6. Materials selection and the DFX methodology for product developments

6.1. Introduction

A topic about how materials selection when integrated into the design methodology can be carried out under several points of view when looking for a methodology for product development. The Design for Excellence, with emphasis in Design for Manufacturing and Assembly as well as a design for life cycle in mechanical design are primarily concerned here; As early postulated by several authors [87-89], however, topics of industrial design, meaning pattern, colour, texture, and consumer appeal are important, the starting point is always a good mechanical design, and the role of materials employed in its manufacturing and assembly, including their life cycle. Several authors have been looking to develop smart systems based on artificial intelligence, neuronal network, genetic algorithm, or even statistical methods in order to develop a methodology for manufacturing processes and materials selection which is design-led; using as inputs, the functional requirements of the design and the its life cycle [90-91]. This chapter introduces and tries to give a brief review of potential of these techniques as well some as new materials and process in order to include in the design for excellence new materials and manufacturing process keeping in mind the idea of sustainability and design for life cycle and the ways in which materials selection links with these.

6.2. Types of design and the materials and technology life cycle

As postulated earlier it is very important to use DFX since from the very early stage of the design. The degree of innovation or maturity (life cycle) of one design conception, will have a big influence on the DFX approach. It is not always necessary to start from the ground just with one abstract idea or a draft scratch. So during a DFX approach, three main types of design can be distinguished [87]:

Original design – does it means the development of a new idea or working principle. In this case new materials can offer some new and unique combinations of properties which enable an original design. High-purity silicon enabled the transistor, high-purity quartz, the optical fibre; new rare earth element with high coercive-force magnets, has enabled a telecommunication revolution, nowadays new nanomaterials are enabling a revolution in biomedical and sensory devices, etc. New materials can pull the development of a new product; or sometimes instead of this the new product can demand the development of a new material: nuclear and aerospace technologies are typical examples of products those have stimulated the development of lightweight materials and high-temperature alloys and ceramics. In the automotive industry, new materials and manufacturing process are enabling in the near future some changes of paradigm for the automotive powertrains as well for the automotive body in white, for instance, in the direction of the hybrid cars and fuel cells.

Adaptive or development design – In this case the designer takes an existing concept and he seeks an incremental advance in performance through a refinement of its operational principle. Here, the usefulness of new materials as well as the of the DFX approach are very important for the continued competitiveness of the product, however depending on freedom and profitability of changes needed for this adaptation, if it is not included already in the early stages of the conception of the former product. The recent needs of a design for compliance to new laws of recycling ecological management has created several demands on materials replacement in adaptive products: polymers replacing metals in household appliances; carbon fibre replacing wood in sports goods are examples that nowadays are going also in the reverse direction due the design for recycling approach. In some product branches there is very competitive market where it is mandatory to look for a continuous improvement on quality management as well as the logistic and economic aspects of the materials supply chain, manufacturing and assembly process. For some niches a product or even a manufacturing plant without this versatility or not allowing an adaptive or improvement, this means finishing a product and/or closing a plant resulting increasing of unemployment and poor social conditions, if these changes are not forecasted and prepared for new paradigms (original products) or at least for adaptive or variants conceptions.

Variant design – involves a change of scale or dimension or detailing without change of function or the method of achieving it. It is worth to mention that this type of design goes against the first commandment of the DFMA-DFX approach, which is the standardization and reduction of the number of parts and variety of a product. Change of scale or range of conditions for power, performance, higher or lower price markets, compliance to national laws may require change of material as well as manufacturing and assembly process. In this case it could be very important to have a reliable supply chain net near the plant or with a good management of the logistic demands, including here transport roads, port and railways connections, as well as energy and telecommunication.

Regarding the issue of technology life cycle, Dobrzanska-Daniekwiecz [91] has distinguished four different groups of technologies:

Basic Technologies – are common and easy and under a frequently use. Their competitiveness is decreasing or even already reduced. They are slowly falling into disuse.

Key Technologies – are regarded as the basis for the competitiveness of a product or service. Mastering them shall be a key factor for the continued success of the company, at least on a perspective of ten years.

Experimental Technologies – they are often in a testing or prototyping phase and their application is not wide accepted or employed. It could be forecasted a glorious future for them as potential key technologies. It is recommended a very strong protection against competitors and disclosures.

Embryonic Technologies – these are technologies in a preliminary stage of research and development. However, fundamental researches and preliminary planning of prototype are already carried out; the first concrete prototype does not exist yet. In this case there is a strong protection against competitors of similar technologies.

