RAPID PROTOTYPING IN TRADITIONAL DECORATIVE METALLIC P EWTER PARTS

J. Lino$^1$, and R. Neto$^2$

$^1$ Faculdade de Engenharia da Universidade do Porto  
Dept. Engenharia Mecânica  
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal  
e-mail: falves@fe.up.pt, Web page: www.fe.up.pt/~falves

$^2$ Instituto de Engenharia Mecânica e Gestão Industrial  
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal  
e-mail: rui.neto@inegi.up.pt, Web page: www.inegi.up.pt

ABSTRACT

In Portugal there a large number of traditional SME’s, operating in different industrial sectors, that still did not awake for the new reality of global competition, where the capacity to develop new products in short periods of time is fundamental to survive in such an aggressive market. Consumers are continuously pressing enterprises for more reliable and sophisticated products that incorporate new materials, new functionalities, and simultaneously have shorter life cycles. These new challenges demand capacities to internally develop new products using digital modelling, rapid prototyping, conversion technologies, rapid manufacturing and others tools that are already common in industrial sectors such as aeronautics, automotive, medical, house appliances, toys and others. In this communication the authors present how the adoption of these technologies were fundamental to rapidly create new products in a traditional manufacturing pewter company that still has an intensive human labour and traditional way for product development, and how these new methodologies were fundamental to quickly manufacture by centrifugal and conventional casting, spinning and sheet metal forming, new products and introduce them, with success, in the international market.

Keywords: Rapid Prototyping; Foundry, Pewter, Product Development, Design
1. INTRODUCTION

The globalization changed completely the way of companies operating in the international markets. The internet allowed the quick dissemination around the world of the innovations about materials, processes, technologies and management. This new reality favors products copies, which associated to countries with lower human labor costs, puts all products manufacturers under a continuous pressure to quickly develop and introduce new and more advanced products in the market [1-2].

The Portuguese industrial sector is characterized by the predominance of SME’s, with many of them still based on intense human labor and inexistence of an internal structure for product development, able to increase the number of new products that they can introduce in the market.

The Department of Mechanical Engineering (DEMEC) of Faculdade de Engenharia da Universidade do Porto (FEUP), Portugal, created in 1986 the INEGI – Institute of Mechanical Engineering and Industrial Management, with the goal of being an interface between the University and Industry. For more than 23 years, the Institute fulfilled this challenge developing projects with hundreds of companies, and presently, more than 60% of INEGI revenues come from direct contracts with companies. Nowadays, is recognized from companies as a R&D and Innovation partner for new projects and has a growing international visibility through European projects and services for different countries.

In 1997 the Institute bought a Rapid Prototyping LOM machine (Laminated Object Manufacturing, from Helysis, USA), in order to improve its capacity to internally develop new products, essentially oriented for foundry applications. Due to the large number of manufactured prototypes and continuous contact with the industry, the authors of this paper quickly realized that the equipment could be much more intensely explored to produce prototypes for other relevant industrial sectors. On the other hand, the 3D CAD, fundamental for RP, with the freedom to design new products that quickly could be materialized in the LOM equipment gave the opportunity to receive young designers from different design schools to join the group for product development [3].

The first projects of design students, together with the INEGI engineers competences in different areas; like foundry, sheet metal forming, composites and mechanical construction, allowed not only the production of prototypes for visualization, but also manufacturing functional prototypes and pre-series.

In the mean time, different direct and indirect conversions technologies, like lost LOM and Quick Cast, investment casting, ceramics block moldings, plaster molding and others, were developed, which quickly strength the internal capacities to help companies operating in different industrial sectors in new products development [4, 5].

The evolution was fast, and the number of students coming from different schools increased continuously, with the team generating products incorporating good ideas that, in the great majority of the cases, stayed in the drawers or in the shelves of the Institute researchers’ offices.

In 2004, the Institute acquired a Viper Si Stereolithography RP machine (SLA), from 3D Systems (USA) that enlarged the type of prototypes that can be produced [6].

Considering the installed software capacities in terms of 3D CAD design, RP machines, conversion technologies, and specialized human labor; designers and engineers, it was decided to purpose to companies the availability of students to develop innovative products for them. If the products were considered market attractive, the company could go ahead with its production and commercialization, paying to the Institute a small fee.
This way of challenge companies that are not familiar with the capacities of the presently available technologies for product development was very profitable, and soon, many others were interested in establishing the same type of collaboration. This was a success not only for INEGI, but more than that, an excellent opportunity to introduce young designers in the market.

