

# **Rapid Prototyping for Foundry Tool Making: Curriculum and Industrial Projects**

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## **Abstract**

This paper presents the evolution of an experimental course at Cal Poly which applies rapid prototyping techniques, enabling a concurrent engineering approach to product development. This is applied within our manufacturing environment of foundry and machining processes. It focuses upon the main problem of rapid tooling for these processes. A contemporary problem provided by industry is used as the vehicle for illustrating rapid prototyping techniques within a concurrent engineering context.

## **Introduction**

Cal Poly has a strong tradition of "hands-on" approaches to undergraduate engineering education. All engineering programs require substantial lab experiences to convey the applications of theory. The curriculum addresses both the Design and Manufacturing Processes, in the traditional manner as functionally independent areas. The problem then becomes of how to engender an integrative perspective which promotes concurrent engineering. Our approach to address this educational problem is to evolve an integrative course, which utilizes rapid prototyping as an enabling technology, for a concurrent engineering based analysis of manufacturability issues within a specific product development.

The course seeks to consolidate the three major areas of: concurrent engineering, manufacturing process design, and rapid prototyping techniques. The experimental course utilizes a product development/manufacturing process problem (the case study) from an industrial sponsor. This provides a sound basis for the application of rapid prototyping techniques.

## Experimental Course Structure

The course format is a combination of seminar presentations and team-based lab activities. The seminars occur on a weekly basis and the lab work is scheduled by the teams as needed. The presenters are typically industrial representatives who then help lead the discussions. The students prepare for the seminars by completing both readings assignments and, where appropriate, lab exercises.

The goal of the seminar portion of the course is to impart an understanding of the sequence of the product development cycle from conceptualization through process design and manufacturing implementation. This is done within the manufacturing environment of foundry related processes. Secondly, we hope to impart an understanding of the application of concurrent engineering and rapid prototyping to this complete sequence. The subjects of the presenters are chosen to build towards this understanding. We began first with an overview of our manufacturing environment and its inherent problems; specifically the "tooling bottleneck." We then introduce concurrent engineering ideals and structures and show how rapid prototyping can provide a set of "enabling technologies" useful for mitigating this "bottleneck." Next we focus on our first case study which shows a traditional approach to a product's development. We then concentrate upon the second case study "The Industrial Problem" which is used as the framework for an in-depth study of the possibilities of the linked applications of concurrent engineering and rapid prototyping.

The goal of the lab portion of the course is to provide the students with the experience of participating in a multiple team project within a rapid prototyping enabled concurrent engineering environment. Each of the three teams were assigned a focussed task/problem area to address: project management, design, and manufacturing. The overall task within the framework of this two credit hour course was for the teams to build a joint overview of the processes, the problems and the possibilities. This sometimes required solely conceptual effort such as understanding the role of laser scanning for digitizing hand produced artistic sole model into cad systems. And, sometimes the task required hands-on lab work such as using RTV silicone to replicate prototypes into foundry core-sand media for casting operations. The framework provides an interesting blend of esoteric theories and dirty manufacturing processes. Without the Industrial Problem it would have been difficult to provide a focus for linking together all the different areas, subjects, and processes that were investigated.

## Case Study 1: Air-motor production

The purpose of this case study was to allow the students to obtain insights into the ongoing process of the design, manufacture and assembly of a product. The design of the original motor, the foundry tooling necessary for the mold making and casting processes and the fixturing required for the subsequent post-casting machining processes were designed and implemented in the Manufacturing tool design courses. After this was completed the foundry courses and clubs within the Industrial Engineering Department designed and implemented the casting processes. They now regularly produce 600 castings annually to be delivered back to the Manufacturing courses.

This whole process, both historical and ongoing, is what is reviewed in this case study. While this case study does provide insight into the inter-dependence of design and manufacturing, it fails to provide a concurrent engineering learning environment, because each topic is covered within sequential independent courses with limited scope for manufacturability feedback and iterative change. The understanding of an existing complete manufacturing sequence and the possibilities for the utilization of rapid prototyping technologies to enable this feedback and iterative change by allowing quick tooling redesign and the communications necessary to drive that change are the hoped for results of this first case study.

