Environmental Engineering and Management Journal August 2014, Vol.13, No. 8, 1997-2004
http://omicron.ch.tuiasi.ro/EEMJ/

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NEW APPROACHES IN THE DESIGN OF PLASTIC PRODUCTS FOR EASY RECYCLING

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Abstract

The researches were initiated in the context emphasized by the competition having the idea of profit at its base, and sustainable development, which imposes limitations through different regulations and standards which would involve supplementary costs.
The research highlights the main trends in plastic product design in conditions of sustainable development of society. Plastics have an important role in the configuration of the new products just in the phase of conception. Having in mind the main advantages of the utilization of plastics, the expectation is to see an increase of the weighting of these ones in the products development. The paper underlies the fact that the new approaches of the life cycle of a product, and especially the conception phase are essential for the entire life cycle, taking into account the fact that the polluting agent is paying and the producer must take into account its extended responsibility, beyond the product sale.
This paper highlights the relevance of the retrieval of the product as a very important phase in sustainable development. It is stressed that, even since the conception phase of the product, there must be taken into account the recycling of each life phase of the product. This is applicable especially in the industry of automotive, which is under the pressure of the sustainability. In this context, the role of plastics will increase simultaneously with the solving of the recycling problems.
The advantages of using plastic materials (optimization the geometry of the product, the possibility to enclose into narrow spaces, the weight decrease, the fuel consumption diminish) are reflected gradually, together with the increase of the recycling rate.

Key words: design, development, plastics, product, sustainable

Received: February, 2014; Revised final: August, 2014; Accepted: August, 2014

1. Introduction

The life cycle of a product, starting from its conception and up to its removal from the environment includes a succession of phases that follows some steps: product idea, fabrication, distribution, elimination.

After the market study the product is developed in the stage of project, passing through the followings steps: feasibility study, conception, designing, creation of the prototype, industrialization. During product design, some objectives are addressed (Per and Zika, 2009).:

- design orientation to ensure efficient production;
- correlating the costs and the performance of the product;
- testing the prototype to highlight product features;
- reduction of the time of launching in manufacturing.

Since the sustainable development principles are associated with the concept of green products, the improvement of the environmental performances of the products is a priority for the development of sustainable production and consumption. The ruthless confrontation between the idea of profit and the costs determined by the green products has widened the objectives of the conception for the product. Therefore, the liability of respecting the

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environmental requirements was included in the product conception objectives.

The paper discusses the context generated by the plastic use in automotive industry and the main challenges in the product design and manufacturing to ensure the reusing of plastic materials resulted from the disassembly of products containing plastic.

2. Research methodology and epistemological reference point

The approach of this paper is considered as a process of reflection regarding the epistemological and methodological conditions which allowed the accomplishment of a thorough scientific research. The research methodology was selected taking into account the following issues: (i) the research subject, respectively the study upon the new approaches regarding the conception of plastic materials; (ii) the approaching way, characterized by empiricism.

Table 1 describes the systematic manner of our methodological options completed on each step of our endeavor and the epistemological choices in close connection with the type of research.

The methodological project was based upon explanation and reasoning. The epistemological reference points were as follows:

- the interpretative paradigm for the comprehension for the reality;
- the constructivist paradigm which emphasizes the building-up of anticipation of some tendencies;
- the positive paradigm, used mainly as an exception for the deductive explanation in report with the theory.

Regarding the epistemological approaching style, the paper is situated between etic and emic. The etic approach type is invoking the general characteristics and objectives of the product conception in order to underline the elements of universal applicability. The emic approach is underlining the importance of the unique characteristics, by indentifying the characteristics specific to the group of products, accentuating the interpretative-comparative dimension. The two approaches are present complementarily during our researches. The methodological study support was sustained by the literature in the field of research.

