DESIGN INTERACTION WITH INDUSTRY THROUGH RAPID PROTOTYPING

F. Jorge Lino¹, Rui J. L. Neto², M. Teresa Vasconcelos³, Pedro V. Vasconcelos³, M. J. Azevedo³, Acácio V. Pereira³, Elizabeth C. Silva³

¹FEUP – Faculdade de Engenharia da Universidade do Porto, DEMEGI – Departamento de Engenharia Mecânica e Gestão Industrial, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal. Tel: 225081704, falves@fe.up.pt www.fe.up.pt/~falves
²INEGI – Instituto de Engenharia Mecânica e Gestão Industrial, CETECOFF – Unidade de Fundição e Novas tecnologias, Rua do Barroco,174-214, 4465-591 Leça do Balio, Porto, Portugal. Tel: 229578714, Fax: 229537352, cetecoff@inegi.up.pt
³ESTG/ IPVC - Instituto Politécnico de Viana do Castelo, Ap. 574, 4900-908 Viana do Castelo, Portugal, Tel: 258819700, pedrovasco@cinformatica.web.pt

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ABSTRACT
The answer to the new market demands requires industry capacity to design new products with just-in-time response. Considering this challenge, the recent Rapid Prototyping and Rapid Tooling technologies must be included in the development and manufacture of new products.

Using a LOM (laminated object manufacturing) rapid prototyping machine, paper models can be made very quickly, allowing a wide industrial sector the possibility to quickly develop new non-functional prototypes, or through the conversion techniques to obtain metallic prototypes, pre-series of quality and tools in a short period of time.

It is the purpose of this paper to describe an initiative that involved an Institute of Mechanical Engineering and Industrial Management (INEGI), a College of Technology and Management (ESTG) and two companies. ESTG Product Design students have undertaken professional training in which they designed and developed new products, lamps and shoe soles, supported by the LOM and foundry processes.
RESUMO
A resposta às novas exigências do mercado exige que a indústria apresente uma boa capacidade de adaptação ao design de novos produtos e resposta rápida (just in time). Perante este desafio, os fabricantes necessitam, cada vez mais, de integrar na fase de desenvolvimento e de produção de novos produtos, as novas tecnologias de prototipagem rápida e de fabrico rápido de ferramentas.

O INEGI-CETECOFF (Instituto de Engenharia Mecânica e Gestão Industrial - Unidade de Fundição e Novas Tecnologias) integrado num projecto PEDIP denominado Rede Nacional de Prototipagem Rápida adquiriu uma máquina de prototipagem rápida LOM (“Laminated Object Manufacturing”, fabrico de objectos por camadas). Este equipamento permite rapidamente fabricar modelos em papel, oferecendo assim a um vasto sector da actividade industrial a possibilidade de obter protótipos não funcionais e, através das tecnologias de conversão e fabrico rápido de ferramentas, protótipos metálicos e pré-séries de qualidade, em prazos muito curtos.

INTRODUCTION
Over the last decade, a radical change in the project field have been witnessed, with the traditional 2D processes progressively replaced by CAD systems, which are able to generate three-dimensional models.

In systems with parametric modelling capacities, it is possible to start by conceptualising the project, and developing different options with simplicity and quickly. Photo-realistic presentations and computer animations help to change the client’s attitude towards prototypes and to avoid costly investments. Therefore, this first step makes it possible to prevent defects, which otherwise, would only be detected at a later stage of the process [1]. However, the design process does not end just because a three-dimensional model was created; these programmes can and should interact with other specialised applications to create a global solution to design and manufacture a product. This is the case of the Rapid Prototyping (RP) and Rapid Tooling (RT) technologies, which enable to create prototypes and pre-series with highly reduced response time to market demands [2-4].
A LOM rapid prototyping machine produces paper models. A CAD file is converted into an .STL file, which is supplied to the LOM computer unit. This unit divided the object into parallel layers. The LOM prototype was then built by laminating successive layers (0.1, 0.2 or 0.4 mm thickness) of paper with thermal glue on its back. Figure 1 represents the operating principle of the machine. Each sheet is individually pressed, glued and subject to a peripheral cut according to the contour defined on the layer. At the end, the surplus is cut into parallelepiped pieces to ease the removal of the prototype(s) (decubing).