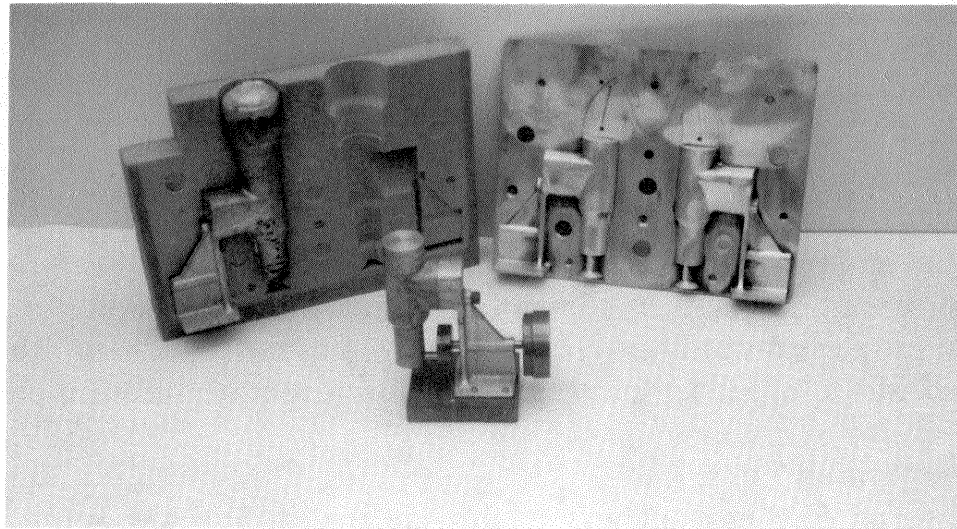


Figure 1: The shell mold face plate, 1/2 of a two unit mold produced from that faceplate (with one casting) and a completed air motor.

## **Case Study 2 : NIKE Midsole Mold**

This case study was the main focus of the course. The lessons from the Air Motor study were applied to this project. The main problem here is the one that we feel is central to our foundry/manufacturing process. It is the need to be able to rapidly and economically produce tooling for both prototyping and production needs. With the NIKE Midsole Mold the problem addressed is how to start with a handmade artistic prototype and to then quickly produce molds for the production of the polyurethane midsoles in a range of sizes. At first this might not appear to be a foundry tooling problem but it can be seen as such in that there is a parallel between the needs of both industries for sets of working molds. Furthermore there needs to be an easily executed process for mold design modification between the design and manufacturing teams. In both industries the main production problem is the "tooling bottleneck." In addition since the foundry processes can be used to make the sole molds themselves there is a tight linkage of possibilities.

The lab project task then becomes that of how to apply rapid prototyping and concurrent engineering techniques to this mold production problem. To do so requires a full understanding of the different possible avenues of production. To accomplish this the three team structure was devised. A project management team would supervise the interaction of a design team and a manufacturing team. The design team would produce the prototypes from which the manufacturing team would produce production molds. At first the main interface between the design and the manufacturing teams was seen to be the deliverable of a physical master positive of the midsole to be produced. This was later expanded to allow the design team to produce the prototypes of the tooling as specified by manufacturing. The missions of teams were:

### **Project Management Team:**

To provide coordination, administrative and team communication services; to facilitate progress towards analysis and solution of the case study. The key role of this team was to engender and enable the concurrent engineering philosophy.

### **Design/Prototyping Team:**

The focus of this team was to provide the CAD/CAM services for the project. Their key tasks were to 1) Capture the original design concept into CAD, 2) Manipulate within CAD for both design modification and the "grading process" needed to produce that design in the different shoe sizes, and 3) Prototype out of

CAD of the physical units needed for the interface to the manufacturing team. For each task a set of options were investigated.

For the Capture task three methods were investigated: 1) Non-contact design capture methods of laser scanning and Industrial Computed Tomography, 2) Contact design capture based on CMM use and 3) Traditional capture based upon micrometers, radius gauges etc. for manual entry into the CAD systems.

