

Efficient use of rapid prototyping in the design process

R. Bastiaens, J. Detand & B. Grimonprez

Howest dept. pih, Kortrijk, Belgium

ABSTRACT: Rapid Prototyping is an important product development tool. Today, this technology is available to a wide range of companies (in-house or outsourced). Because of affordable pricing and low technical knowledge requirements, even SME's can/will use RP.

Many of these (new) users have little technical knowledge, despite available expertise, and have no methodology for the use of RP in the product development process. This results in a "random" use, not improving development time, cost and design verification. Common questions are: When to use RP in the process? What are opportunities of the technology?

For three different fields of application, over thirty final years students at HOWEST investigated this matter. In Architecture, prototypes are often only made at the end of the design process. The projects gave insights in how RP can be used during the process; the real costs; how to make hi-quality presentation models; and the "rapid" aspect of RP...

In Product development, RP was used to shorten the time-to-market for different types of products. Learning about efficient use of RP during the process; step-by-step design verification; and the limitation of having only one RP-technology available.

For Ergotherapy, designers made proof-of-concepts for the use of RP as personalized manufacturing technique.

INTRODUCTION

The following paper introduces the reader to several projects and case studies conducted by students and staff of the University College of West-Flanders (HOWEST dept. PIH, Kortrijk, Belgium). In every project, rapid prototyping was used in a different context or field of application varying from architecture to ergotherapy and industrial product design. The projects learn about the use of rapid prototyping in the design process.

Cases were conducted in association with ProtoLab, the rapid prototyping department at HOWEST. www.protolab.be.

1 ASSISTIVE TECHNOLOGY

Orthopedic equipment and assistive technology is often expensive, because of its unique and "one of" nature.

Because these products are often not mass-produced only limited players are active in this range of prod-

ucts. They offer standards that have to be modified to customers need.

1.1 *About the project*

For this project, 14 teams of final year industrial design engineering students at the University College of West-Flanders (HOWEST dept. PIH, Kortrijk, Belgium) worked together with their colleagues of the ergotherapy program. They had the support of InHAM, the innovation centre for housing and adjusted means.

Based on work field research, they had to develop a new assistive tool or improve an existing one. The students had access to FDM technology and a z-corp printer, using it in combination with other prototyping techniques. First to make several design validations along the process, second to use RP for custom fit "one of" parts in the final product. We have to mention the focus of the project was on the quality of the designed product, not on the use of RP. But

then again, RP was one of the strongest elements for achieving a well-designed assistive tool.

Assistive tools made were for example: Customer fit joysticks for wheelchair users; “helping hands” for use indoors, during shopping, ...; Foot supports; Guitar help;...

Industrial Design Engineers are familiar to using prototypes along the design process for validation and communication. In this project, prototypes were used during ergonomic tests and validation of mechanic principles. Since these prototypes often require very precise shapes or represent complex mechanisms (in comparison to manual prototyping) RP is the only technique that reaches these requirements the fastest. Besides technical validation, the prototypes improved communication with ergotherapists and potential users of the assistive tool.

For the eventual products, students also used RP as a tool to make adjustable parts of the assistive tool to customize the product for each specific user. In some cases the ABS models from the FDM machines already met the requirements for the parts, in other cases e.g. vacuum casting was used to make parts in other materials. Since the assistive tools were modeled parametrical in CAD adjusting parts to make them custom fit is very easy.

Figure 1.a. and 1.b. show some CAD models and results of the project, as exhibited on the assistive technology seminar at In-HAM, June 2008. Students finally resulted in “proof of concept” designs, produced by RP and other production techniques.

1.2 Findings and experiences

This project confirmed the valuable role of RP in the product development process. It was used as a communication and validation tool. We believe here RP was successful here because students were made very aware of the use, as explicitly stipulated in the assignment. We learned from experience that product design engineers not always have the reflex to use RP to its full potential in the process, more as an ad-hoc feature available.