This paper describes the different stages involved in new products development for a traditional pewter company, since the initial contact with the company until the commercialization of appealing products with short deadlines. The projects comprises RP processes, conversion technologies with silicone and resin moulds and different manufacturing processes that incorporates composite materials, metallic alloys, sheet metal forming, glasses and other type of materials.

Details about RP processes and conversion technologies are not given in this paper due to the fact that nowadays are already well established technologies, but the more details can be obtained in references [2, 6, 7].

2. MATERIALS

2.1 Pewter

The main material used in this work is the pewter (Portuguese standard EN 611). Pewter is a tin alloy that in the majority of the cases contain 90% of tin, and the remaining percentage is composed of antimony, copper and low amounts of lead (0.25%). The tin alloy used in this work is the Sn-4.5Sb-4.5Cu, cast at temperatures between 300 and 380ºC, depending on the process and type of part to be produced. Figure 1 shows the optical microstructure of this alloy after polishing and etching with 2ml HCl, 5ml HNO₃ and 93ml H₂O, for 5 seconds. This microstructure is composed by a reach tin solid solution containing needles of small particles of Cu₆Sn₅ (white color) [8].

![Figure 1. Microstructure of the Sn-4.5Sb-4.5Cu alloy after polishing and etching.](image)

2.2 Other materials

One of the goals of the project was the production of pewter products that combine different materials and technologies, and that are difficult to copy. It was also intended to interrupt the monochromatic color and image associated to tin parts with the goal to attract young costumers that generally do not buy this type of products. With the use of a range of different materials it was intended to achieve a more diversified visual color and textures and aesthetic effects to promote value and product differentiation [9-12].
The materials that were employed are:
1. Epoxy and polyurethane resins that can be filled with different particles;
2. Aluminum;
3. Silicone;
4. Glass;
5. Noble woods (wenge, jambire, takula or betula).

3. EXPERIMENTAL PROCEDURE

3.1 Identification of market necessities

The project group, composed by the manufacturing company, INEGI engineers and designers, identified several fields where there was a great chance to interview and to penetrate, and that allows the company to enlarge the range of products to be offered. Later, a more ambitious strategy was set seeking the development of an entire new line of products together with a products catalogue, labels, packaging, advertising brochures and presentations in fairs and conferences.

After a market study to foresee the state of the art and tendencies and deep knowledge about the company manufacturing processes, understand the flux line of the products since the raw materials reception until the packaging and shipping, and availability to invest in new materials and technologies, the group decided to develop the following products:
1. Wine funnels to decant wine;
2. Fruit bowls;
3. Candelabras;
4. Other decorative parts.

After the creative phase [11-16], the first solutions gained raw shapes. Innovative products based on strong concepts were developed by virtual 3D CAD modelling and the respective assemblies. Then, virtual parts, which were very different from the actual market and company offer, were evaluated in terms of visual appearance and functional specifications.

The creative phase was very rich with many new ideas and respective digital products. In this paper only are presented the products that were decided to be immediately manufactured.

3.2 Products developed

3.2.1 Wine funnels

In the decanting process, wine from the original bottle is poured into the decanter vessel to aerate the wine, allowing it “to breathe”. When old wines are used, a funnel is also demanded to filtrate sediments. If these funnels also force the wine to travel a long way before reaching the glass decanter, an extra aeration is obtained. Considering this, the main functional requirements were that the decanting funnels must filter the wine and have a large exposed surface area, allowing the wine to react with air.

Wine decanting funnels with incorporated filters, and unique original designs with channels that conducted the wine down to the inner walls of the glass decanter vessel, to quickly intensify the aromas that normally are developed with years into bottle, were conceived (Figures 2 and 3). The funnel grape shape of Figure 3 is an unusual approach that fulfils the same objective but has a simultaneous very attractive decorative function.
3.2.2 Fruit bowls, candelabras and other decorative parts

The decorative objects were inspired in floral motifs with organic shapes where sometimes it was seek the colours profusion existing in a garden or on the waves produced by a drop in the water and marine motifs.

Parts definition and respective characteristics were defined using 3D CAD modelling (in this particular case SolidWorks 2007). For a better final perception of the final aspect of the objects, they were rendered using Cinema 4D software.

