Concurrent Engineering – A Case Study involving University and Industry

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Abstract

Time to market, competition and manufacturing costs are only some of the reasons why concurrent engineering is an increasingly used methodology for product development. The present paper deals with a case study of university-industry cooperation to develop an improved part for an automotive application, with three main concerns: economic, performance and environmental. Four universities gathered to attack this problem with an automotive company, joined by a technology research center. The very short time span of the project called for the application of concurrent engineering project planning and execution. The brainstorming that ensued resulted in, among other significant outcomes, a new methodology for materials selection. Also, the application of concurrent engineering methods to university-industry collaboration was very successful, regardless of the usual different timings of industry and university.

Keywords

Product development, concurrent engineering, materials selection, manufacturing cost

1 Introduction

Nowadays, any innovation process and particularly product development is a concurrent effort involving engineers, business planners, marketing staff and environmental professionals functioning as integrated teams [Cooper, 2001]. Leading firms are introducing new products with high-perceived quality, forcing other companies to respond accordingly in order to maintain their competitiveness. This dynamic flow of new products is achieved by adopting new product development methods [Rouibah, Caskey, 2003]. Emerging in this context, Concurrent Engineering (CE) is a process in which a number of specialists from different areas work interactively to meet pre-determined targets [Hilmes, Schatz, 2004]. CE philosophy has been discussed since the beginning of the twentieth century, but only in the past decades it has become the main approach in product development, due to the fast development of science and technology and to the increasing multidisciplinarity and interdisciplinary nature of current engineering problems [Jian, Oriet, 2005]. Within a product development context the main purposes for CE principles are the creation of products with shortened development process, lower costs and higher quality [Xu, Li, Li, Tang, 2004]. Many studies have been developed in this area; some are focused on information exchange between expertise areas [Yassine, Sreenivas, Zhu, 2006; Wognum, Bondarouk, 2003; Farinha, Gonçalves, Garção, 2003], some explore leadership and team management strategies [Lin, Chai, Wong, Brombacher, 2007; Stach, Pfennig, 2004] and others focus on applications and case studies involving concurrent engineering applied to product development [McBeth, Tennant, Neailey, 2005; Loh, 2005; Xiuchun, Ning, 2005]. Nevertheless, and whatever their approach is, all of them agree that the basic principles of CE rely on concurrent work-flow, cross-functional work teams and early involvement of constituencies, whose competences will be required or will be disturbed at some point along the product development process.

The concurrent work-flow, based on the parallelism of activities, is stimulated by an early release of information [Koufteros, Vonderembse, Doll, 2001]. If information and partial outcomes from on-going activities are released early, engineers can begin working on different phases of the problem while final designs are still evolving. Time-consuming rework is also avoided because the detection of design nonconformities is promoted.

Cross functional work-teams appear in CE as a logical answer to overcome barriers to communication and information sharing particularly when decision processes cut across the distinctive competences and functional authority [Wang, Wu, Zhou, Yan, 1996].

Finally the early involvement of various constituents in the development process provides an avenue for various interest groups to express their concerns and to provide their input early into the process. For example, getting in manufacturing engineers in preliminary product development phases brings manufacturability issues into light, and contributes to the reduction of lead time from design conception to delivery of the product.

2 Project goals and objectives

Although CE practice has mainly been applied to product and process development activities [Chen, Hsiao, 1997], its basic principles can be extended to cooperative research environments, involving universities and other research institutes together with industrial companies with or without formal R&TD departments. In fact, there is a major benefit from the integration of CE principles to increase interaction between different research groups in university and industry. As in any cooperative environment, project goals definition is important, thereby establishing the project teams. Projects involving university and industrial professionals are often originated in teams with different objectives. While university professionals work with the main purpose of creating scientific results, industrials seek to obtain the best results in terms of production. As teams have different purposes, these purposes have to be adjusted to the global aim of the project, thereby reaching industrial results as well as scientific work in the end of the project. As a result, organization and leadership of this type of teams is a challenging task [Allen, 2001], as a well coordinated effort to involve many areas into interdisciplinary teams has a great importance to the project duration and success.