Table 1. The synthesis of our epistemological and methodological options

	Options	***Chosen solution***	***Observations***
1. The layout of the research			
Demers	Hypothetical-deductive Hypothetico-inductive	Contextual study	The approaches are based on the approaching empiricism
Assumptions	Theoretical or deducted Induced or empirical	Induced or empirical	It is based on experience and the approaching empiricism
Tools	Theoretical concepts Operational concepts	Theoretical concepts Operational concepts	It is underlining the criteria which are allowing the outlining of the performance referring to the conception of the products made of plastic materials
2. The epistemological posture and the dimension of the research			
Epistemolo gical posture	Positivism Interpretivism Constructivism	Constructivism Positivism Interpretivism	The epistemological position adapted to each type of products
Dimension research	Description Explanation	Description Explanation	It is highlighted the particular dimension of each step of the research
Methodology			
Appropriated epistemological distinction	Etic. Emic.	Emic. Etic.	It is followed especially the understanding of the specific situations when there are used in the car industry plastic materials
Method	Quantitative Qualitative	Qualitative Quantitative	It is achieved a mixture between the qualitative and the quantitative methods
Data collection	Observation. Interview Questionnaire Analysis of statistical data.	Observation. Interview Questionnaire Analysis of statistical data.	The orientation of the research towards the analysis of the phenomena within the organizational structures which are supplying the car components and accessories
Implications			
Implications	It is followed a complex research of the product conception. It is followed to build-up a support in order to facilitate the process of taking decisions	It is followed a complex research of the product conception. It is followed to build-up a support in order to facilitate the process of taking decisions	There are proposed different instruments for the exemplification and the insurance of the performances in the area of car products (replacing the metallic parts with plastic parts)

The research techniques were based upon comparative analysis and prognosis, and optimization of product design in order to achieve an explicative and predictive construction. The methodic plan is based upon both the inductive and the deductive methods (it is achieved a mixture between the qualitative and the quantitative approach).

3. Plastic product design in the current view

During the creation of a product, the majority of the enterprises still apply a linear approach. This approach has been imposed by the organisation way of the company and by the informational flow between the different departments (Beju et al., 2006). The organisation of the company into departments corresponding to activities associated with the product life cycle, endowment with informational means according to the Computer Integrated Manufacturing - CIM concept remains a linear and sequential structure, taking into consideration the activities chain and extending the production cycle duration, until the product delivery. This traditional vision has the merit of restructuring and defining a necessary order in riffling the life time of a product, as well as its production processes, establishing clearly the responsibilities. Division of labour between different departments as well as inside them determines yet a narrow specialisation of the staff and the grouping conforming to the tasks they have to achieve. This way, each group is closed into its own idea on the product, in its culture and communication language (Ciobanu et al., 2006).

In the present time, different models of integrated engineering are in opposition to the sequential organisation. The activities overlap can be imagined first of all eliminating the borders between the phases of the product creation stage.

Organisation in parallel of the activities does not solve absolutely all aspects, the main difficulty being related to the human problems. To facilitate this restructuring, a solution consists in re-grouping physically the participants to the project in the same room, even if problems of communication between the different professions often occur. The distinction by respect to the sequential organization is to constitute project multidisciplinary teams that regroup the different specialists which intervene during the product life time cycle (Johnston and Bate, 2003; Sundström and Zika-Viktorsson, 2009). These teams represent the centerline of the integrated engineering and allow catalyzing the innovation, ensuring an adequate quality level in what concerns the market exigencies.

The cooperation inside the team energizes every one's responsibility, this resulting in an increased motivation. The responsibility reaction is reinforced by the decentralization of functions and de-structuring the traditional hierarchical way. By creation of a common data structure, interactive, based on the putting into the net of the specialized means, the coherence of the informational flow, indispensable to an integrated engineering approach can be guarantied (Ojasalo, 2008).

In order to achieve an integrated conception, the integration of the knowledge must be achieved by developing the product model, which expresses the fulfilled functions and the steps of the real product life cycle: manufacture, maintenance and recycling. The priority objective is to disengage the systemic integration methods and means of the act of product conception from the enforcements generated by the compromise cost-term-quality. The tactic of development and manufacture of a new product has in view the diversity, simultaneity and integration (Edquist, 2005).