In this project RP was considered also as one of the possible production techniques. Therefore, one has to consider all technical aspects of an RP model. Through RP it's possible to make pieces not possible in any other technique. On the other hand, for example strength or thickness of layers are limiting factors. So the designer needs to be aware he's designing for production on a RP machine. We believe RP-technology and materials evolves this quick it can become a very interesting new production technique for “one off's” up to relatively large batches.



Figure 1.a. 3D model of a supporting part for a “helping hand”.



Figure 1.b. Adjustable version of a “helping hand”.

2 THE INTENSIVE PROGRAM

Different disciplines arise in higher educated students. On the other hand, future engineers will be confronted with product/process innovation. In order to keep innovation in Europe, innovation skills must be taught to our engineering students. (Gerson et al. 2007)

2.1 About the project

An intensive Program of 2 weeks, organized by University College of West-Flanders (HOWEST dept. PIH, Kortrijk, Belgium) aims at developing skills for product innovation through a multidisciplinary approach. (D’Hulster et al. 2008) The IP brings together engineering students of different countries (Belgium, Spain, Portugal, Italy, Turkey, The Netherlands, Estonia and Finland) and of several

disciplines (electronic, mechanic, informatics ICT, human technology, industrial design, product design) for two weeks. Through morning seminars the students develop skills for product innovation. In the afternoon workshops, these techniques are implemented on industrial innovation cases by means of a multidisciplinary team for companies as Philips innovative applications, Bekaert, Burodep-Gispem, Deslee Clama, Ama Wellness and Recticel.

The program of the IP is focused on the entire design flow. Very important for this is the IP-workshop flexible environment, consisting of space-dividers, brainstorming walls, wireless internet, 3D-printers, materialization and testing rooms. The students however were only presented a general introduction of Rapid Prototyping and its functionality. The FDM technology as well as a z-corp machine were available for use in the design process. It was not explicitly mentioned in the project assignment to use these techniques.

Only five out of ten teams used RP as a tool in their project. In comparison to the project on “assistive technology”, students first struggled in the integration and use of RP in the design process. In few cases, RP models were used only as a gadget to please the jury. Three teams really used RP in their development, in the beginning printing every 3D CAD file they made. After a while they learned these models didn’t give any added value. Once this was understood, prints were made for very specific reasons like verification of a design principle, comparing variations in the design, validation of technical aspects like strength and production.

In general, the IP resulted in some strong new and innovative-engineered products, ready for patenting and further development in the companies. This happened mainly because of the multidisciplinary approach which leads to more ideas and better communication between the different engineering disciplines. This multidisciplinary approach also shortened the “time to market”. Often one encounters a designer with a great idea, but when checking with an engineer, the idea proves to be “impossible to produce”. When putting all the people at the table at the same time, one is saving a lot of time, since one immediately gets a clear idea of the viability of the product. In this, the rapid prototyped models were very valuable. It showed that teams using prototypes benefit from this in their communication, bringing them faster to materialization and working products.

Figure 2.a. and 2.b. show students at work during the IP and some of the results they developed.



Figure 2.a. Student team in IP2008. Discussion with company engineer on design using prototype.



Figure 2.b. Some of the final prototypes used during IP2008.

2.2 Findings and experiences

We learned in this particular student project and from experience with projects in professional companies, that RP is often still used as an “ad hoc” tool, printing models without true knowledge of the return for the development process. In order to efficiently use RP, there has to be a good understanding of design methodology. Also a correct understanding of different RP techniques is crucial but sometimes limited (even in companies), despite all expertise centers and publicly available knowledge.

We believe, when applied efficiently, RP is a powerful tool in shortening time to market and as a communication tool between developers or even customers. The students resulted in prototypes that better communicate the products and concepts to the companies who had given the assignment, helping them to further develop the products. In this particular case, prototypes also took away the language bar-

rier. Interesting if you come to think of e.g. the problems in communication with production companies in china.