The objective of this project was to bring together one company, one technology center and three universities to study the application of three different material types in the manufacturing of an automobile fender already in production.

Automakers have already demonstrated fender designs in several different materials, including steel, light metals, fiber reinforced composites, and plastics. Each of these materials choices must satisfy a set of structural requirements: the fender must be strong and stiff, exceed vibration standards, and be able to withstand the high temperatures of the paint shop and low temperatures of winter. A successful alternative fender design must also fit current manufacturing needs and standards, such as the package space for the part on the vehicle and the attachment points to the vehicle body. Furthermore, the decision as a whole is extremely cost driven, implying that each technical component cannot be evaluated without considering its economic impact. Yet the incentives to find a successful lightweight fender solution are real, especially in an environment of rising fuel costs and increasing emphasis on the environmental impact of motor vehicle designs.

The study would focus in comparing different material alternatives in producing the fender, including investigation of structural performance, process based cost modelling and environmental analysis. Each university was chosen because of its expertise in metals (Instituto Superior Técnico, IST), polymers (Universidade do Minho), composites (Faculdade de Engenharia da Universidade do Porto) and process-based cost modelling (Massachusetts Institute of Technology). CEIIA (Centro de Engenharia e Inovação par a Industria Automóvel) was brought in as technology centre and as liaison with the company (AutoEuropa). Hence, the management was based on CE practices, coordinating teams and planning the project in advance.

3 Work methodology and timetable

The first step was to establish the project scope and goals. Goals validation was needed, especially with industrials, as the project targets were not the same within partners. While the research team goal was to obtain scientific results from the study with possible use in education, the industry purpose was to reach the best production results in terms of economic outcome. The goals were different between partners but were not conflicting, so this issue was not critical. Note that at first, some of the research team specific goals were not fully understood by the industry team. Yet, they were considered to be potentially important. The organization and leadership of these project teams revealed to be a demanding task, as subgroups existed within each university team. Each subgroup had a leader, which had to solicit cooperation from other subgroups during the project.

Project deadlines were defined, planning the tasks and goals in order to integrate MSc Theses. This incorporation was possible by the perception of the project length. Project planning was developed using CE principles, thereby seeking to promote cooperation not only between university groups, but also between university and industry. Team cooperation was intended to transform the project into a more agile, dynamic process.

As the research teams had a wider scope, that is, its aims went beyond the project punctual results, modular and parameterised models were developed. These models allow comparisons and sensitivity analysis to different situations, being therefore possible to spread out the particular case study and acquire systemic knowledge about the conducted analysis. Another important purpose for these models was the project context of concurrent engineering, where new or different data and results can appear and have to be rapidly integrated.

Figure 1 shows the timetable of the project, with a total duration of six months. There is a clear difference between conventional design project and concurrent project in terms of parallel activities, as parallelism is intimately associated to concurrent engineering. Therefore, it is necessary to plan carefully for network activities [Haberle, Burke, Graves, 2000]. Planning the project in advance is a crucial part in CE, as it becomes possible to coordinate teams with the purpose of concluding the project in the shortest time. The success of CE largely depends on the ability of sharing timely information among cross-functional teams [Yassine, Braha, 2003]. To achieve this purpose, meetings were planned every other week between university teams, and every week within each university team of groups. These meetings were held throughout the project along with some meetings between university and industry. These meetings proved to be very useful, as not only information exchange was required for the project development, but also some innovative ideas were achieved by the brainstorm meetings involving professionals with different expertise.

4 Project description, methods and outcomes

The present project aimed to select a material for an automobile fender, considering not only the materials technical performance, but also costs and environmental impacts.