Figure 1  LOM rapid prototyping machine.

The work here described used the LOM process because it is the one available for this initiative [5]. This process is particularly indicated to produce prototypes for the foundry industry.
**CASE STUDY**

After finishing their studies, Product Design students of the ESTG undertake professional training, supervised by a lecturer and an industrial supervisor. This study attempts to divulge the results of two work placements with innovative features of cooperation between a higher education institution - the ESTG, a research laboratory - the INEGI, and the industrial environment. The goal of the agreement was to develop new products using prototypes achieved via one RP process (see figure 2).

![Diagram](image)

**Figure 2** Partnering entities.

Training placements covered the following steps:

- Design new products for the companies (lamps and shoe soles);
- Create CAD models and convert them into STL representation;
- Input STL file into the RP machine software and generate the LOM models;
- Manufacture metallic prototypes of the lamps through casting an aluminium alloy (AlSi5Cu3) and use conversion techniques to create moulds for shoe soles injection;
- Evaluate the new products in view of possible production and commercialisation.

Trainees started by contacting the two companies and then developed projects for new products keeping in mind their priority and prospective needs.
The shoes project consisted in a proposal for women snickers and shoes for the Spring/Summer season, and followed all specifications and planning pointed out by the company.

For the lamps, trainees have just developed prospective design projects with the purpose of enlarging and diversifying the company products offer. This type of project consists in searching for new concepts about products, which will provide opportunities that the company may eventually develop. The purpose is thus to develop projects that pick all the worries and produce a prospective creation, fitting the company’s medium and long-term product strategies and policies [6]. In this way, different interior wall lamps have been designed.

After having defined market and product specifications, including business priorities, technical criteria and constraints, the design process started by the creative development of concepts or by the search for general solutions to the project (see fig. 3).

![General Design Process Development](image)

**Figure 3** Design Process.
In principle, design is a commitment between the various criteria to take into consideration in the project and of which results the need for a hierarchy. Quality and liability must be regarded as elements for careful consideration. The ratio cost/value for the client or the estimation price/performance are the basis for that hierarchy.

Once defined the product general solutions and management, the team started working on the option chosen. After more particular and detailed study and research, the final 3D design was made using specific software tools: AutoCAD and SolidEdge. The CAD file was converted into an .STL file, which was supplied to the LOM computer unit to generate the LOM model with a paper thickness of 0.1 mm. After decubing, an epoxidic resin was applied to protect the prototype from humidity, improve surface finishing and increase the mechanical resistance [3]. Then the prototype was successively polished and impregnated with resin until the desired surface finishing was obtained.

METHODOLOGY APPLIED TO THE LAMP PROJECT

In the area of interior lighting design, highly divergent approaches have been developed in parallel. There is the purely technical approach, which tries to use the luminous source based on its functionality, and therefore eliminating what is merely an accessory. Moreover, there is still the tendency for people to buy “luminous objects” that play aesthetically with the environment. This last tendency enable to link product design and contemporary design trends found in the furniture sector.

As an example of the methodology used in the design process development, what follows refers the boundary constraints and the description of the concept applied to the interior lamp project.

To start with, a commitment was made between the company’s management and the design process to be developed, through the definition of project boundary constraints. These constraints consist in a set of requirements that the new product should meet in order to be viable [7]:
- Production constraints – The main component or the whole product should be manufactured through gravity casting.
- Produce a small amount in a short term. The company has the necessary experience, expertise and technology for this market, however the present facilities are located in a highly limited area, which will condition production capacity.
- Previous analysis of competition and market research enabled to determine production viability.
- Container – Aluminium or any other non-ferrous casting alloy.
- Minimise project development process delays and costs.
- Minimise production costs.