It must be mentioned that the RP-equipment was available in the same building as the IP program. If the students should have been using RP through service providers, it wouldn't have been used in a similar way and probably wouldn't have been as powerful.

3 THE SMALL BUSINESS PROJECTS

The translation from a finished product design into true production isn't as easy as might be expected. It requires production preparation, development of specific tools, supply of materials, planning...

3.1 About the project

For this project, 7 teams of final year industrial product design students at the University College of West-Flanders (HOWEST dept. PIH, Kortrijk, Belgium), developed summer season products for the company Dreamland/Colruyt. To do this, they had to start their own temporary design company and go through the entire process from market study and design brief up to production. They had the support of Vlajo, the Flemish young entrepreneurs. The expected result was the design of a product translated to production of a small range of 30 to 50 pieces.

These students have studied the Rapid prototyping process by Todd Grimm's user's guide (Grimm 2004), as do they know other relevant techniques as CNC milling, vacuum casting, vacuum forming, RIM, 3D CAD, optical scanning, manual prototyping,... Besides prototyping during the design process, the students mainly used RP as a part of their production process, mostly for making mother-models for vacuum casting and -forming. The FDM technology and a z-corp machine were available for use.

Results varied from toys to outdoor lighting, party-gadgets, candles and Furniture. Once the conceptual design was finished and styled, teams switched to the engineering phase. Most students started from a 3D CAD model to validate the design and organize the production of the small range. Intermediate mockups were used to verify technical production aspects like mould complexity or ergonomic and aesthetic aspects like texture of the finished product's surface.

In the cases that used RP in production, the RP model was a basis for making a vacuum casting mould. One team investigated the possibility of printing their entire range through a service provider in SLS,

but moved away from this idea because of the cost (and economic aspect of this assignment).

Figures 3.a., 3.b. and 3.c. show the design and production of the BOO, a decorative outdoor light, produced in a range of 50 pieces. They chose to use RP, instead of e.g. milling, because of the complexity of the product. The students achieved high quality products and "sold out" even before the.



Figure 3.a. The BOO. A decorative light in its packaging.



Figure 3.b. Rapid prototyping model used as master model

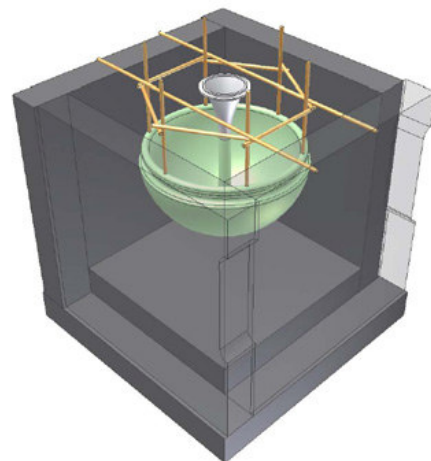


Figure 3.c. Basic principle of the vacuum-casting setup

3.2 Findings and experiences

These projects show the feasibility of producing in small ranges, but also the complexity. It requires good knowledge of traditional- and RP techniques, but also a strong knowledge of materials and applications. In fact, RP is often only a small aspect of the complete prototyping cycle. We believe there is a future for companies that specialize in the production of small ranges for specific niches, of course not based on prototyping alone. We also believe, what is now known as personalized manufacturing will be commonly used on short term, thanks to RP and associated technologies.

4 RAPID PROTOTYPING IN ARCHITECTURE

In architecture, rapid prototyping isn't yet commonly used during the design process. In Belgium, only few service providers start to offer services for architects, mainly to make final presentation mockups using Z-corp technology or SLS.

4.1 About the project

For this project, 5 teams of final year architecture students at the University College of West-Flanders (HOWEST dept. SST, Bruges, Belgium) worked together with Turkish architecture students at Middle East Technical University (METU) to develop hotels and guesthouses. In this project, a goal was to investigate the use of RP during this entire process. For that, students had access to FDM technology. Students already have a good understanding of working in teams using computer aided design in architecture using the mecano (van Helvoort 2003) digital learning environment.