Last but not least, it is worth to regard the characteristics of the different macroenvironments' scenarios, where the design and manufacturing engineering are predicting to integration between Materials Selection and the DFX methodology for the product development. Here, Dobrzanska-Danikiewicz [91] has distinguished five different macroenvironments' scenarios:

Social environment – The social environment includes two main aspects:

Demographical aspects: are connected with the society size and age distribution. It represents the availability of a labour force (human resources) as well as an internal market and determines the profitability and development of some industrial and trade branches.

Cultural aspects: are connected to the lifestyle, fashion and peoples tastes. They influence the popularity of some product and services in certain social groups.

Technological environment – It assign the trend for the speed the technological changes. Among some favourable conditions, it can be mentioned: no limits for innovation and higher R&D budgets. It pays attention on the author's rights and an increasing of legalized product concerning and protecting the technological changes. Fast technological changes, sometimes even the birth of a completely new paradigm of technological innovation can contribute to the decline of a former technology and the creation of other ones. Thus, it can turn the new technologies into opportunity or threat.

Economic environment – It can be regarded as one of the most important macroenvironments. It is determined by the index of the domestic economy situation. Ex: economic growth rate, interest rates, exchange rate (currency appreciation), inflation rate, consumption rate, unemployment level and public debt.

Ecological environment – It is connected with the natural factors and environmental protection. The key issues concerning it are: raw materials deficiency, increasing cost of energy and pollution level control. It is also worth to mention the level increasing of the ecological consciousness of the people.

Political environment – The government political and legal environment is represented by the laws and legal acts. Domestic government stability, transparent tax systems, customs regulation and corruption level, are factors important to encourage an attitude positive for productive investments of the capital.

6.3. DFMA methodology, DFX and PLM product development

In recent years several new methodologies have been introduced and are contributing significantly to increase the quality and cost reduction, often related to simple efficiency gains. An example is the tools of Concurrent Engineering:

- DFMA – Design for Manufacturability and Assembly;
- DFX, where *X* stays for:
  - DF*R* – Design for Recyclability,
  - DF*E* – Design for Environment,
  - DF*D* – Design for Disassembly,
- PLM – Product Lifecycle Management.

This chapter discusses the use of those methodologies in the product development, first in general terms, and after this is exemplified for some automotive parts.

6.4. Concurrent Engineering

The conventional flow of product development in the automotive industry, in a simplified manner, through the following departments:

- Marketing, Sales Finance.
- Product Planning, Strategic Planning.
- Design Studio
- Product Engineering
- Shopping
- Manufacturing Engineering
- Production Engineering

Normally a new program starts in the commercial area involving: Sales, Marketing, Finance and Strategic Planning, but then go into the technical area of Product Engineering, Manufacturing, Purchasing and Production. Each department, with its duties and responsibilities are integrated into the product development process with the costs and times are strongly related to efficiency in communication between departments. Thus an efficient Project Management means planning activities seamlessly between different areas and ensures compliance within the time schedule of the pre-set so as not to harm anyone in the development chain and supply chain. The Concurrent Engineering a development tool that is assigned to unify areas around a common goal: meeting schedule (zero delay), reduce costs and ensure practice of continuous improvement processes. One of the first technical activities involving Concurrent Engineering will occur between the Studio & Product Engineering, which can often extend to the Manufacturing Engineering. At this stage the Engineering starts the advanced studies and definitions of design criteria. These criteria are some of the entries in the Studio process and show the technical requirements (laws, performance, and minimum clearances among others) that must be met for making such a digital mock-up or a Clay Model (Figure 6.1). In this step the product engineers meet with the so-called "Studio Engineer" to perform a job that will ensure that the surface to be released by the "Studio" will meet all technical requirements to the product. The Manufacturing Engineering can also be called to evaluate the proposals and discuss the technical feasibility or not of the ideas of creators (designers). Otherwise, i.e. if there is this work of Concurrent Engineering, it runs great risk of work being rejected by the Product Engineering, returning to the "Studio" to rework, generating unnecessary costs and precious time consuming, and compromise project schedule.

The next step occurs early in Concurrent Engineering of advanced studies and extends throughout the development of product design, involving Product Engineering and Manufacturing Engineering. In terms of internal groups, the most affected are:

- Product Engineering
  - Design Engineering - CAD (Product Design)
  - Development Engineering (Design Responsible Engineer)
  - Dimensional Engineering (GD&T)
  - Structure & Simulation Engineering (CAE)
  - Integration Engineering
  - Experimental Engineering
  - Field Test
- Manufacturing Engineering
  - Mould Design
  - Assembly (GA – General Assembly)
  - Body Shop (Jig and Fixturing Devices)
  - Tooling Shop

