbelts are the most important safety device in automotive, both in the front seats and in the back seats. According to NTF a three-point seatbelt decrease the risk of severe injury in a collision by 50 % [5].
When a car collides with an obstacle at high speeds, the occupant's inertial speed is very high and it takes a high force to stop the occupants. If the car collides with an obstacle during low speed, the force to stop the occupant is not as high. This means that the seatbelt will have to withstand a higher force to stop you when colliding at a higher speed. The result of this is that the seatbelt will apply a higher chest compression to the occupant.

2. FROM CUSTOMER REQUEST TO MANUFACTURING CONCEPT

For any new car platform, the same platform could be used form multiple car models, the manufacturer will make a design goal document (DGD) in which he defines and lays-out all the important information for the component manufacturers. The important information for seatbelt design is defining the safety and comfort requirements, this will include: positioning of each seatbelt component; the vehicle destination market, as each market has their own set of standards and directives or regulations for car safety systems (ex: ECE-R16 for Europe, FMVSS 208 and 210 for North America, CCC for China, etc.) [1]. Also a note must be made that a standard is different from a directive or a regulation.
A standard is considered by the general public or by the authorities as a basis for comparisons between different products or just to ensure that a product meets a certain level but in most cases only serve as a guideline and are not included in national legislation [2].
A directive in the EU is defined as a direction from authorities or as an instruction, such as a rule or specific order, this can over time be adopted as a national law by member states over time [2].
Based on the documents mentioned above if there is no current serial part that can fulfill the customer's request a multi-department team is formed in order to assure all needed factors will be taken into account. This factors impact departments such as: development, sales, purchasing, quality, manufacturing and logistics.
In the concept phase the department leading the team should be the development department, but it has to take into consideration all the requests and limitations imposed by the other team members.

3. DESIGN CHALANGES

A design methodology provides two important characteristics. First, it acts as a check list to ensure all design steps have been completed. Second, it provides focus on what the design must accomplish, based on the user's needs [4].
The design challenges for seat belt suppliers are in meeting the quality, innovation, time to market, global standardization and pricing requirements from the car manufacturers as they became stricter in all global region.
The quality aspect is higher as new revisions for the safety regulations of seat belt systems in a car become more demanding in order to allow car manufactures to have the same New Car Assessment Program (NCAP) rating. An evolution of the Euro NCAP ratings obtained from 1997 to 2007 is shown in *figure 1*.