In these conditions it was possible to design some new products, made of plastic, which can replace the heavy products made of metal, with the advantage of significant recycling potential.

Table 2 illustrates the main new products made from plastic, used by the cars industry.

Table 2. Plastic products used in automotive

Material	*Company*	*Product*
Nomex- cellular plastic materials	DuPont de Nemours (France)	External elements for land transport
STC- polypropylene thermoplastic composite	Farmington Hill (USA)	Flooring steering, noise screens, brake pedal bracket, column directions, front layer of resistance.
Reinforced polyester	Ford (USA)	Collectors working in the aggressive
25% epoxy plastic +65% glass fiber +10% carbon fiber	Rubery Owen + Bristol (England)	Springs
Epoxy plastic fiber reinforced	Mahle (Germany)	Piston floating, caps
Composite material: plastic + steel	Mahle (Germany)	Declutch bearings, belt stretching roller, diversion wheel motor mechanism

The products are carried out with a very good geometry, characterized by high homogeneity.

4. Current aspects of expenses for the development of plastic product

The experience of the original equipment of the majority of the industries has shown that 80% of the total time and of the cost related to the product development are involved in the initial phases of roduct development. Improvement of product development is efficient if it could allow the solving of the initial phases of conception and projection as good as possible, having in mind the weighting of the total time and of the cost of the product development involved in the initial steps (Corabieru, 2009).

From the estimation of the expenses for the phases of the life cycle of the product until the phase of manufacture and evaluation, (Fig. 1), it was found that almost 80% of the entire cycle is already consumed. This warns on the importance that of the feasibility studies, system defining and analysis, design of manufacture and development.

The phenomenon is due to the fact that in the conception phases the fundamental decision are taken with respect to the base geometry, materials, system and manufacture processes configuration, while during the product life cycle the transformations are achieved with difficulty (Velicu et al., 2009).

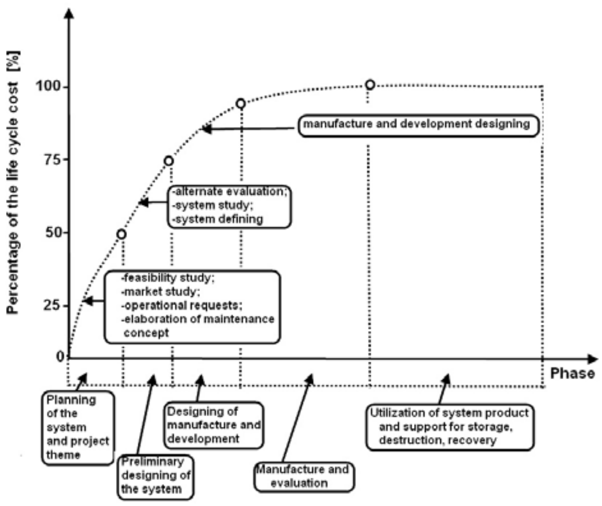

Fig. 1. Cost of the product development in different phases of the life time

The design phases are even more important in the case of plastic materials, which are aiming to replace the metallic parts. Having the property to fill in the small voids, it is achieved almost perfection as we are obtaining a complex geometry cumulated with low rigidity and thermal dilatation. The utilization of the plastic materials had imposed a principle: high-quality design from the very first time. All major decisions are made in the initial phase of the product life span, respectively in the phase of product conception.

5. New approach in the rapid development of the plastics product

The purpose of the improvement of the products development is to concentrate the human imagination so as the result of the designing processes represents a complex system acceptable from the point of view of utilization and efficiency. On a global scale, the accent is put on the digital development, in order to shorten the project loops and thoughtful forming of the subordinated organizational culture and structure. In Fig. 2 the new way of approach of the products development is schematically shown. For example, one of the studies achieved by a company producing cars shows that, by using the Opera software, the best selections of materials and great facilities of disassembling have been performed.

By using this software it was found that a recycling rate of 95% by using the plastics. Using the Opera software, the recycle of propylene at the vehicle Renault should reach a rate of 50 kg per vehicle in 2016, as illustrated in the Fig. 3.