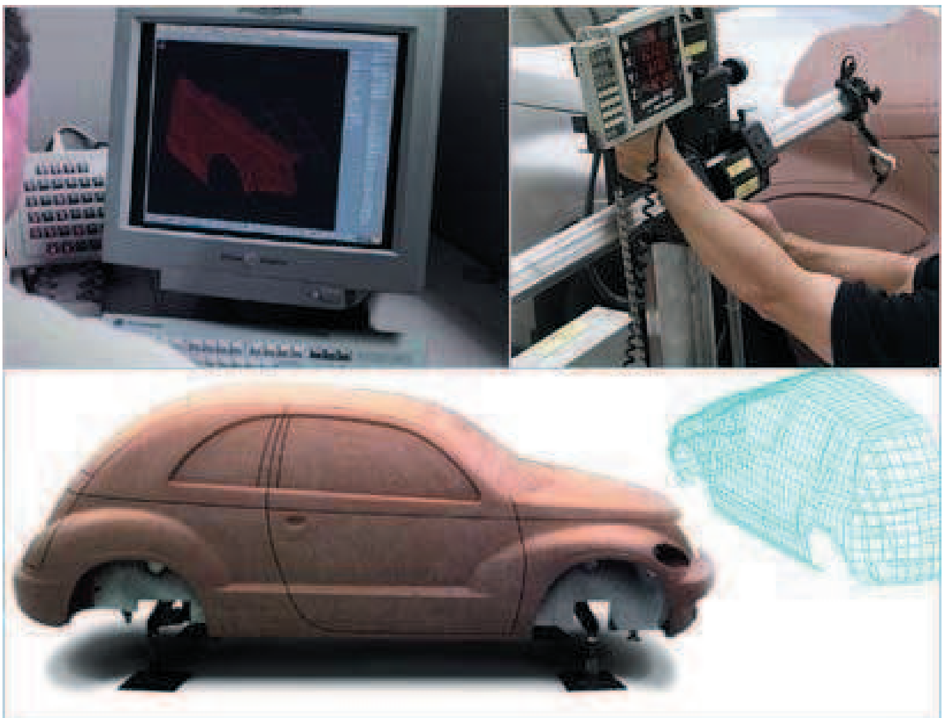

Figure 6.1. *Studio engineering for design process (http://www.chrysler.com/design/vehicle_design/process/index5.htm)*

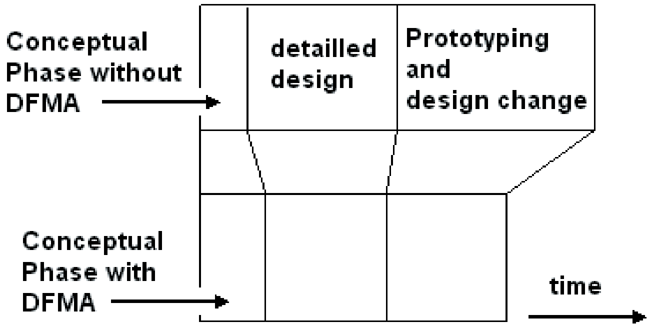

Figure 6.2. *Benefits of the DFMA use in early phases of the conceptual design through a concurrent engineering approach resulting in shorter chronogram for design process [27]*

The Concurrent Engineering activity between these two areas is of great importance given the weight they have in the final product cost. It is estimated that the stage of design consumes about 5% of the budget, but affects more than 70% of the final cost. After all the effect is a reduction on whole cycle of product development process (Figure 6.2). So all the effort applied by the DFX-Concurrent Engineering team at the beginning of the project will be valid.

The changes in this phase have cost almost zero or very low besides facilitating the work of all involved later. The converse of this is, unfortunately, it still occurs in many companies, all subsequent amendments to the release of drawings for production, has high costs and may cause schedule delays.

6.5. DFM & DFA

According K.L. Edwards [92], DFM is a systematic procedure to maximize the use of manufacturing processes during the design of parts and components. DFA is a systematic procedure that optimizes the use of components during the product design. Thus the goal of DFMA is to maximize the use of manufacturing processes and minimize the number of components in an assembly or final product.

For a long time in the department of Product Engineering, the designers worked in accordance with the internal criteria and hardly received feedback from other departments. The functional structure of the companies did not provide that information. The result was released without analysing pieces of Manufacturing Engineering, who elaborated when necessary document requesting the modification of the part. Was lost time and money by restarting the study and not infrequently the designer responsible for the analysis of the change was different from others who designed the component.

The methodology of Concurrent Engineering, with a focus on DFMA, resulted in products that are more functional, reliable, simple to manufacture, to assemble and cheaper. However, outbreaks in these costs, manufacturability and assembly, eventually bringing a new problem: the cost of repair and maintenance beyond the problem of environmental impact caused by the disposal of the whole set even if the failure occurred in only one component of together. With this new development tools had to be developed to mitigate the negative impacts caused by DFMA. This tool is the DFX.