The project scope was defined between the industry and university, considering the industry requirements and design limitations. In the particular case of the Instituto Superior Tecnico project team, in charge of studying metallic alternatives, the team included a design group, responsible for the fender design specifications, a manufacture group, in charge of the manufacture process analysis, a materials group for the pre-selection and analysis of possible materials, an economics group for the study of the material alternatives costs and an environment group for the estimation of the options on the environmental impacts. The group's tasks were not independent and communication between them was crucial for finalising the project in time, which had six months duration.

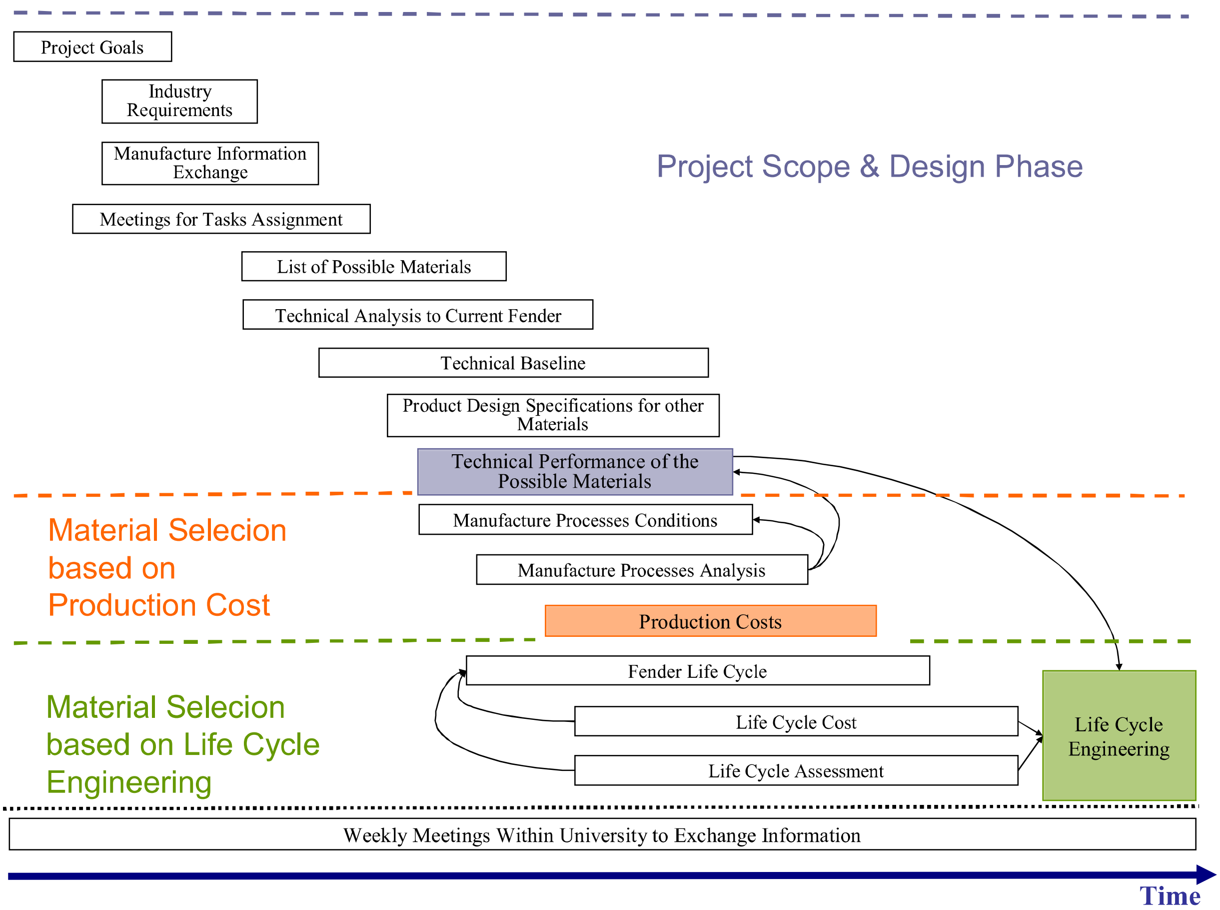


Figure 1 – Project timetable, with a total duration of six months for the Instituto Superior Técnico team.

