CONCURRENT ENGINEERING – PROCESS REQUIREMENTS AND LIFE CYCLE INFLUENCES ON THE DEVELOPMENT OF AUTOMOBILE STAMPED PARTS

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Abstract. *This paper describes an application of Design for Manufacturability case in the development of sheet metal components for a Brazilian autobody design to aim structural cost reduction at the press shops, besides reducing the vehicle program schedule. Some topics of DFX toward the attendance of environment criteria during design development will be also described. The main objectives and the results achieved with the adoption of this strategy during the project development for a new vehicle model will be presented.*
Key Words: concurrent Engineering, DFM, DFX, forming, sheet metal.

1. INTRODUCTION

The globalization and the Brazilian politics of commercial opening in the beginning of the ninety decade had been economic and politician processes that influenced decisively in the transformation occurred in the automobile industry in these last times. The vehicles imported with accessible prices had provided to the Brazilian consumer, a new vision of car in terms of quality and what it could have in technology, style and comfort. The creation of the Mercosul economic block (Brazil, Argentina, Paraguay and Uruguay) offered a great chance of business for world-wide automobile companies in commercializing vehicles in these countries, besides being able to be polar regions for exporting global platforms makers (DI SERIO, 2000; DA MOTTA, 2001). Then, companies world-wide assembly plants had come to mount business structures in Argentina and Brazil - as the Toyota, Honda, Mitsubishi, Renault, Citroën-Peugeot (PSA), VW-Audi and Daimler-Chrysler - inciting the competition with the established and dominant companies already in the Brazilian market at that time - Volkswagen, General Motors, Fiat e Ford (DA MOTTA, 2001; AGUIAR, 2001).

Due keeping competitiveness, the companies of the Brazilian automobile sector, since middle of the decade of ninety, has invested heavily in the modernization of the productive area and makes strategically plans to launch new vehicles in the market in lesser possible time, then, the concepts and tools of simultaneous engineering are primordial to these companies to remain alive and, at the same time, attending market demands, norms and laws.

Competition incited for the domestic market, structure to be able to held projects and production of vehicles for world-wide distribution, was not new experiences for these new assembly plants. Then, to have fast development vehicle design, since its conception until its launching, inside of the stipulated budget, quality above of its competitors and on-line with the new world-wide trends, the application of the simultaneous engineering concepts were fundamental for the assembly plants installed in Brazil and the components vehicle makers, too.

The design development schedule of the metallic die stamping of autobody parts is one of the longest activities inside vehicle design schedule. Then, the application of the simultaneous engineering concepts in the stamped parts design is extremely necessary to achieve the programmed targets for the vehicle design. One of the simultaneous engineering tools is the Design for Manufacturability (DFM) which successfully applied to stamped metallic panel design for autobody.

2. SIMULTANEOUS ENGINEERING

According to Chiusoli and De Toledo (2000), there are many simultaneous engineering definitions from several authors. Basically, the main proposal of simultaneous engineering is the product development in the lesser possible stated period through the execution of the diverse phases of the engineering activities in parallel, including requirements demanded for all the elements of the product cycle of life. Many papers about simultaneous engineering show that the project influences, more than any other factor, the cost to produce a product. A traditional plot from Figure 1 shows two curves, one of them represents the influence of the product changing cost during the phase of the project and the another sample represents the influence of these alterations during this same period. Researches show that, just using traditional accounting, the automotive design process cost is about five percent (5%) of total product cost, in the other hand, seventy percent (70%) is its influence on total cost, and the rest of this accounting - material, labor, burden – is responsible for the other thirty percent (30%). From the perspective of the manufacture, less of the one than thirty percent of the product cost can be affected by initiatives of continuous improvement; taking account that product is already defined. Therefore, the project of the product exerts an enormous influence in terms of the company to compete in quality and cost (BOOTHROYD; DEWHURST; KNIGHT, 1994, HARTLEY, 1998). The designer should attend requirements from the different places, for instance, attend the maker who wants easy manufacturing process and less budget to implement it; the consumer wants product stile, functional, durability, reliability; the distributor needs easy way to transport and storage, the reuse company that wants easiness to recovery the components and materials; and to attend the society that desires environmental friendly product.