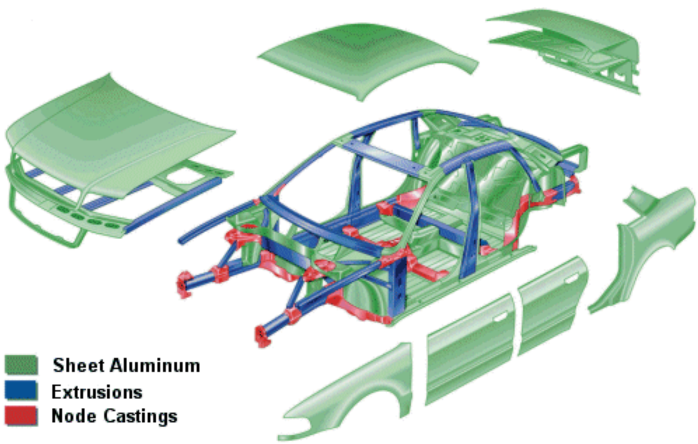

Figure 6.3. *Car Body in White: (http://www.ussautomotive.com/auto/steelvsal/alintensive.htm)*

Figure 6.4. *Monobloc automotive "body in white" structure. Colour-marked elements are made of stamped steel sheets: red: advanced ultra-high strength, yellow: very high strength steel, blue: - High strength steel, light blue – steel parts prone to absorb impact energy, purple - hot-stamped steel sheet*

In the case of external panels such as Roof, Fenders, Front Cover and Rear Panel, Door and Side Panel (Fig. 6.3), the use of concurrent engineering between Studio, Product Engineering and Manufacturing is extremely important since the study viability (feasibility study) can completely change the theme proposed by the designers. So get a lot of time in developing the project, although some heated discussions often occur at this stage, especially when the design surfaces are rejected. In this case the use of the light construction concepts as light alloys (Figure 6.3) or new high strength steels (Figures 6.4 to 6.7) as well sheet metal forming process represents a great synergy in terms of ecology and competiveness of the new cars [93-94].

Regarding yet the DFMA approach, it is worth to mention here the investigations carried out by the author and his graduating students towards the development of the tube and sheet metal hydroforming process. However the difficulty to control the geometrical tolerances and quality management, the hydroforming process presents a feasible alternative for the aspects of reduction of the number of parts and assemblies.[93-98]

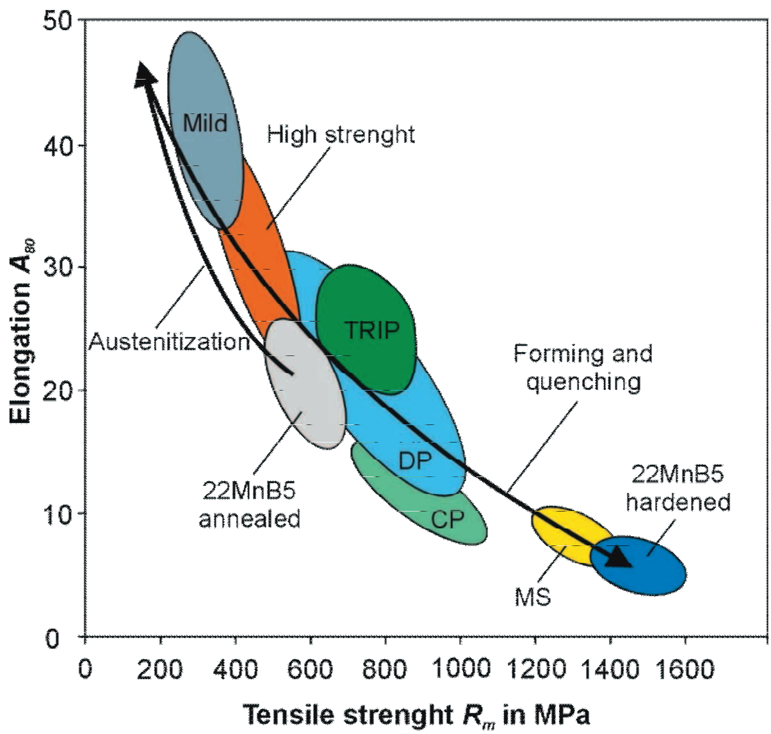

Figure 6.5.*New high strength steel sheets for one-box car body "body in white", outstanding new boron steels processed by hot stamping. (See figures 6.4 , 6.6 and 6.7)[102]*