Early on in the process, the switch was made from drawings to CAD models. Using the 3D CAD software to explore and visualize the designs. This eliminated the use of physical models during the development process. Only few study models were made. Most of the teams, chose to use prototypes only in the final stage of the process, making a presentation mockup.

Problems raised in this final stage. Most of the 3D printing software, takes in files and models from common CAD software, requiring no or little fixing. In the field of Architecture, this still is a difficult issue. Since architects use the 3D models only for exploration and visualization, most of this software isn't ready for the step towards CAM and RP. In all models, there were walls overlapping, stairs floating in the air and gaps between the model and used

library elements. Besides that, architecture software doesn't work with solid models but with representations and rendered surfaces, making it hard to import in the printing software. Also the issue of scale, made it difficult to use the 3D models. If 3D models were simply scaled, walls of course had to be printed very thin, sometime beyond the limits of the machine. Eventually, most parts of the designs had to be remodeled specially for printing, other parts could be fixed using magics by materialize.

Figures 4.a., 4.b. and 4.c. below show one of the projects. Students finally chose to make about 80% of their final mockup using RP, only 20% in traditional prototyping techniques. To print their hotel, they had to slice the model up in several pieces, fitting to the modeling platform of the FDM machine. The result was impressive, but was also showing the downsides of using RP.

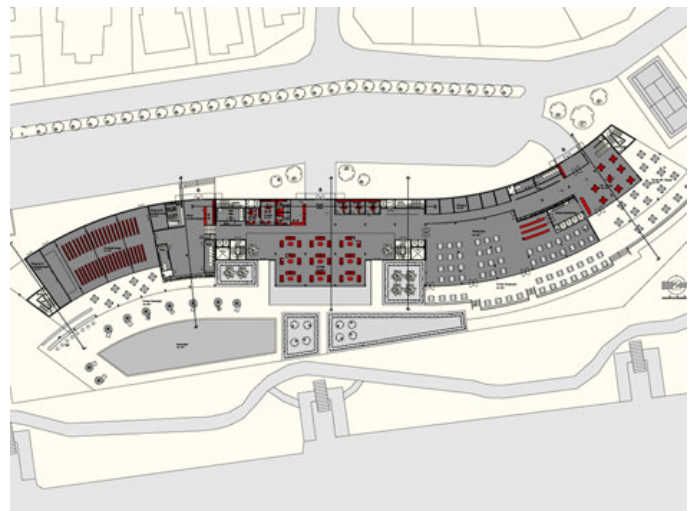


Figure 4.a. CAD drawing of the kemer building



Figure 4.b. Prototype of the kemer building using RP

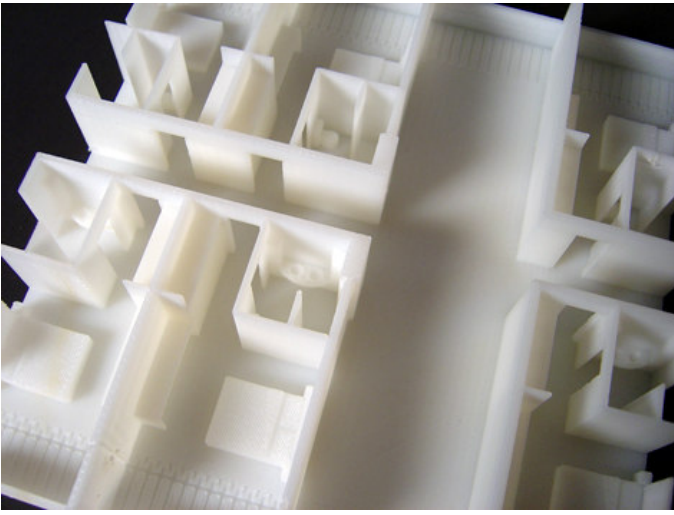


Figure 4.c. Close up of a concept prototype.