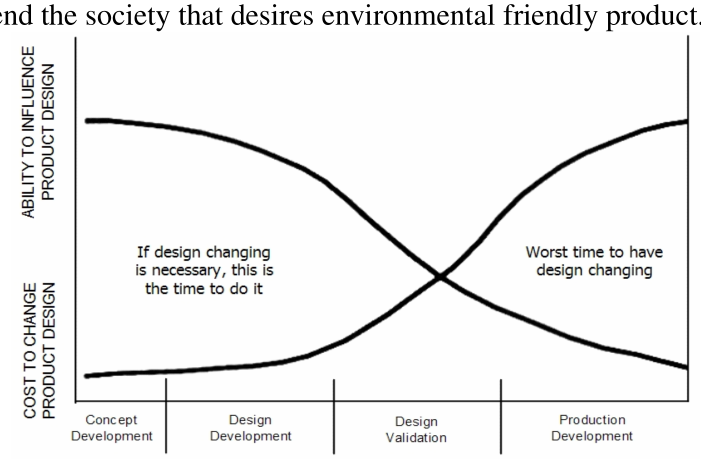

Figure 1: Cost and influence level during design.

3. DFM/A & DFX –SUPPORT TOOLS TO SIMULTANEOUS ENGINEERING

3.1 DFM

DFM (*Design for Manufacturability*) set of methods and tools that support simultaneous engineering and that can be interpreted as an analytical process structure of simultaneous engineering tools that provides to the product development and process multidiscipline groups conditions to design a product considering its *manufacturability*. Through the use of the DFM concepts, designers and engineers can reach their main target: to satisfy the requirements of the customer in terms of functionality, performance, style and quality to a low cost.

Each DFM tool focuses in a specialty of manufacture or a manufacture processes family. DFM-*Assembly* (DFA or *Design for Assembly*) indicated to product architecture and assembly. Other DFM tools (for instance, DFM – Sheet Metal Forming, DFM – Injection Molding, DFM - Machining) are indicated to parts fabricating. The development team work can use their variants to DFM for high or low volume, simple or complex and bigger or smaller products. DFM benefits are:

• Simpler fabrication and assembly	• Better quality;
• Improved ergonomics	• Reduced logistic time;
• Reduced rework	• Reduced time to market launching;
• Reduced mass	• Less production problems;
• Improved serviceability	• Reduced programmed beginning Investments.

3.2 DFA

DFA (*Design for Assembly*) is a DFM specialty; it is a structured method for improvements in the product components assembling. The both, DFM and DFA are essentials applications during product design and, many times they are defined as one tool called DFMA (*Design for Manufacturability and Assembly*). The following criteria are considered in a DFA study:

- Reduce and optimize part counts and types.	- Design parts so that they are easy to self-align & locate.
- Utilize optimum attachment methods.	- Ensure adequate access and unrestricted vision.
- Use layered assembly approach. Let gravity help.	- Ensure ease and safety of part and assembly handling.
- Minimize reorientations during assembly.	- Design parts that can only be installed correctly.
- Eliminate the need for adjustments.	- Minimize the number of tools required.

3.3 DFX

Conceptual simultaneous engineering tools as DFR (Design for *Recyclability*), DFE (Design for Environment), DFD (Design for Disassembly), etc, are contemplated in DFX (Design for X). The Design for X is a generic term for all types of simultaneous engineering tools which are oriented to consider environment, recycling, disassembly, life cycle, etc, requirements (KUO; HUANG; ZHANG, 2001; SCHMIDT, 1998).

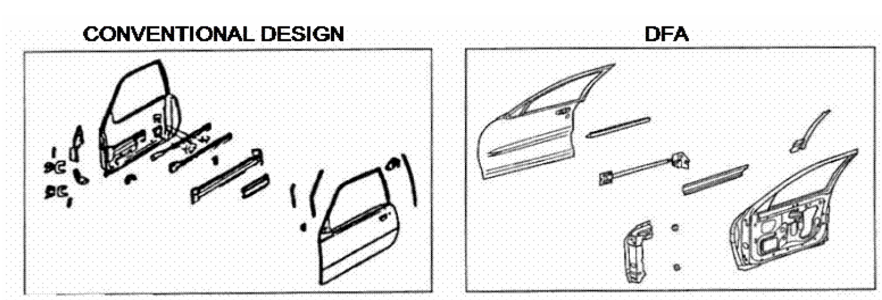

Figure 2: Door sets from conventional design and using DFA tools.