After defining the projects scope, several requirements and constraints were imposed by the automotive company, in particular in fender design. As the automobile already exists in the market, the actual fender was analysed in order to develop a technical baseline for the study, as fenders using other materials had to perform similarly in terms of response to external loads. A list of material candidates was proposed and based on the current fender technical baseline, the design team determined other fender designs using the material candidates. In the particular case of the IST team, different fender designs only differ on the fender thickness, because all he materials envisioned were metallic. The other university teams had to come up with very different designs, because composites and polymers have a radically different mechanical behaviour.

With the fender designs for the other metallic materials, the manufacture group studied the production process, defining among others the production time, required machines and tools and necessary raw material. Manufacture optimizations were developed at this point, in particular a reduction of production scrap.

Information from the manufacture group and industry allowed the economics group to estimate production costs for the candidate materials. Materials selection based only on production costs, therefore supported by the automotive company, could be made at this point. However, this project aimed to include also technical and environmental considerations to materials selection. In order to achieve this, the materials group evaluated materials only considering their mechanical and chemical properties and the environment group developed a life cycle approach using a Life Cycle Engineering (LCE) methodology, in cooperation with the economics and materials groups. LCE can be defined as a decision-making methodology that considers performance, environmental, and cost dimensions throughout the duration of a product, guiding design engineers towards informed decisions [Wanyama, Ertas, Zhang, Ekwaro-Osire, 2003; Betz, Schuckert, Herrmann, 1998]. LCE includes Life Cycle Assessment (LCA - developed by the environment group) and Life Cycle Cost (LCC – developed by the economics group) methodologies, and a technical evaluation of the materials (materials group). This evaluation based on life cycle approaches (LCC and LCA) and on material properties allows materials selection under these three dimensions (economical, environmental and technical). Industry plays an important role at this point, as the importance to give to each dimension refers to the company strategy.

The present project was therefore a combination of conventional tools for material selection, life cycle perspective methodologies and the principles of CE for the team management. Figure 2 shows a simplified diagram of the project development within the Instituto Superior Tecnico team.