Figures 4 to 7 show some of the products developed.

Figure 4. Pewter fruit bowls combining pewter and resin filled with different materials (design by Hélder Faria and Vasco Sepúlveda).
Figure 5. Candelabras with curved and straight tubes rendered using Cinema 4D (design by Hélder Faria).

The Love Story part (Figure 5, left) is inspired in a poetic side of love, in the relation between couples. The espiral (Figure 5, middle) combines the pewter with a glass tube to enable the easy use of the product and the candelabra Cube (Figure 5 right) is a mixture of two arts, the pewter and noble woods.

Other parts seek the promotion of light effects and textures obtained with the contrast among tin, glass, resin or aluminium (Figure 6, left), and others have the particularity to join modular elements to create different parts in accordance with owner desire.

Figure 6. Pewter boxes with the interior in a different material that can be glass, coloured resin or aluminium (design by Hélder Faria).

Figure 7 is a result of joining an innovative material in its conception, a composite (the base for the part on the left) mixed with pewter and exploring the visual effect of melted wax, creating an innovative profusion of colours. This figure shows a thematic explored in this work which is the sculptures that can be obtained with colour melted wax that can be created for decorative purposes in tables of restaurants and others public locals.

Figure 7. Candelabra. The melted wax is accumulated on the base (made in pewter or in composites), producing coloured wax sculptures (design Vasco Sepúlveda).
3.3 Prototypes

After several meetings and discussions about the products conceived and corrections, 3D CAD files were approved and exported to STL format to be sent to the RP equipment. The SLA equipment (Viper Si from 3D Systems, USA) built, layer by layer, the physical prototypes from liquid resin [5, 6]. After the layer construction was completed, the SLA parts were subjected to finishing operations to remove the support structures from the unbalanced regions. To increase the mechanical strength, the parts were then submitted to a post-curing treatment in a UV woven. Prototypes were then finished by manual polishing and painted (Figure 8) for presentation to the company and discussion about aesthetic requirements and perform some tests to validate the concepts (see Figure 9). This step allows the detection of conception mistakes and gives the opportunity to improve the design to achieve more functional and optimized shapes/geometries in a short period of time. During these meetings it was enhanced the “lack of feeling” about the tin mechanical resistance, drafts on the moulds, brazing limitations (this aspect opened another possibility of collaboration to develop joining procedures using adhesives), etc.

![Figure 8. Finishing of the SLA prototypes obtained in different SLA resins.](image1)

![Figure 9. Functional tests with SLA prototypes.](image2)

The products that needed corrections or improvements were redesigned, and new prototypes were produced, performing the necessary number of iterations until the final approvement.
The final prototypes were then obtained and polished and painted with a metallic color (look like real pewter parts).

The prototypes and a promotional brochure in Portuguese and English (defining an effective marketing strategy) were presented in the industrial company (Figure 10) that immediately expressed great interest to produce and commercialize many of the proposals.

![Figure 10. Final brochures of the products.](image)

Using the prototypes, the pewter company produced the respective moulds to get the final pewter prototypes to be sent to customers or to present them in national and international fairs.

### 3.4 Parts Manufacturing

The product development and manufacturing process involved the following main steps:

1. 3D CAD models – Concept evaluation using Solidworks software;
2. RP models and master patterns – Physical evaluation and testing of the SLA prototypes;
3. Mould halves production - Master patterns are placed on uncured rubber discs (in some cases traditional sand casting was used);
4. Vulcanizing the silicone rubber mould and remove the pattern (figure 11 left);
5. Gating and Venting - gates, runner system and air vents are easily cut into the cured rubber mould;
6. Centrifugal casting machine - centrifugal force drives the molten metal into all the cavities within the mould (figure 11 right) [17];
7. Parts removal and finishing operations, including brazing, polishing, patine and packaging [18].

![Figure 12. Cured rubber moulds and open mould after centrifugal casting.](image)

Centrifugal casting is the largely used process in the company due to fact that allows high productivity and has the capacity to produce very thin parts with complex geometries and textures.
Other important manufacturing process was the metal spinning that uses wood or resin moulds. A tin sheet in symmetrical rotation is pressed by the operator, with different metallic tools, against the mould until acquiring its shape (Figure 13). This is a process where the operator experience is fundamental to produce complex high quality parts.