3.4 DFE

Design for Environment (DFE) is an industrial ecological tool that takes account all environment aspects in each phase of the product development process. Then, it is focused in reducing how much is possible, the impact in the environment of this product during its life cycle, since its manufacture until its disposal. This will only be possible, linking the analysis of the cycle of life of a product (LCA) results with the professional experiences of the engineers and designers (ADDOUCHE, 2003).
According to Hockerts et al. (1998), from DFE tools are expected to:

- Provide meaningful results based on simplified LCI (Li data and product descriptions;
- Be user-friendly and must not require special LCA expertise of its users (designer, R&D or marketing).
- Provide means of environmental exchange between members of an organization;
- Be adaptable to each individual company's need to assure the free choice of each company's policy in terms of database, and end result indicators.
- Produce design and end of life indicators.

In Addouche (2003), a series of questions and answer about DFE exist to guide us to better understanding of this concept:

3.4.1 Why using DFE?

The advantages are:

- Cost reduction;
- Product improvement;
- Pressure reduction from governmental laws ;
- Trademark image improvement;
- Environmental performance improvement.

3.4.2 How to apply DFE?

The design integration varies according to each company and it is basically applied in four main items:

- The investigation (according to the right directions);
- The promotion (according to the company political procedures);
- The follow-up of the integration process (reports and gratuities);
- The information feedback.

Three main activities resulting from DFE methodologies and are referring directly to product valorization in its end life cycle:

- Design for Disassembly - DFD;
- Design for *Recyclability* - DFR;
- Design for Remanufacturing.
- Activities whose main attributions are:
- The valorization rate improvement, facilitating the product components & raw material recovering;
- Material recycling capability improved;
- Components reuse to reduce the wastefulness of the natural resources.

3.5 DFD

According to Desai and Mital (2003), in the engineering context, disassembly may be defined as the organized process of taking apart a systematically assembled product (assembly of components). Products may be disassembled to enable maintenance, enhance serviceability and/or to affect end-of-life (EOL) objectives such as product reuse, remanufacture and recycling.
Then, the design for disassembly is necessary condition so that the products can economically be

recycle, improvement of the components and material reuse and remanufacture processes, extending the useful life of the products and components and the maintenance can be simpler, the output of all these improvements mean less raw material and energy waste and better performance in terms life cycle of evaluation. Benefits by using DFD (Duarte, 1997):

- "Core business components" can be recovered;
- Metals separation with no contamination, improving process quality;
- Dismountable non metallic parts can be re-processed.

Examples of vehicles dismantling lines - Car Recycling System (CRS) - can be found in the countries of the Europe, USA and Japan. An analogy of an assembly line plant can be made, however dedicated to disassembly, thus the vehicles are carried continuously in cradles/skids and, sequentially, parts of its structure (*autobody*, transmission, engines, cockpit, etc) are dismantled and separated until, in the end of this line, only metallic reinforcement structure remains (Nakamura; Yokota; Batalha, 2002).

3.6 DFR

The DFR success depends on the good DFD output. The DFD and DFR are closed related, because they are part of DFE methodology and should be applied together during design product development. According to Schoech et. Al, 2001, the DFR focuses on the *Recyclability*, maximum disassembly rate & end of life treatment of product.

3.7 - DFM APPLICATION TO AUTOBODY SHEET METALS

This case will be about the application of DFM in a specific sheet metal part designed for product and manufacturing engineering from a multinational automaker and has been manufacturing stamped parts in Brazil for decades. Until the end of eighty decade, any size and type of metallic parts was fabricated from press shop of this company. One of the strategies adopted in the beginning of nineties, was to be focused only in main stamped parts, for example, door, side panel, hood, fender, etc. Small parts and not "core business", small inner parts for instance, were outsourced, and then, the main results were reduction of structural press shop cost because of the disposal of smaller presses ("C" type and progressive presses) and labor. Nowadays, the press shops have only mechanical presses line which one with its die stamping. The stamped sheet metal part manufacturability criteria must be already established before starting its design, because it will be the manufacturing engineering standard and support to have the part defined with product and design areas (see the following maximum panel drawn depth and blank size criteria examples).