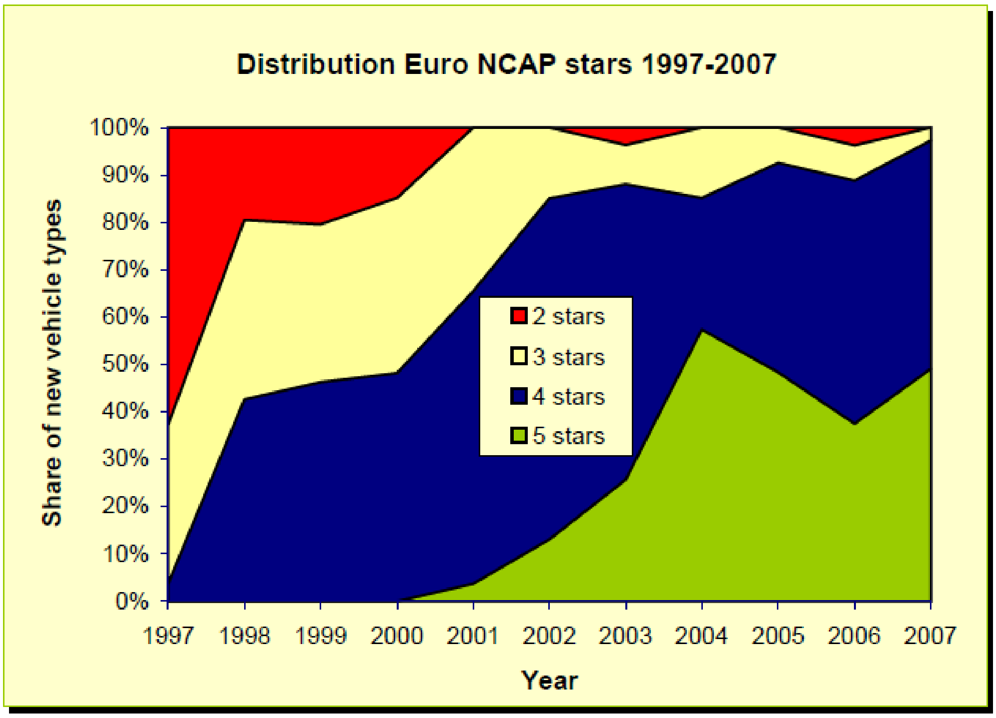

Figure 1: Share of Euro NCAP stars for new types of vehicle on the European market for the safety of adult occupants in the old Euro NCAP system [7]

Quality issues are raised as more pressure is put on the part supplier and given the high volumes of common parts between Original Equipment Manufacturers (OEMs) and this can result in potential "lethal" penalty fees [5].
Innovation is a key aspect in large seat belt manufacturing companies as they always try to stay ahead of the market, in regards of product performance, durability, weight, applications, size and last but not least cost. The innovation factor is important as it gives the company an edge over their competitor. This allows the part manufacturer to set a more favorable price could translate into a higher Earning Before Interest and Taxes (EBIT), resulting in more capital for future development investment.
Time to market for a product gets shorter every time, as the OEMs request products to be developed quicker for them to be able to maintain or gain a lead over the competition with the proposed innovation. So the time that you can best save is in the concept development stage as the tests and tooling manufacturing time tend to get longer due to high demand.
Global standardization is important for any part manufacturer as this will allow them to reduce costs due to needing les development time (one product) and les time to build and set up the manufacturing process (one process). Also the lessons learned could be shared more effectively and if the product can meet standards and regulations from different regions than after it is developed it could be sold as a standard product.
Pricing is a delicate balance between just seeing one project or also the future business it might result from an innovation. With this in mind the cost of a part is influenced by factors such as the impact it will have in terms of being a regional project versus a global one, or impacting only one customer versus multiple customers.

The trend in the automotive industry is to reduce the cost/part as the project life moves towards end of production. Also a careful consideration has to be mad in regards to the other project that may result from the same OEM as they can have a big difference in volumes, thus impacting the cost/part.

4. CONCEPT ANALYSIS AND IMPROVMENT

The first concept id built in a Computer Aided Design (CAD) interface to allow for easier future adjustments to the model, also in this case an initial check of the system integration form the component could be performed. After an optimization of the model is performed in order to better allow for easier real live part production and assembly a simulation should be performed using programs for Finite Element Analysis (FEA) studies on the part as shown in *figure 2*, also if the assembly has any moving component this could also be simulated to better understand the forces in the system.

This initial CAD model and simulation should allow for a quick and effective concept verification and improvement. Based on the simulation results the geometry or material of the part could change.

A prototype part could then be build using 3D printers as shown in *figure 3*. This will be used to verify product or part dimensions, any potential assembly problems and also possible manufacturing issues or difficulties.

After the development team decides that they have the best concept based on available data that prototype parts from a more robust material and closer to the real life product could be built for testing. This testing will be performed with only a few samples and it has the purpose to uncover any possible design flaws in the product durability or performance and at the same time to give an indication if the sample could be over engineered.