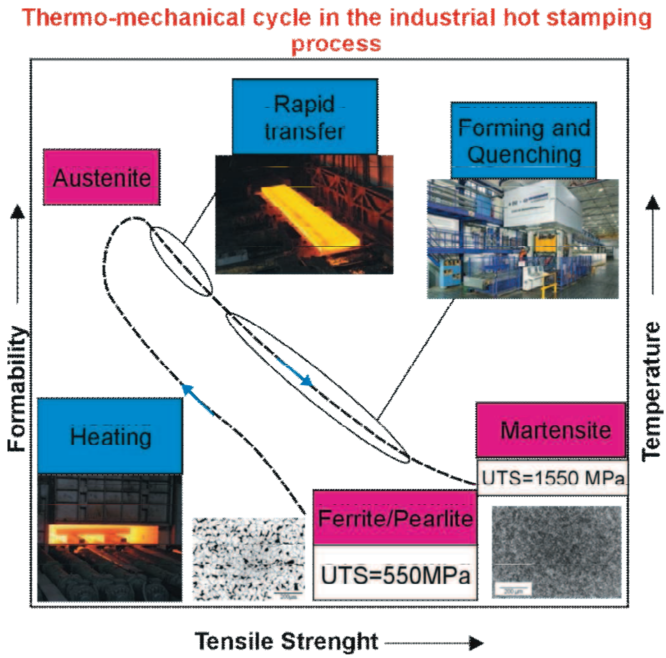

Figure 6.6. *Thermomechanical heat new high strength steels by hot stamping [93]*

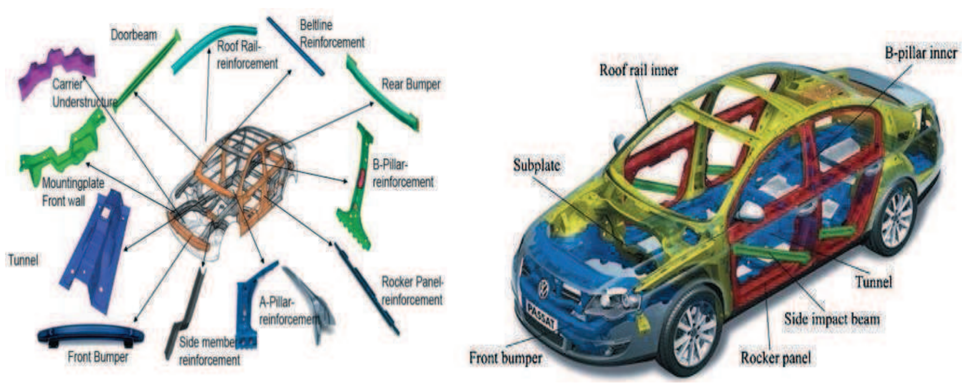

Figure 6.7. *Typical components of an car body produced by hot stamping of high strength steels [93]*

6.6. DFX – DFE – Design for environment

Social Responsibility and respect for the environment has been an issue addressed by the companies very seriously, because there is no way to ignore environmental problems. Many consumers are doing their part by requiring certificates attesting the compliance of companies to the environment. Certified as ISO 14000 ensure that companies manage risks and take care of waste generated in manufacturing or in laboratories and are concerned about recycling. In the project area, today it is imperative to eliminate the use of toxic elements such as Hexavalent Chromium, Lead, Asbestos, CFC, among others. Finally, works is focused on minimizing use of non-renewable resources, increased use of recyclable products and reduce pollution, conserve natural resources, accident prevention, emergency plan for containment and management of environmental accidents losses. Studies in the field of nanotechnology have shown that technology can help, and much in preserving the environment. Already there are paintings with Nano coating that are mechanically extremely resistant and keep the shine much longer. Windshield shall be coated with Nano-structured films and hydrophobic eliminating the need for traditional cleaners. The plastics will be stronger, lighter and with less material. The tires will be more compliant, more durable and with LED lights will consume much less power, which means smaller batteries. The Nano catalysts are more efficient and emission levels will fall considerably, not to mention the fuel cells to replace the current one day and polluting combustion engines. All this is already a reality, but at a cost still high. Research and investments in this direction will reduce costs and will enable a better and cleaner world (See Figures 6.8 to 6.13)[97-109].

Even some conventional manufacturing processes are facing some new ecological challenges, the development of machining technologies for mould and engine blocks, can be stated here as good example. Regarding an emphasis on reduction of cutting fluid on industry, some of them prone to cause diseases, the author has carried out together with his graduating students, several attempts to develop the so called dry machining during hard turning operations, by the introduction of special coatings or even with some innovative cryogenic process, using nitrogen as cutting fluid [110-114] as well as fundamental investigation about how to obtain ecological improvements through a better understanding of the tribological conditions at the interface tool-workpiece as well as at the chip formation process in manufacturing processes [115-118].