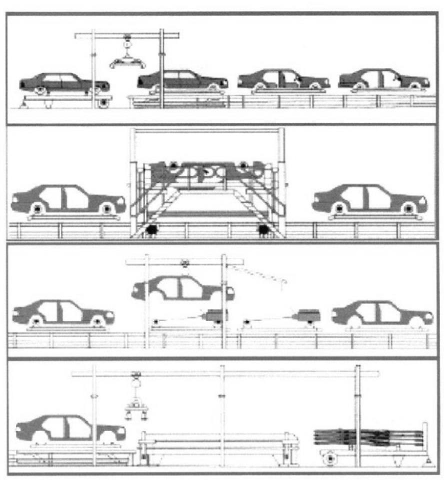

Figure 3 – Typical vehicle dismantling line (NAKAMURA; YOKOTA; BATALHA, 2002).

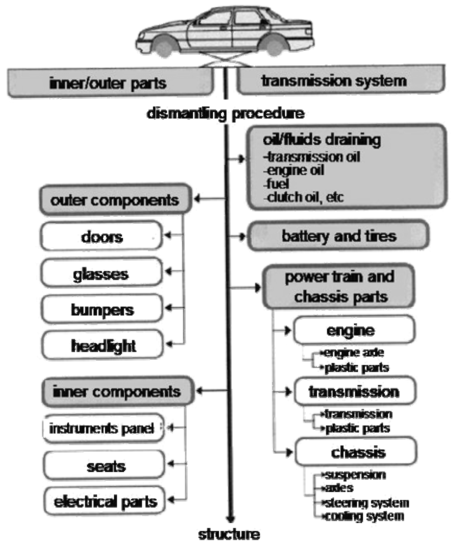

Figure 4 Car components & material from dismantling (NAKAMURA; YOKOTA; BATALHA, 2002)

Definition: Panel draw depth is the greatest depth of the panel in an elevation view in die position. Do not analyze flanges because they are drawn out flat in the draw die normal to the surface that the flange bends off from.

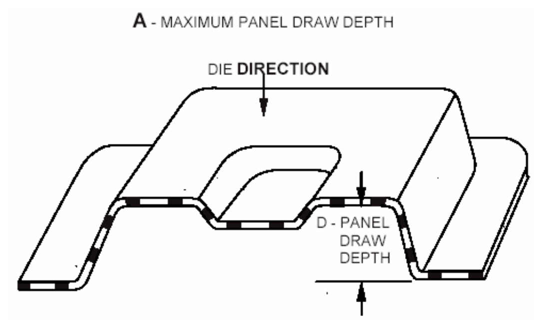

Figure 5: Panel draw depth.

The purpose of this characteristic analysis is to evaluate the blank dimension and if the sheet metal part neither being super estimated nor sub estimated to the presses line.

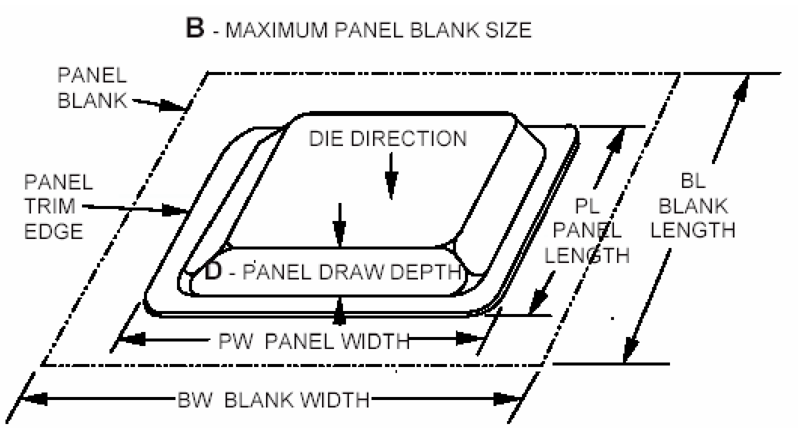

Figure 6: Blank dimensioning estimation.