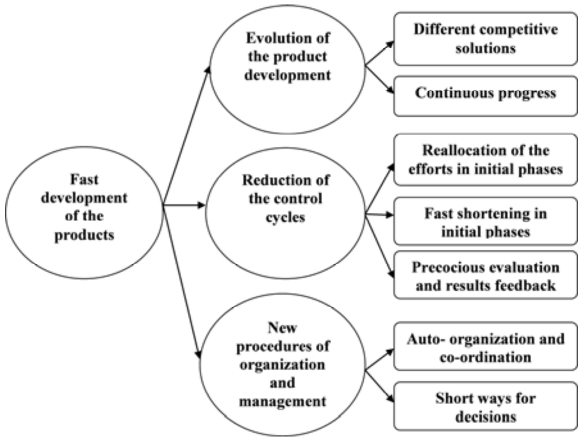

Fig. 2. New way to the fast development of the products

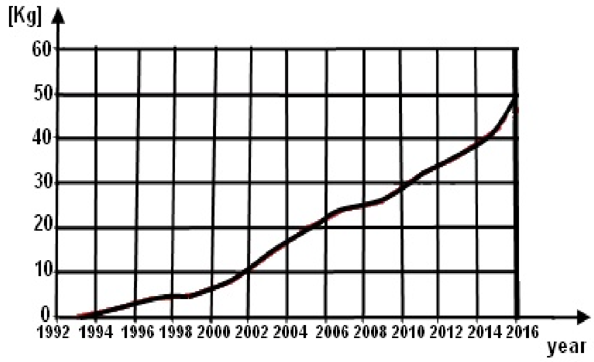

Fig. 3. Evolution of propylene recycling on the vehicles in an automotive company for the period 1992-2016

The internal norms and the recommendations regarding the choice of the materials in terms of eco-design for the norms Renault are illustrated in Fig. 4. (Norme Renault Conception en Vue du Recyclage 00-10-060/ 2002) (Corabieru, 2007).

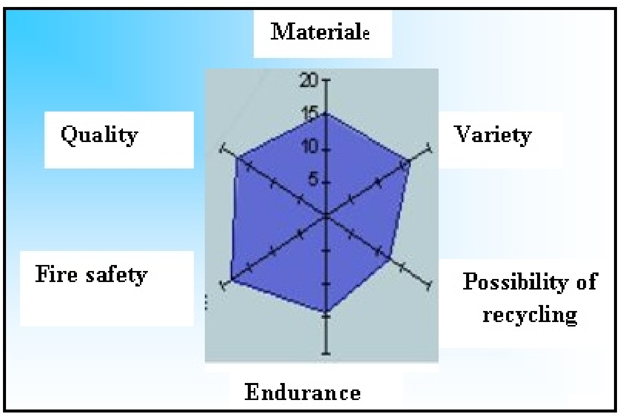

Fig. 4. Criteria and constraints of materials selection in an automotive company

Evolution of plastics in comparison with other materials used in Europe is shown in Fig. 5. As per the Federation of the Producers of Plastics the improvement of the participation quota of these materials is much faster than of the aluminium, opening a great perspective in this process.

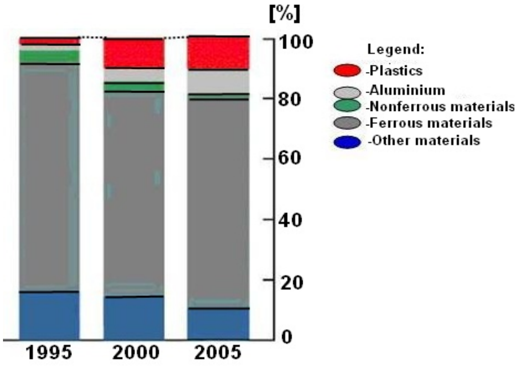

Fig. 5. Evolution of the materials used in the manufacture of products for vehicles (Corabieru, 2007)

An automotive company focuses on two main directions in the products development:
- replacement of the metallic materials that leads to the decrease of the product weight having a direct effect on the reduction of the fuel consumption and implicitly the reduction of the pollutant emissions quantities;
- increasing the capacity of products recycling.