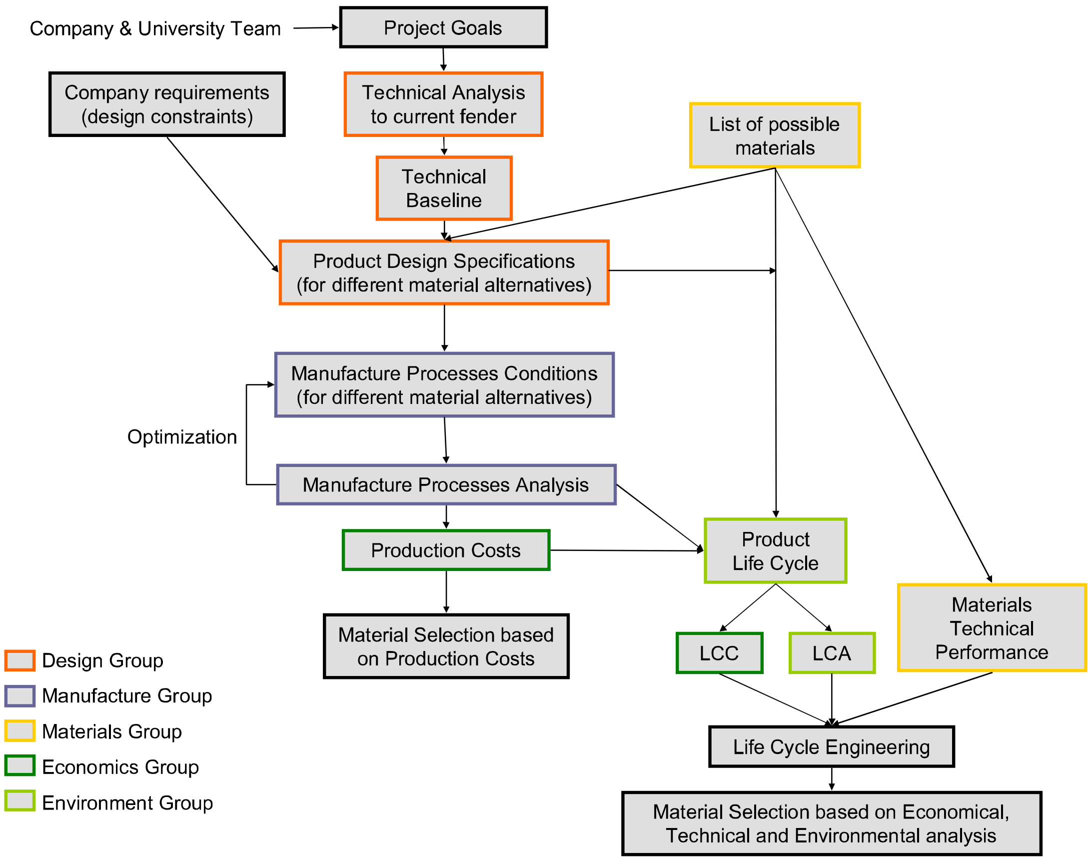


Figure 2 – Project diagram within the Instituto Superior Tecnico team

5 Some project results

A very brief description of the project results is presented here [Roth, Camanho, Silva, Viana, 2008]. These results will focus mainly on the work performed by the Instituto Superior Técnico team on metallic materials, and some final results comparing all the material solutions from all the university teams. The first step of the project was the technical analysis of the fender. Since no standards are available for this part, an experimental and numerical structural analysis was performed on the current fender, to define a set of baseline design parameters for future designs to meet or exceed. Static and vibration tests were performed to extract strength, stiffness and natural frequencies of the existing fender. Figure 3 shows some of the results.

The methodology used lead to the creation of a triangular chart that can ultimately plot technical performance, environmental impact and economic performance as competing criteria for the selection of a particular material to the given application [Silva, Henriques, 2008; Ribeiro, I, Peças, P., Silva, A., Henriques, E., 2008]. Figure 4 shows an example of this type of plot for competing metallic materials.