If panel depth is deeper than the press size:

- Increases manufacturing costs due to requirement of a double action press resulting in a reduction

of throughput;
- Increases investment costs due to the requirement of a panel turnover;
- Reduces part quality and increases manufacturing scrap due to down dings caused by dirt in lower die cavity;

If panel size is bigger than the press size:

- Increases manufacturing costs due to the requirement of a larger press size resulting in a reduction of throughput.

This standard is making sense since applied in the beginning of the part design, through workshops, among design area, product and manufacturing engineering. In this phase the vehicle model is clay type and discussion is just about body stile. Once the clay model is "frozen", product and manufacturing engineering will work together to define the inner extension of body parts and the inner parts also. In this stage, the manufacturing criteria are well applied, because referring parts which, generally, does not affect de vehicle body stile.

Besides of the *manufacturability* criteria standards, other tools are essential for the DFM promotion in these phases of project, as cited below

- CAE (Computer Aided Engineering) - finite elements software: useful to estimate the sheet metal forming flow (mainly in the drawing operation), blank size and blank nesting. By using it, the following outputs can be achieved (DAMOULIS; BATALHA, 2003):
- Stamped part geometry and sheet metal forming evolution;
- Width sheet metal distribution;
- Equivalent plastic forming;
- Material flow;
- Blank holder and female die stamping force;
- Failure (tearing and wrinkle).

The finite-element method is effective in analyzing general structural problems. In sheet metal forming practice, two main finite element approaches have been used: one-step and incremental. One-step is more useful if not so accurate output requirements are needed just right after and before the frozen car stile phase. In a typical one-step solver, the final part geometry and boundary conditions are known and are used to predict blank geometry and size, thickness, strain and stress distribution and *springback* prediction (BATALHA; SCHWARZWALD; DAMOULIS, 2004).

- Engineered scrap has been used to have better relation between blank size dimension and its stamped, this data are based on similar past parts produced and benchmarking, all these database is from CAD system;
- CAD (Computer Aided Design): is an essential tool for promoting simultaneous engineering, because of the time saving to analyze the part characteristics and engineered scrap.

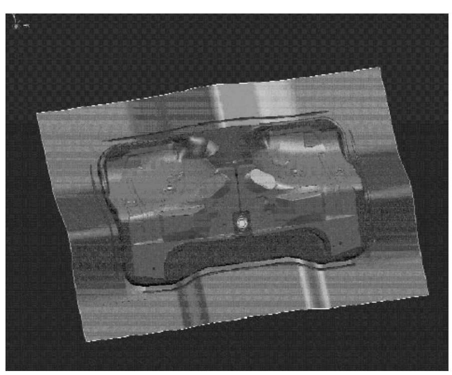

Figure 7: CAD example.

As example, the application of DFM to inner side panel will be described. Initially, the process planning was based to following stamped panel and blank size and shape:

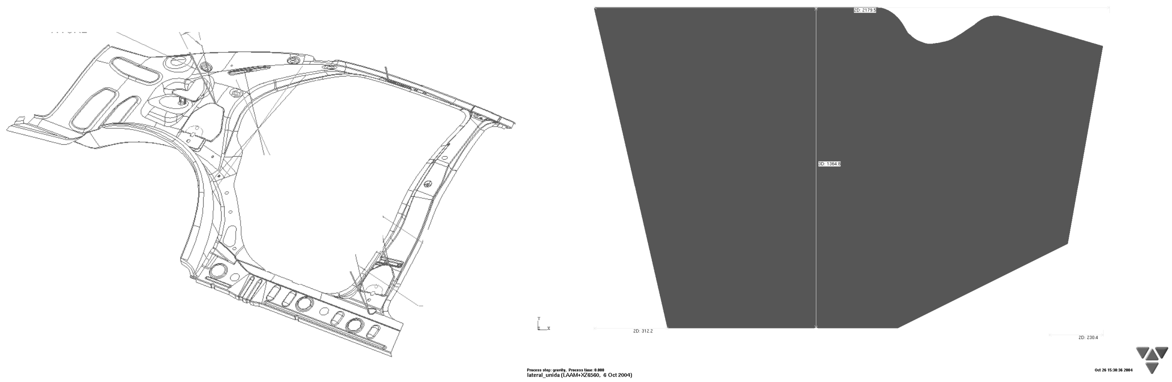

Figure 8: Preliminary part and blank.