![Figure 13. Metal spinning.](image)

The parts manufacturing also involved wheel forming to get the desired pewter sheet thickness, manual panel beating (Figure 14), tube bending, brazing, polishing and patine application [17].

![Figure 14. Manual beating of the pewter sheet and tubes bending and brazing.](image)

The resin parts that were incorporated in the final products were produced through indirect conversion technologies [5]. The RP model was placed in a box where a degassed silicone was cast. After curing the model was removed and a resin filled with different particles was cast into the silicone mold (Figure 15). In other cases the resin was not filled and after curing was painted with the desired colour.

![Figure 15. Resin casting on silicone moulds.](image)

With the objective of attracting different types of costumers, some of the products were developed to have the possibility to engrave companies or institutions logos, in a clear strategy to be used as conferences gifts and other commemorative events (figure 16).
Figure 16. Capacity to engrave different logos on parts surfaces, in this case noble woods.

A special cardboard packaging was developed for each product together with a label indicating the name of the product, its characteristics and other details. Finally, a special catalogue was created with the complete line of the products developed (Figure 17).

Figure 17. Packaging, labelling and catalogue of the products.

4. RESULTS AND DISCUSSION

Using the product development methodology indicated in the previous sections, the final pewter products were produced and presented in a National fair. In the case of the funnels (Figure 18), the company started immediately their production because they have a request of 325 parts from an American costumer.

Figure 18. Final pewter products (design of Filipe Amaral and Isabel Machado, 2007).

The fruit bowls of Figure 19 are a result of combining different materials and manufacturing technologies. The plate is in pewter, obtained through metal spinning, and the support or other parts are manufactured mixing different materials (small stone particles, cork, sand, mica, fibers or others) with a polymeric resin, following a process internally developed at INEGI.
In these objects it was intended to combine artisanal techniques with more developed technological processes and which are based in more rigorous project methodologies, assisted by the engineering.

Figure 20 shows pewter parts painted on one side (one costumer request) and two candelabra with a glass tube to place a flower.

Figure 21 presents two different candelabras integrally in pewter or using a base in other type of material, like carbon composite.

The products developed in cooperation among people with different competences in the field of product design, engineering and manufacturing, enhances the enormous competitive advantages that can be obtained in a traditional market characterized by the easy products copy from countries with low cost human labor. Introducing advanced technologies and competences that are not easily found in a single company, opens the opportunity to innovate and gain competitive advantages relatively to the companies operating in the same business area.

The work here presented shows pewter parts, but the global concept and many of the technologies presented can easily be applied in other important industrial sectors.
5. CONCLUSION

As we enter in the new millenium, industries based in intensive knowledge are being a key part in the industrial universe. In the current economy, innovation, design, quality and entrepreneurship are essentials in the management of innovative R&D projects, including the management of collaborative projects involving several organizations. Teaching, research and industry should converge in collaborative actions. One paradigmatic example is the collaboration that has been pursued between INEGI and different teaching institutions, and nowadays, already in a continuous way, with companies, and which will be enlarged in a near future with a growing connection with different industrial sectors.

When we assist to a fast emergence of new industrial economies from East Europe and Asia, where their strength is based in the lower human labor costs, the innovation and design can be the differentiation factor of our productive industry. Most of the products that we already buy are Made in China, introduced in the market by multinational European companies that strongly beat in the design and innovation and manage the commercialization of these products.

In the actual crisis conjuncture, Portuguese companies need to change from a cost competitiveness, which leadership is maintained by the new industrialized countries, to a technological competitiveness. Design and innovation are tools that allow create new products, increase their quality levels, functionality, image and differentiation, with a clear competitiveness enhancement.

Considering this, it is fundamental to use the market available tools to shrink the time to market. Companies that do not have these technologies should find support from Universities and Research and Development Institutions to together create value.

Finally we should emphasize that is common to say that “One image worth more than thousand words”, however, presently the things are not like in the past, and so, it seems to be more correct to say that “It worth more one object than thousand images”, and simultaneously the old concept that “The bigger ones eat the smallers” should be replaced by “The quickers (to innovate) eat the slowers (to copy!!!)”

6. ACKNOWLEDGEMENTS

To Freitas & Dores, the designers Isabel Machado, Filipe Amaral, Hélder Faria and Vasco Sepúlveda and all the INEGI technicians that actively participated in this project.

7. REFERENCES


12