6.6.1. DFD and DFR – design for disassembly and design for recyclability

The amount of waste generated by industries has been the subject of criticism by public opinion and, in view of the social responsibility issues; the industries have given emphasis to material recycling. A new concept is central to recycling is economically viable: the DFD.

Draw considering dismantling the practice helps a lot of recycling, but unfortunately that is what is in practice. Many products are difficult to disassemble or require special tools, in addition to not bring instructions for disassembly. The disassembly for repair, exchange or replacement often results in destruction of or damage to all other components. In low-cost equipment until the damage is tolerable, but in high value-added maintenance costs can often be exorbitant.

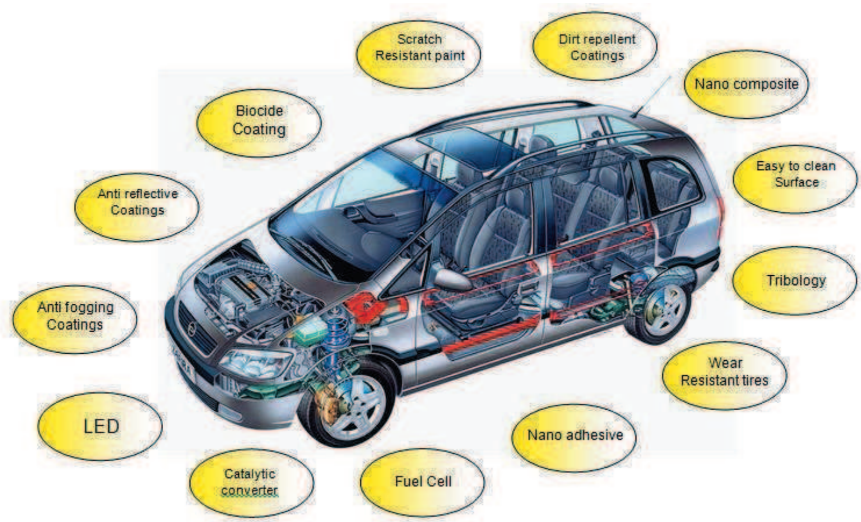

Figure 6.8. *Examples of potential applications of nanotechnology in cars*

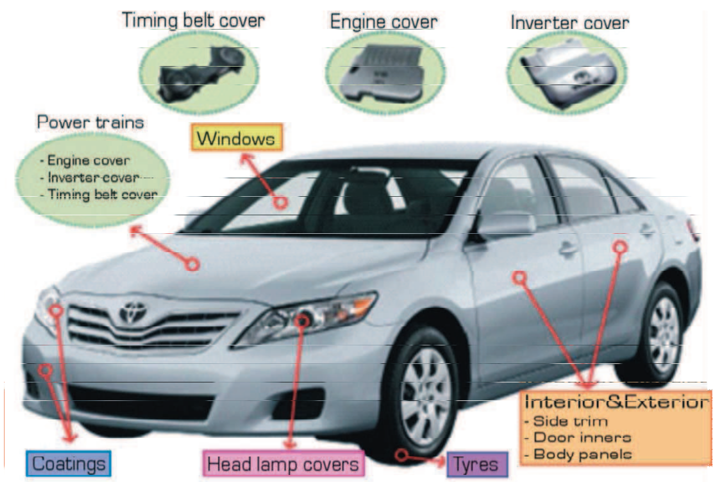

Figure 6.9. *Illustration of the usage of polymer Nano composites parts*

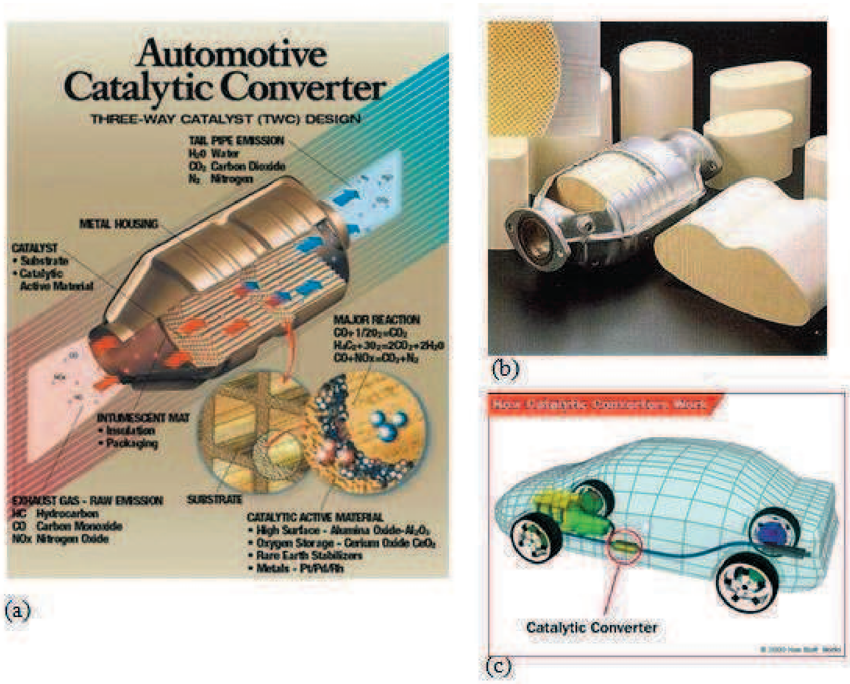

Figure 6.10. Automotive catalitic converter (a) – opeational schema b- Brick, c- place at car

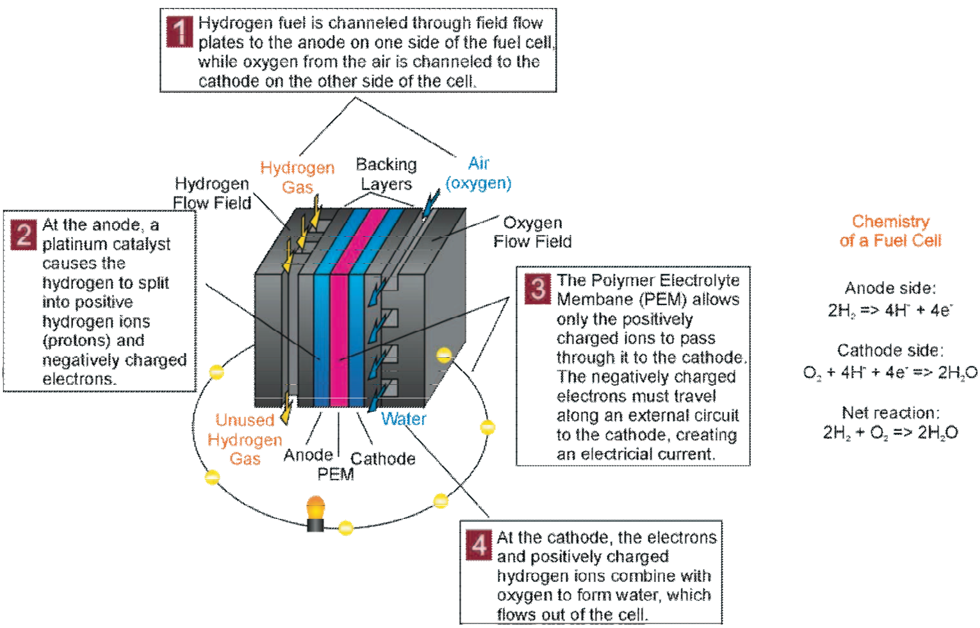

Figure 6.11. Hydrogen fuel cell – main materials, components and chemical principle

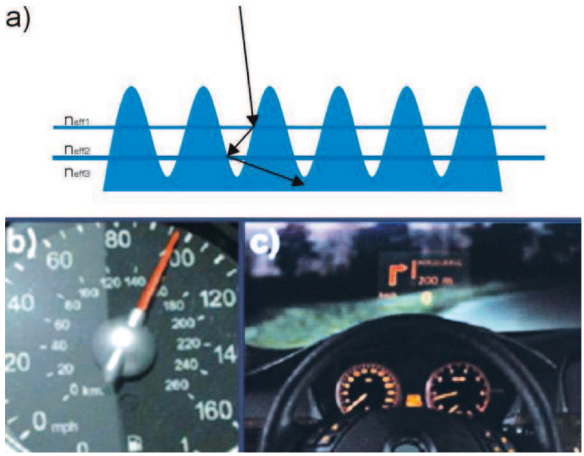

Figure 6.12. *Nano textured Anti-reflex surface (a) Light Deflection at a nanotextured surface (b) comparison of two nano texturing (c) automotive dashpot with antireflex surfaces*

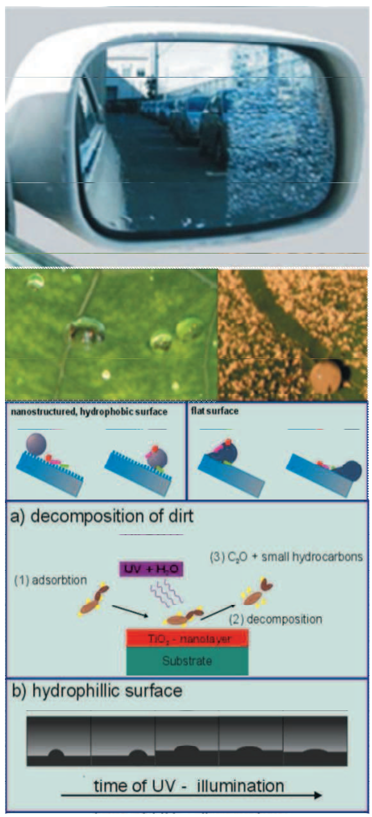

Figure 6.13. *Selfcleaning surfaces produced by a nanotechnology of hydrophobic nanofilm*