The approaches of another automotive company consider the product development as a design oriented towards the recycling, that increases the product efficiency. The purpose of these initiatives addresses the waste reduction by specific measures during vehicles production and the recovery of waste at the end of the life cycle, conserving this way the valuable raw materials and the energetic resources (Corabieru, 2007). The recycling strategy of this company into the context of the product development is a part of the integrated responsibility by respect to the product (Fig. 6) and is based on two fundamental elements:

- design oriented towards waste recycling;
- development and utilisation of materials recycling in closed loop, in the vehicle production (Fig. 7).

To take into consideration these objectives even in the phase of product development, a global team of experts created a specification for the design oriented towards the recycling, compulsory into the framework of the entire automotive group in the world (Corabieru, 2007).

The objective of this specification is to assist both the engineers and the suppliers in developing vehicles and component parts oriented towards the recycling. Further, this specification helps the researchers to study the parts, component parts and vehicles from the point of view of the recycling capacity and recovery and to determine the product specific features (Velicu et al., 2009; Zait et al., 2008).

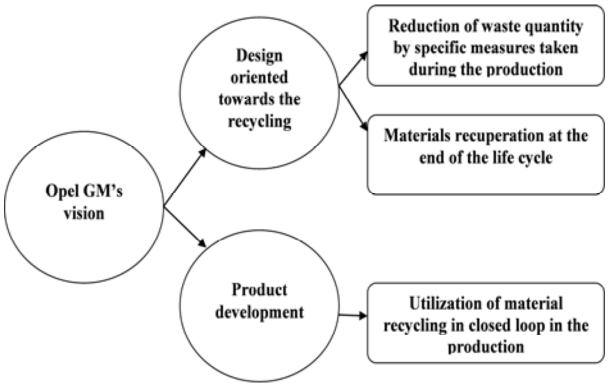

Fig. 6. Vision of an automotive company, associated to the integrated responsibility against the product life cycle

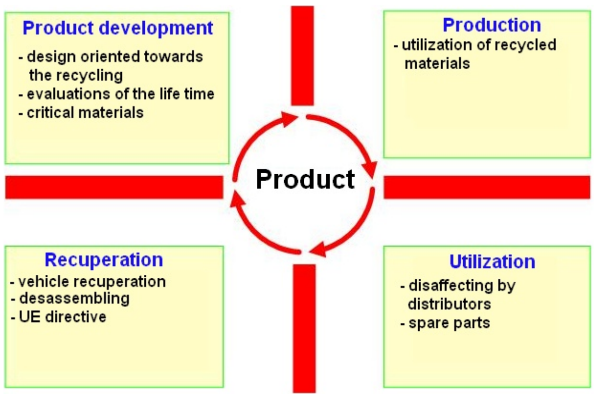

Fig. 7. Development and utilization of materials recycling in closed loop

Fig. 8 summarizes the main elements of design for recycling.

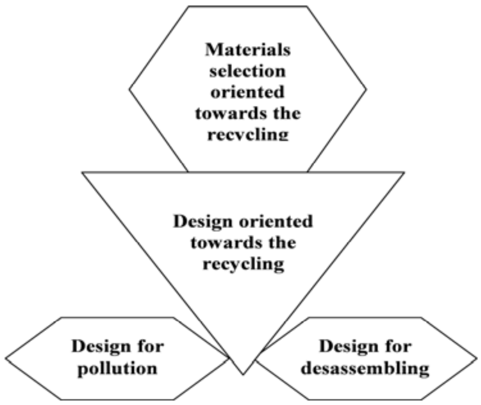

Fig. 8. Elements of designing for recycling

Utilization of the recycled materials represents a tradition of some automotive groups. A company, for example, used more than 30.000 tons of recycled materials in 2001 for the production of new vehicles. Until now, more than 70 types of recycled plastics have been specified and launched in production. The recycled materials are preferred to the new materials if they can be produced at lower costs and in the same time they fulfil all the technical specifications. The aim is to increase continuously the recycled plastics quantity during the life time of the pattern.