Two lamps were conceived; a lamp with an adjustable diffuser and an alate lamp. The criteria set for the adjustable diffuser lamp were the following:

Functional criteria
- Easy to assemble, disassemble and maintain
- Easy to understand (shape logic)
- Optimised safety and visual comfort
- Diffuser’s versatile orientation

Aesthetic criteria
- Major capacity to blend into a wide diversity of environments, assuring harmony with the surrounding space and furniture. The different possible types of finish aim to enhance that capacity, personalising the lamp in line with the buyer’s aesthetic sense.
- Visual comfort able to generate emotional satisfaction
- Rational and integrated combination of several materials, so that they all blend into surrounding elements
- Different luminous effects

Ergonomic criteria
- Easy to assemble
- Access to bulb and other parts
- Compliance with safety regulations

Technical criteria
- Easy to handle parts
- Minimal number of parts and use of only standard electric parts
- Compliance with regulations

The goal was to design a wall lamp, which followed the maximum number of criteria, functional, aesthetic, ergonomic or technical. The key word was versatility, which may be confirmed at different levels:

- Possibility to use other orientation besides horizontal
- Availability to move the diffuser in a 180° angle, creating different light effects
- The great variety of materials and finish available helps to optimise and personalise the product according to the client’s taste, and to blend it into the surrounding environment.

For the alate lamp, after some research, based on a dynamic and spatial specific purpose and constantly seeking to match the answer and the objectives set in the beginning, concepts of bionic character were followed. Animal shape, more specifically of birds, captures and communicates grace and dynamism. Moreover, as an image of the collective memory, it allows the observer to apprehend it clearly.

The proposed design transmits emotional stimulation based on the synthesised movement of a purified and balanced shape, which reinforces the quality of the surrounding environment. Figures 4 and 5 present the two types of interior lamps developed.
Figure 4  Interior lamp with adjustable diffuser: a) CAD design, b) LOM prototype, and c) casted aluminium (AlSi5Cu3) parts.

Figure 5  Interior alate lamp: a) CAD design, b) LOM prototypes, and c) two final products with different finishings.
METHODOLOGY APPLIED TO THE SHOES SOLES

Since the technology used in the footwear industry is highly specific, the sole project was developed in a singular way. Figure 6 shows the new product development steps, and figure 7 shows two products selected. From the design of the new shoe, corresponding “patterns” were made out in PVC through CNC machining. The “pattern” consists in a model that reproduces the shoe inner configuration and which serves to make its sole and upper part [8]. After that, 3D models were created in CAD, following the design proposed in the project and guided by the dimensions of the “pattern” and by the constraints of the rapid prototyping system employed.

Figure 6  Shoe sole project development.
Once finished, the LOM model (see figure 8) was subjected to the application of textures and further adjustments, by the hand of the company’s model maker. The injection mould was made by a conversion technique. This phase involves the following steps: reproduction of the LOM model through a silicone elastomer (figure 8), casting of a plaster mould on the silicone, and finally casting an aluminium alloy on the plaster mould. The aluminium mould obtained, after inspection and finishing operations, was used to inject the thermoplastic rubber (TPR) soles of the figure 9.

Figure 7  Two of the selected projects

Figure 8  Shoe LOM soles and their reproduction with a silicone rubber mould.
**CONCLUSIONS**

Computer modelling allied with rapid prototyping represent a critical tool in the search for innovation at the design level and in the capacity to offer personalised products and solutions in a very short period of time.

Over the last decade, design significantly increased in Portugal, and tried to endow our industry with the capacity to be innovative and creative, as an alternative to simply reproduce foreign products. In parallel to the ever-growing interest from companies in the qualification of their products and corresponding production process, the increasing sophistication of demand has also stimulated the interest in design, not only as a way to promote the company’s image, but as a deliberate strategy of differentiation. The initiative presented here intends to contribute for the emergence of the Designer’s role, so that he may more easily fit the client’s needs and desires and offer a wider range of tailor-made proposals.

Design teaching must keep up with the technological and social progresses that characterise today’s world, ruled by communication speed, economy globalisation, society trends and commercial demands, in order to provide a reliable solution for future employers. The fact that some countries provide today highly cheap labour forces national companies to introduce expertise in their products and consequently to
implement new development technologies into their products, or else they may continuously loose clients for those countries.

The open spirit that guided this outstanding initiative represents a desirable paradigm of school / industry relationship to implement in the future.

REFERENCES