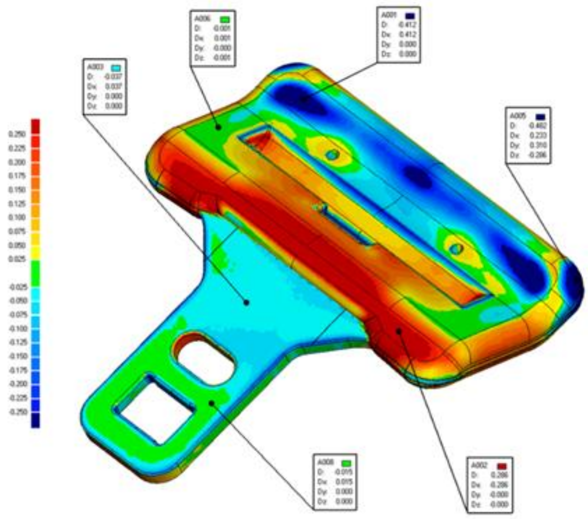

Figure 2: FEA analysis on seatbelt tongue [6]

Figure 3: Tongue produced using a 3D printer

Failure Modes and Effects Analysis (FMEA) is a method used for predict what errors that can occur and how serious they can be. A table is used where all the possible failures are presented. They are then rated on a scale from one to ten, the higher number they get the greater influence they have [5].

The method is about identification of errors in the components on system level and the consequences of them. An evaluation of how severe damage they can do, how likely it occurs and the probability that the failure is detected before it occurs. This will result in a greater chance to fix the problem before it occurs.
In this case a Design Failure Modes and Effects Analysis (DFMEA) will suit the needs and is better used when doing a concept evaluation for a new design.

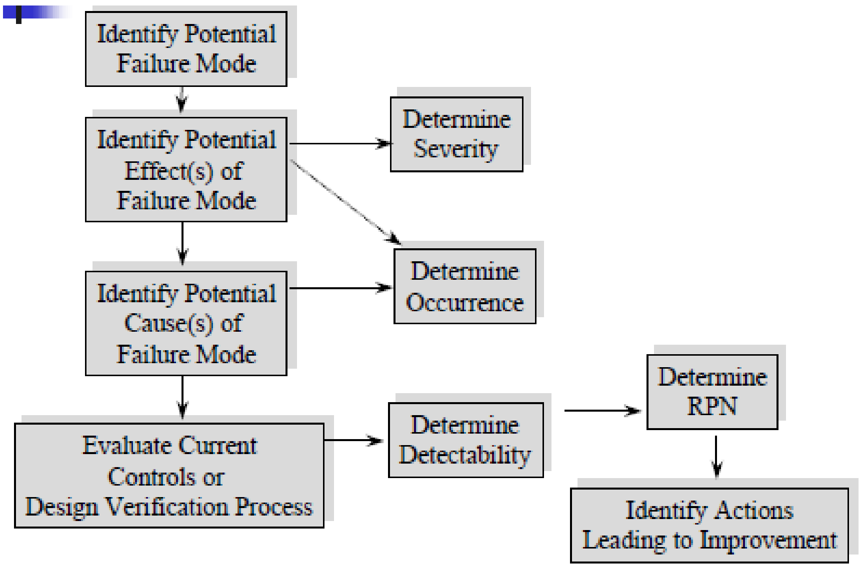

Figure 4: FMEA roadmap [6]

Using the FMEA analysis a product can be improved in all the phases from its life cycle, from concept to end of productions, and the lessons learned could be applied in the next concept design.
To aid this structure and because most durability and robustness test are destructive test, it is important to use statistic tools and guidelines to track the product performance over time and to better optimize it.

5. CONCLUSION

For the future of car safety the seat belt system will always be needed and it will always need improving as to reduce the risk of injury or death as much as possible.
That is why it is so important to have the improvements start using lessons learned, know-how and keeping an open mind for new innovation. The analysis of the concept should be done using 6 Sigma tools to better optimize the resources needed bought in terms of numbers of samples tested and also result interpretation.
Seat belt components can be and must be improved in any number of categories, from materials used for their parts to radical new concepts and designs, but this has to be controlled as to assure a product that it is not mature or lacks enough performance data is introduced to market.

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