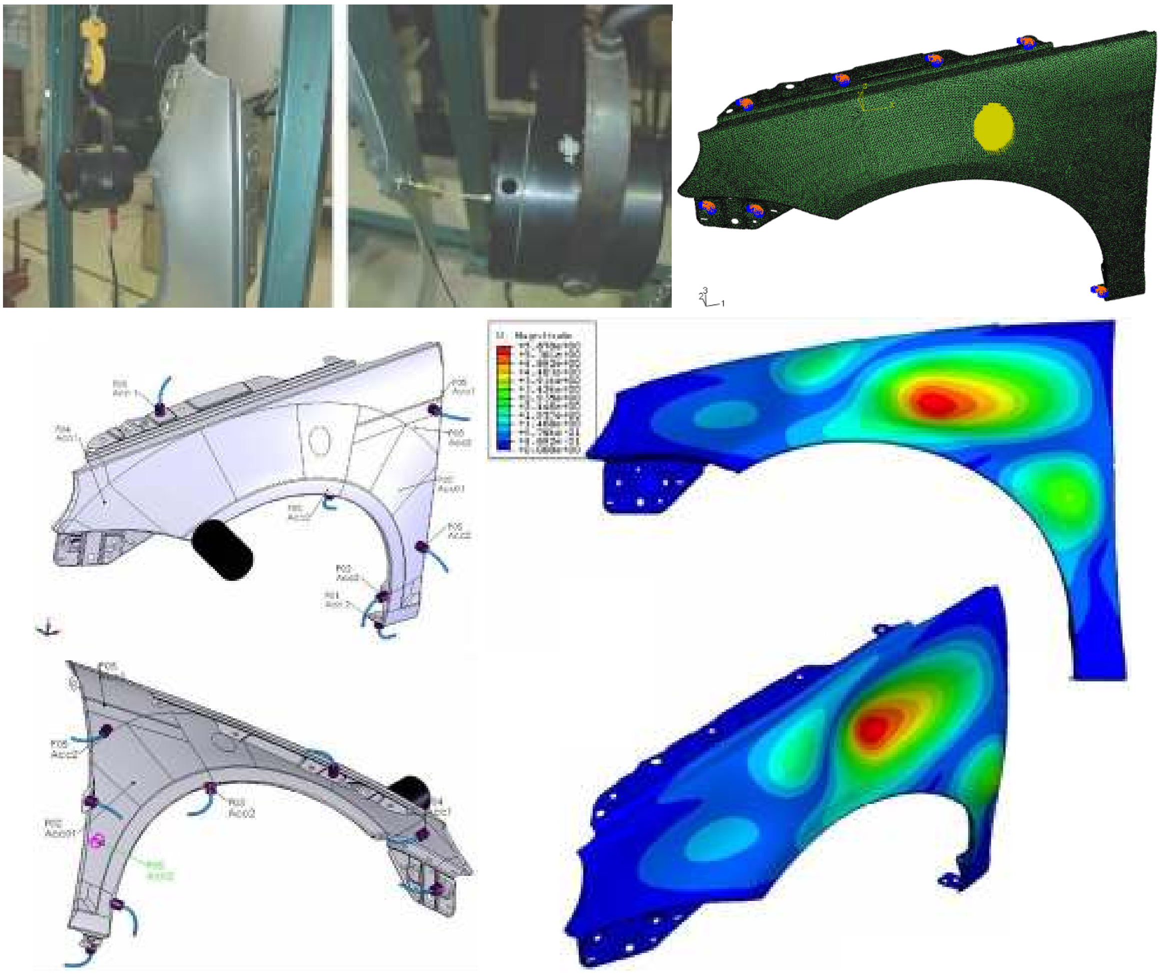
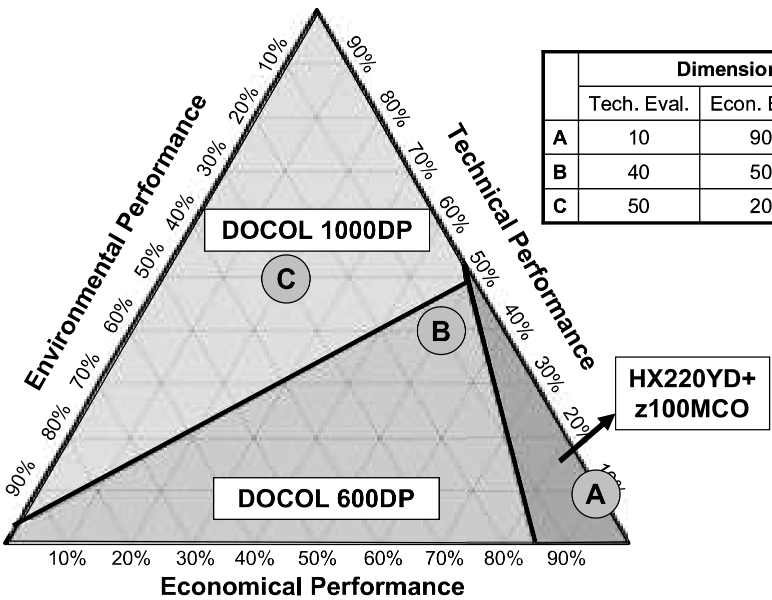


Figure 3 – Experimental setup and loading and acquisition points of dynamic data, on the left, and FEM mesh with loading and constraints and static analysis results on the right.