4.2 Findings and experiences

We believe using 3D mockups (RP or manual prototyping) can improve the architectural development and design process. Learning to better understand, concepts, volumes, construction,... possibly in combination with the 3D CAD software for intermediate models. Now, once the architects steps to his CAD station, he has actually started building his “final” design, only making slight adjustments to the concept. Only the big architecture offices like e.g. Foster and partners effectively use RP in their design process, using their own developed methodology. To achieve the efficient use of prototypes, the introduction or prototypes in the design methodology should be researched more in depth.

Using RP to make full scale presentation mockups is expensive, which makes it only interesting for big projects, extreme complex models, participating in contract competitions or project developers. For the design of a single-family house, RP is too expensive even in relation to time-consuming manual prototyping of a mockup. Having to mention, rapid prototyping isn't that “rapid” either because of model size and manual assembly afterwards. In the students projects RP became interesting in combination with other prototyping techniques, making complex parts or elements that needed a high quality finishing. We believe, RP mockups could also be very interesting in very specific aspect of validation like e.g. aerodynamic simulations.

In order to introduce RP into the architecture segment, adapted software is required and architects should change their use of 3D CAD. Using RP requires more accurate 3D CAD models. Biggest problem stays in the export-quality of the CAD models from the architects and the import in fixing and printing software, even in market leading software

like e.g. Magics. In essence, software should improve, not demanding the architect to adapt. For this project, we didn't have the right technology at that point. Using FDM, the quality was sometimes lower than expected. Some small cases show that using a Z-corp technology during the design process for validation and using SLS for strong high quality presentation models is the best option.

5 THE ROBOT PROJECT

In this small case, 15 teams of 2nd year industrial product design students at the University College of West-Flanders (HOWEST dept. PIH, Kortrijk, Belgium) worked on the design of fighter robots. This assignment fits in the range of technical/mechanical design exercises and was inspired by the BBC's TV show “Robot Wars”. As probably obvious, the students got carte blanche to design, automate and build a robot using all available techniques at our campus. The assignment required a fully engineered CAD model and advised students to use RP specific for fine mechanical parts like transmissions, reductions,...

Building these robots proved the possibility of building small mechanical systems that can be used for functional prototypes of e.g. consumer goods. Even small ranges of mechanical systems for commercial purposes might be feasible in several RP-techniques. The possibility to make complex mechanical systems in one piece, not being limited by having to assemble them, in this case is a big advantage.

As we knew in advance, for heavy-duty mechanisms, these RP-techniques aren't strong, precise and durable enough. Metal-based technologies will be more suitable.

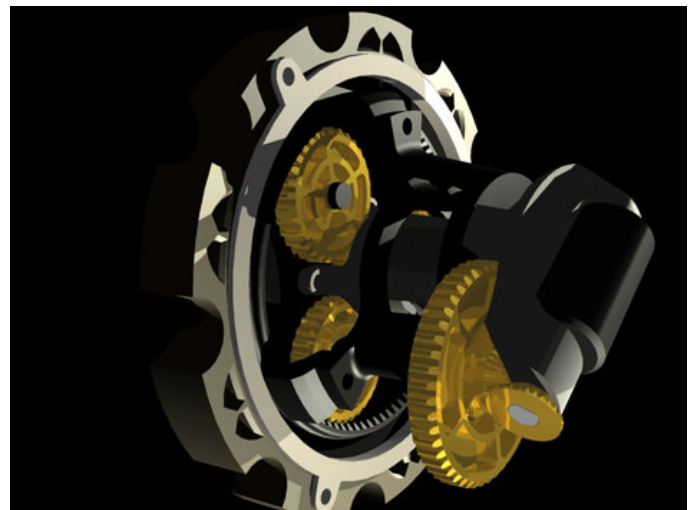


Figure 5.a. Fine mechanical system of a Fighter Robot



Figure 5.b. Student working on his Fighter Robot.