The common element of strategies in all big companies which refers to the development of plastic products is the guidance of the product development towards the production oriented towards recycling.

6. Analysis of current guidelines on recycling in the life cycle phases

Early in the design phase it has to be taken into consideration that the recycling activity is deployed on the entire life time of the product, so we'll have recycling in the stage of product development, in the production stage, in the exploitation phase and in the cassation phase.

6.1. Recycling during the product development

The products will incorporate new designing technologies that take into consideration the recycling process that will be applied to the product after utilization. The measures taken in the stage of product development with a view to improving the products recycling are shown in the Table 3.

Table 3. Measures and effects of the recycling during the stage of the product development

	Measures	***Effects***
1	Utilization of easy recyclable materials	The parts are specially burned indicating if they can be recycled or if they have already been submitted to this process. Improvement of the actual recycling rata from 75% to 90%
2	Reduction of the plastics range	Reduction of sorting costs
3	New techniques that are based on discoveries at molecular level	Reduction of the parts number → these ones will be easier dismantled
4	Tendency of using a single type of plastics	Elimination of sorting → facilitating of the recycling process → application of the material Super-oletin Polymer

Still in the designing stage the new nanotechnologies are tried to be used having a direct effect on the decrease of the number of component parts integrated in the product facilitating this way the assembling and dismantling.

6.2. Recycling in the utilization stage

Recycling in the utilization stage is related to the component parts of the products that are put out of use during the utilization period. In this stage, all the parts and component parts that are out of use in the utilization period are in the view, planning the costs of the detachment, transport, preparation for the recycling and treatment with a view to obtaining a recycled product considered as new.

6.3. Recycling after disposal

Recycling after putting out of use of the products supposes the following objectives: the product has to be dismantled as easier as possible, the dismantling company has to be very well developed, the remaining parts after dismantling have to be as few as possible. The tendency at world wide level is to refine the technologies of plastics recycling and of the residual dust.

Recycling of plastics is hard to be made including a big quantity of plastic fibres and rubber materials. Plastic fibers could not be recycled until now. The residual dust represents 25% of the vehicle put out of use and it is the material the most difficult to recycle due to the heterogeneous composition represented in Fig. 9.

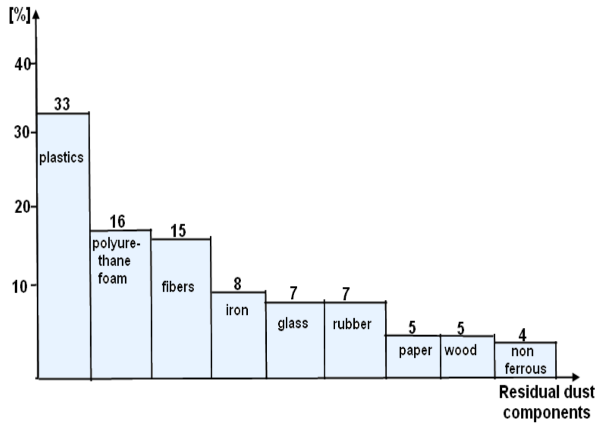

Fig. 9. Percentage composition of the residual dust

Without solving the problems related to the recycling of the residual dust the actual rate of products recycling cannot be increased from 75% to 90%. In the Table 4 technological solutions for the recycling of the residual dust are presented.

Table 4. Aspects regarding the recycling of the residual dust

Strategies	***Technological solutions***	***Results/utilization***
1. Removal of the component parts and their recycling by categories they belong to.	- sorting of iron using the magnetic force; - separation of nonferrous materials; - separation of the polyurethane foam, fibers and plastics using the air jet.	- Toyota obtained the recycling of 80% of the polyurethane foam and 20% of the fibers → the materials have been used at the manufacture of sound filters.
2. The residual dust seen as source of technical energy.	- furnace with a daily capacity of 4,6t, uses 90% dust+10% combustible; T=900°C	- the material is reduced to the 30th part of the initial mass

In the vehicles industry, recycling is not approached as a phenomenon intervened after putting the vehicles out of use, but it is configured into the stage of the product conception and in that of the product utilization. Ensuring the recycling is the main condition necessary for the plastic materials to become the main material used in the car industry.