	Dimension Weight		
	Tech. Eval.	Econ. Eval.	Envir. Eval.
A	10	90	0
B	40	50	10
C	50	20	30

Figure 4 – Triangular plot with the best metallic material for the different criteria.

In the end, the result was a plot of different materials (metallic and non-metallic) with the cost of a fender for different production volumes. Figure 5 shows the plot obtained. This plot includes all the manufacturing costs. It can be seen that, with the assumptions made, there is a significant difference in manufacturing cost for the different material types studied, and this cost varies substantially with production volume.

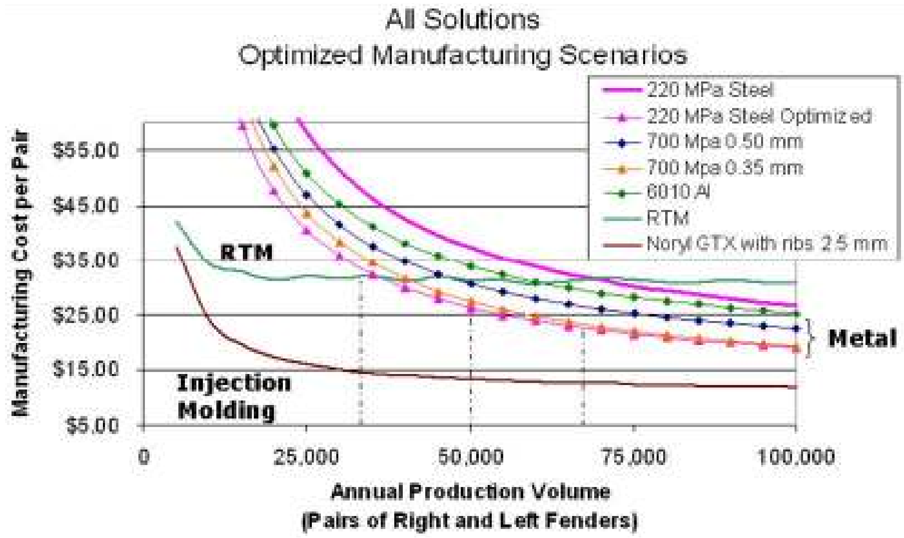


Figure 5 – Manufacturing cost varying with production volume, for the different materials considered.

6 Conclusions

This project was possible because of the involvement of the four universities with expertise in different areas of knowledge, and a company with real interest in the Project outcome. It shows that, when the objectives are well defined from the beginning and the outcome will have a significant impact, it is possible to have industry and university working together in a very short time span, using concurrent engineering methods of product development.

The project is a combination of conventional approaches for material selection (the ones currently used by the industry) and advanced methodologies based on life cycle perspectives designed in order to allow a detailed evaluation of the different impacts on technical, economical and environmental performance of the final product. The complexity and short time frame of the project and the need to make compatible different objectives of the partners involved called for the application of CE principles. The outcome, an integrated framework to support materials selection, its application to an industrial case and the transfer of knowledge between academia and industry in the field of global comparisons of materials, relied on concurrent work-flow, cross-functional work teams and early involvement of constituencies affected by the results. Also, the application of concurrent engineering methods to university-industry collaboration was very successful. Traditionally, there is a notion that university research occurs in a time span that is incompatible with industry time constraints. This project proves otherwise. As long as there is a clear understanding of the main expectations of all the partners involved, and the different goals are compatible within the expected timeframe, university and industry can collaborate fruitfully.

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References

Allen, T. J., (2001) Organizing for Product Development [online]. Lean Advanced Initiative, Massachusetts Institute of Technology (MIT), December 2001. Available on <http://lean.mit.edu/>.