Parallel to this that designer should consider the concept of maximizing the reuse and remanufacturing, and select recycled materials in applications where no compromise security, since in some cases recycling denigrates the quality (plastic).

a)

b)

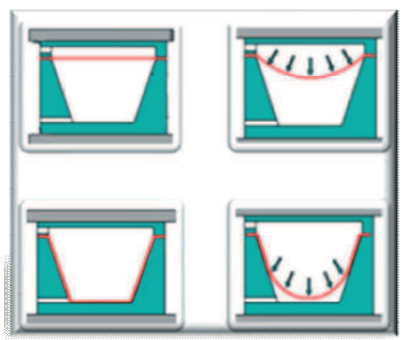

Figure 6.14. *Superplastic forming as a DFMA approach for automotive bodies; a) Examples of practical applications of superplastic formed parts in cars. b) Schematic principle of the sheet metal superplastic forming process*

A very common application for exterior parts such as headlights, the lens is polycarbonate and ABS housing or other material. The mounting assembly is made by ultrasonic welding which makes the separation and removal for recycling.

As mentioned earlier, the design-oriented disassembly also facilitates maintenance and reduces repair costs and replacement parts (serviceability).

Here it is worth to mention some works from the author about the new possibilities of joining processes in the assembly of automotive bodies, including in this case not only welding but regarding seriously the option of polymeric adhesive materials as well as polymeric sealing materials for the automotive design [117-119] . Superplastic Forming (SPF) can be also regarded here as a practical DFMA solution already applied to some cars (see Figure 6.14).

6.7. PLM - Product Life Cycle Management

Some tools already available in the market help manage the lifecycle of the product. Provide a collaborative environment where the product starts its life and continues until the end of production. Centralize all the data does not allow illegal copies and ensures the correct information in the correct way to the right people at the right time. Form a knowledge base for best practice (Best Practice) and continuous learning (Lessons Learned) in addition to efficiently manage changes (Change Management). All these facilities will help in reuse, standardization, in learning DFMA, DFX and consequently reduce costs and decrease development time.

Studies of the Aberdeen Group [94] show that management of a change is always difficult. It is often a source of inefficiency and a source of irritation for manufacturing. Usually when a project is to begin, it is in this moment of changes and conception that the problems begin to emerge, so manage them efficiently is very important. Even the giant Airbus A380 project has suffered from lack of integration when the German and French engineers were working separately on the fuselage and when they joined the sets just not mounted. What would be the reason? The two engineering were working with outdated data and failed communication. That same study shows that the best Aberdeen companies (Best in Class) often leads to serious changes and adopt the most advanced technologies for better control. Table 6.1 resumes the status quo of the integration PDM+PLM+DMU as recorded by the Aberdeen group [94]

In this sense, the author has recently discussed the importance to include the concepts and methodology of concurrent engineering and design for excellence at early stages of the engineering formation for the new generations of engineers [120].

Table 6.1. Status quo of the of PDM/PLM/DMU integration in the Design Studios [94]

	Top Companies	*Average*	*Worst*
PDM *- Product Data Management*	71%	39%	39%
PLM *- Product Lifecycle Management*	41%	19%	17%
DMU *- Digital Mock-up*	75%	32%	12%

6.8. Conclusion

The world's best companies adopt good engineering practices caring for the environment, being socially responsible and respecting the client. They are always anxious to improve their results and are open to new ideas and technologies. Accept the idea that any tool that will contribute to a more efficient outcome should be studied and adopted in the company if possible. Invest in training and encourage their employees to seek other forms of continuous improvement.

DFMA tools, DFX are reasonably well known in the market, but adopting them is no simple task. It is necessary to break paradigms and create a new culture among employees throughout the chain of product development, with Concurrent Engineering. Negotiator must have spirit, but with the attitude of win-win, while respecting all the difficulties and seeking the best solution that satisfies everyone. The implementation of ISO 9000 quality tools is also a good indicator that the company has a Quality Policy, a Vision and Mission in each department.

Managing the Product Lifecycle (PLM) market is relatively new and until recently was restricted to large companies due to the high cost of deployment. But with the falling costs of many medium-sized businesses are adopting and getting good results. Costs should fall, increasing the quality and customers will thank you.