For the Manipulate task different systems were compared including Cadkey, CadCam, Pro/Engineer covering traditional constructive solid model methods and parametric based options, and FEA analysis.

For the Prototyping task the methods investigated included Stereo-Lithography, Selective Laser Sintering, traditional CNC machining of both metal molds and investment castable machinable waxes and the growing set of other rapid prototyping technologies.

#### **Manufacturing Team:**

The main task of this team was to translate the deliverables from the Design/Prototyping Team into production tooling. This requires interaction with the design team to continually redefine the deliverables set and to explore the range of production method possibilities. The processes investigated by this team were extensive and included the direct investment casting of prototypes; the direct use of prototypes for wax injection molds; the replication from prototypes for producing wax injection molds, spray-metal based molds, foundry cores for the direct casting of molds; and plastic foundry tooling production. Some of these processes were only studied, others were tested.

The three teams worked well together and a well rounded understanding of the problem was achieved. The project management team provided a continuing focus for the other teams and their sub-groups. Without this focus there was a tendency for a sub-group to get carried away with its investigation of a subject and lose sight of the scope of the subject's relevancy to the overall problem. The team structure allowed the students to both concentrate on areas of personal interest while gaining a good overview. It is a structure that we will maintain in future course offerings.

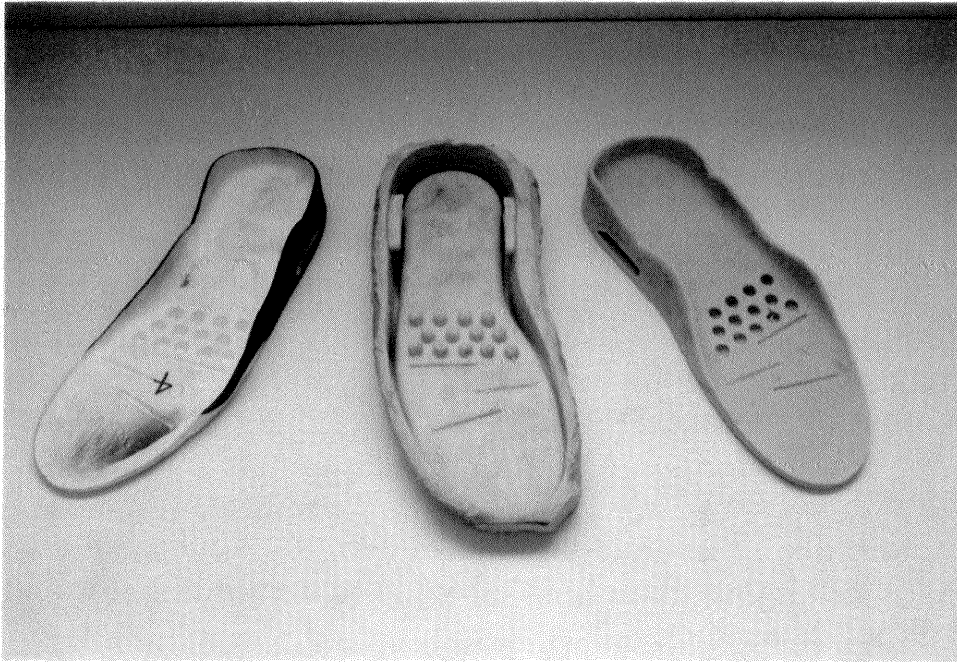


Figure 2 shows the process where a prototype (in this case an actual midsole) was used to make an RTV Silicone mold (via the Ciba-Geigy method) which was then used to produce a replicate of the prototype in foundry core-sand material (either epoxy or shell binder systems). This core can then be used with both spray-metal and traditional aluminum casting processes to produce metal molds for subsequent polyurethane midsole production.

### Conclusions

An experimental course has been offered which applies rapid prototyping technologies and concurrent engineering structures to foundry based manufacturing problems. The format is a combination of seminar presentations by industrial representatives and "hands-on" lab activities by teams addressing different aspects of a product development problem described by industry, in this case: the NIKE Corporation. The focusing upon a case study problem with the realm of a specific set of manufacturing processes is seen to be the key for studying the wide variety of subjects which are related to rapid prototyping.

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