After having product and manufacture engineers' workshops, a definition was established in terms of part processing and blank size and shape, see figure 9. Through analyzing stamped parts manufacturing requirements by means of finite element simulation and engineered scrap, the simultaneous process of two parts was possible to be made; the inner side panel and the outer extension side panel could be stamped just using a die set. Moreover, an operation was reduced comparing the preliminary process planning, it means one die stamping less.

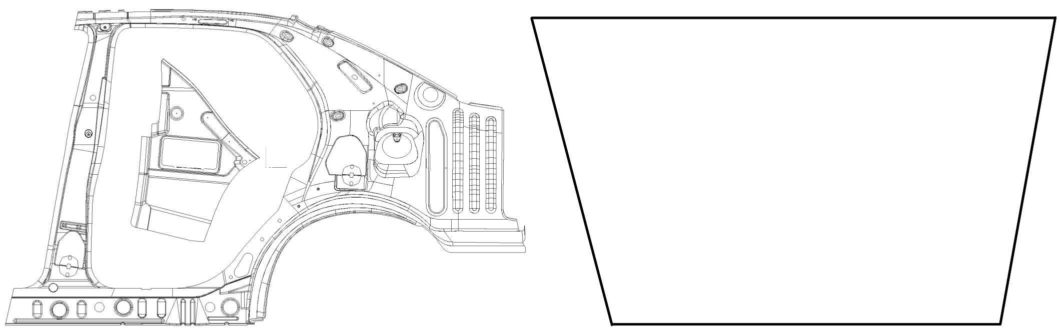

Figure 9: Parts and blank after DFM application.

4. CONCLUSION

In terms of the factory, the main results were:

- Layout optimization;
- Press line automation feasibility;
- Setup reduced and productivity increased;
- Racks logistic improved;
- Overhead reduced;
- Reduced stamped part scraps;
- Resources with mechanical presses selling.

In terms of the planning activities, the main results were:

- Time to market vehicle launching reduced;
- Press shop machinery and die stamping investments reduced;
- Indirect cost reduced.

The attendance of the manufacture criteria, not only anticipated the manufacturing engineering *autobody* design activities and, with this, reduced the time to market car launching, but also it made the reduction of investments and structural cost of the plant possible. This strategy will generate resources with the mechanical presses selling and create a new platform of process with lesser number of operations for part, in the average, comparing similar parts with previous designs. The use of the concepts of DFX in terms of the product life cycle analysis concerns of environment requirements is not really applied in sheet metal parts and their assembly in the *autobody* design in Brazil, as the DFE, DFD and DFR methodologies. Basically two external factors can promote the environmental, dismantling and recycling inputs in the *autobody* parts and assembly design: a legislation that regulates this kind of subject and the client's demanding for having car whose maker is adopting environmental issues in his designs.

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ENGENHARIA SIMULTÃNEA – INFLUENCIAS DOS REQUISITOS DE PROCESSO E CICLO DE VIDA NO DESENVOLVIMENTO DE PEÇAS AUTOMOTIVAS ESTAMPADAS.

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Resumo. *Este trabalho apresenta um caso de aplicação de projeto para manufaturabilidade no desenvolvimento de componentes de chapas de aço para a projeto de uma carroceria automotiva brasileira visando massa estrutural e custo nas estamparias, reduzindo também o tempo de desenvolvimento e produção. Alguns tópicos de DFX visando o atendimento de critérios ambientais durante o desenvolvimento do produto são também descritos. Os principais objetivos e resultados atingidos com a adoção desta estratégia durante o desenvolvimento de produto para o lançamento de um novo modelo são apresentados.*
Key Words: Simultaneous Engineering, DFM, DFX, forming, sheet metal.