6 THE FINAL YEAR PROJECTS

As a crown on their work, students graduate every year after finishing a graduation project. The best place to learn about the real world is in the real world. For that, yearly about 80 of our final years students in Bachelor and Master Industrials Product Design at HOWEST dept. PIH, are placed in companies in Belgium and abroad. They develop products in several markets, as can be seen on the website www.industrieeelontwerpers.be that showcases these projects.

About 1/3th of these projects use Rapid Prototyping during the process or at the end as presentation and possibly commercial mockup. For that the companies use in-house RP or go to a service provider. This shows that many design offices and R&D departments have already integrated the use of RP in their design flow for several years. On the other hand, still many companies don't have a good understanding of RP, or even get introduced to it by the students.

6.1 Findings and experiences

We noticed, companies that are familiar with RP sometimes consider buying a specific RP technology. They doubt about buying a machine of their own or keep working with service providers. The answer of course depends on the use of RP in your process and the mix of RP technologies required.

We noticed some companies that have invested in a machine, but are still searching how to use it in their process. They can't say how they gain in the design process or how there is a return of investment. The

use it at the wrong time, for the wrong reasons, too much, too little,...

We noticed, prototypes are often seen only as a final result of a design process as presentation (which is of course a good reason for prototyping), but don't use it in their design process or see it as an opportunity for new applications and techniques. Because of that, companies are sometimes sensitive to RP-costs or tend to experience prototypes as not useful.

CONCLUSION

During the past academic year, we've looked in to the use of RP in the design process. This for different types of projects conducted by students, discovering new and newer fields of application. As anyone familiar with RP will confirm, it was a valuable enrichment of our educational program as of the project results. This way, RP became a powerful design tool, embedded in the methodology thought to our students.

Rapid prototyping speeds up the development process and time to market of a product. It also provides better communication and helps selling the product to the customer.

Still we experience a lot of questions both with students and companies. Many struggle with the integration of RP in their process, searching for a better design methodology. Others worry about the economic aspects or doubt about buying a machine or outsourcing. In some fields, like architecture, the currently available software is the biggest limitation.

The RP technologies and materials are developing very fast and become accessible to anyone. For that, we believe there are many opportunities ahead. Thinking of personalized manufacturing, using RP as a production technology, producing small ranges, finding new fields of application.

First of all, there should be more attention to low-level introduction for companies new to the technology. Answering their questions, teaching them how to use Rapid Prototyping in their design methodology. For that, HOWEST organized a Rapid Prototyping event on January 16th, 2008 welcoming over 150 visitors. HOWEST also participated in the 3D academy symposium on may 9th 2007 (Bastiaens 2007), and published in "Kunststof and rubber" magazine (Grimonprez et al. 2007) introducing existing technologies and new developments.

REFERENCES

- Gerson, Ph.M., Taylor, A. J. & Ramond, B. 2007. Dedicated workshops to educate T-shaped engineers. *Proceedings of IMECE2007*. Seattle, Washington, US.
- D'Hulster, F. & Gerson, Ph.M. 2008. Multidisciplinary workshops preparing future engineers for technical innovation. *Proceedings of the 4th International CDIO Conference, Hogeschool Gent*. Gent, Belgium: Hogent.
- Grimm, T. 2004. *Users's guide to rapid prototyping*. Dearborn, Michigan, USA: Society of manufacturing engineers.
- van Helvoort, R., Stellingwerff, M. & Verbeke, J. 2004. Mecano – when CAAD meets ICT, Local values in a networked design world – added value of computer aided architectural design. *DUP Science*. Delft, The Netherlands: Delft University Press.
- Bastiaens, R. 2007. Rapid prototyping and 3D printing for industry, architecture and arts. *Proceedings of the 3D Academy conference*. Kortrijk, Belgium: Howest.
- Grimonprez, B. et al. 2007. Rapid prototyping – Bestaande technieken, nieuwe ontwikkelingen. *Kunststof en rubber 5*.