7. Trends in the use of plastics in industry

Light constructions are a distinct purpose for the achievement of the innovative products in all industrial fields. Creating light construction involved the usage of composite and plastic materials.

The main advantages of the utilization of composite materials are as follows:

- thermoplastics reinforced with glass fibres could allow the replacement of the metals and in the places strongly stressed. They are used to confection vehicles bodies, having the possibility to provide a geometric perfection, homogeneity, big rigidity, low thermal dilatation and different colouring. Weight savings can reach 60% and the price reduction, 30%; (Corabieru A., 2009; Corabieru A., 2010).
- plastics reinforced with glass fibres can be easily manufactured using usual procedures as: lamination, spraying, extruding and injection. Composite materials based on plastics are less energy-intensive than the steel, aluminium and copper;
- resistance practically unlimited to the action of the processes determined by the atmosphere and environment agents (oxidation, corrosion, micro-organisms) (Popovic and Milenkovic, 2009);
- high capacity of vibrations amortization, the vibrations, three times bigger than that of the aluminium;
- low dilatation coefficient in comparison with metals;
- chemical stability at high temperatures;
- high endurance in service (Corabieru et al., 2009).

Decrease of the vehicles weight and aerodynamic and power improvement represented a permanent target for the vehicles manufacturers. Replacement of the steel with plastic components brought advantages but created also a series of disadvantages, conforming to those presented in the Table 5 (Corabieru A., 2009; Corabieru P., 2009).

In order to substitute the metals at a large scale, the polymers have to be superior from a technical point of view, at a lower cost. The medium term challenge aiming to increase the recyclability is represented by the attenuation of the plastic products and the tendency of using only one type of plastic material: the polymer.

8. Conclusions

The research results discussed in this paper allowed us to draw the following conclusions:

- any improvement in the development of a product will be very opportune if a better exploitation and solving of the changes of the systems in the initial project definition stages are allowed, since the time and the cost of defects correction or of elimination would increase exponentially with each step of the cycle of product development;
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Table 5. Advantages and disadvantages of plastics in vehicles construction

Advantages:
• *Resistance to corrosion of the parts of plastics*
• *Light weight of the parts of plastics*
• *Integration of the parts in bigger component parts*
• *Relatively low costs of the tools*
• *Reduction of the number of phases of the manufacture process*
• *Chemical resistance*
• *A bigger ability for design and modelling*
Disadvantages:
• *Instability at low temperatures*
• *Degradation of polymers (PP) under UV limit*
• *Technical difficulties in obtaining high quality surfaces at finishing (to note the thermostatic materials)*
• *Long production times*
• *High costs of materials*
• *A multitude of aptitudes and experience that are necessary*

- as the weighting of the plastics on the market increased considerably, the global tendency is to improve the recycling technologies of plastics and residual dust;
- plastics recycling is difficult to achieve because they contain a big quantity of plastic fibres and rubber materials. Scientific research didn't make important progresses in the last decade in what concerns the recycling of the plastic fibres;
- more sustained efforts are needed in the direction of solving of the problems related to the plastics and residual dust recycling for the increase of the actual rate of products recycling; the increase of the recycling rate is the main condition that the plastic materials have to fulfill in order to be used on large scale as replacements for the metals; in the near future the plastic can become the main manufacture material used in the car industry;
- plastics will be more and more developed in the same time with the settlement of the problems related to the increase of the recycling rate over 90%, conforming to the international agreements in force;
- substitution of metals with plastics is aimed at making products more flexible, adaptable and dynamic at a lower price; if the range of plastic material will decrease to only one area – respectively the polymers – we can reach up to 95% recycling rate. If they will respect the conditions imposed by the protection of the environment, the plastic materials will have a bright future.

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