MACHINE DESIGN

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RAPID PROTOTYPING ACCELERATES THE DESIGN PROCESS

Engineers need to adopt new habits to make the most of rapid prototyping.

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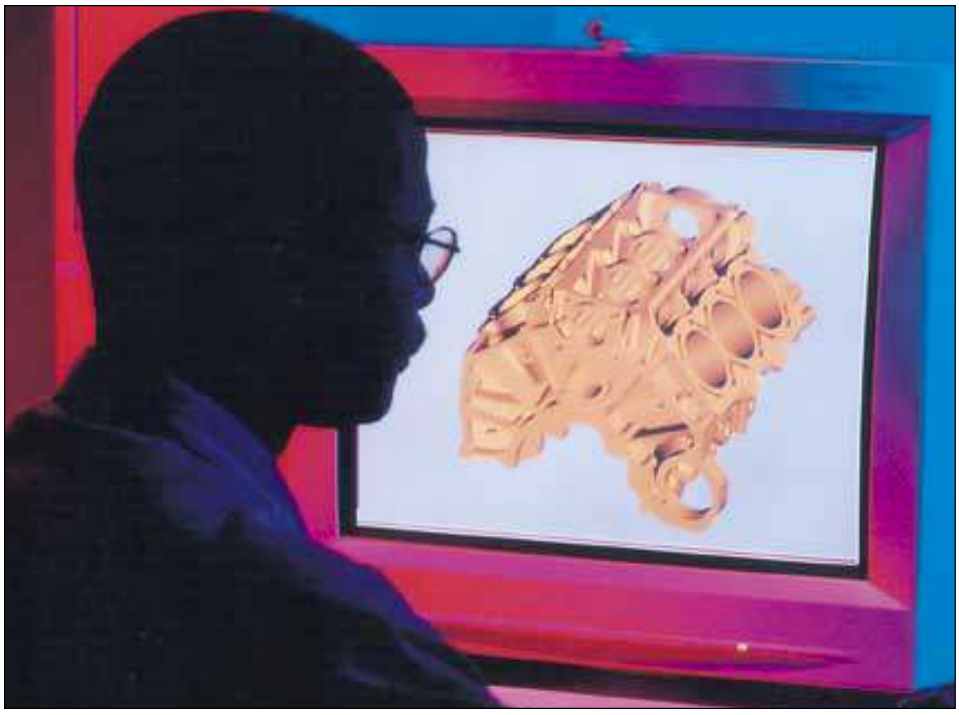
Rapid prototyping has been a tool in the designer's arsenal for over a decade now, and the technologies behind it have improved greatly. The main impact of these technologies, however, has been to replace traditional modeling techniques in the final stages of product development and the transition to manufacturing. But the greatest potential for 3D modeling lies earlier in the design process where superior designs are conceived and the roots of development delays are put down.

Properly used, rapid prototyping can greatly accelerate product development and lead to high-quality, defect-free products. Fortunately, the new generation of rapid prototyping tools, variously known as conceptual modelers, desktop modelers, and 3D printers, are much faster than earlier versions. They lend themselves to use by engineers in office environments.



TIGHTENING UP THE FRONT END

Traditionally, rapid prototyping (RP) has helped engineers shorten the design cycle by letting them make in 2 hr a prototype that would have taken a week without it. Such a savings in time is impressive on a percentage basis, but the week saved is meager compared to the typical 12-month development cycle.

To really save time with RP, managers and engineers need to update the product-development process to reflect the power of next-generation RP tools. And to trim the most time from that process, they should examine the slowest parts of it with an eye to applying RP's potential to radically accelerate these activities. Ironically, the biggest opportunity to save time is before most companies even start their clocks — the fuzzy front end prior to concept approval. Few firms are aware of the large amounts of time that slip by unnoticed in that fuzzy front end.

Many companies conveniently define the conceptual stage out of existence — or more precisely, out of their minds. They simply define the start of a development project as when they have approved a concept. But the internal milestone of concept approval is immaterial to the marketplace and the competition, which start their clocks when the market opportunity arises. There are several ways

companies fritter away precious time prior to concept approval.

Delayed decision making. Later stages of the design process have well-defined decision points with clear, objective data on which to base decisions. In earlier stages, however, the process and the data are all softer and relevant parties to the discussion may not have a common base of communication. It might not even be clear who the relevant parties are.

Lack of a common decision-making medium. Those involved in key decisions — marketers, engineers, manufacturing staff — may not have convenient access to the same, commonly understood product information.

Lack of communication. Design processes can wander with too many or too few possibilities being investigated. A sensor company recently found that the different segments of its design team, which are located in different states, were each pursuing ideas subtly incompatible with concepts evolving at the other sites. After these different branches of development grew apart for several months, the groups had a dramatic shock when two of the three groups were forced to perform substantial redesign to be compatible with the third.

Lack of consensus. Those involved in the design process may disagree on which direction to take with a product. In many cases, designers develop strong ideas about which way the product should go. They are often limited to debating relevant advantages based only on CAD drawings and 2D renderings. The relevant arbiter of the discussion, the customer, can't be brought into the discussion to offer input and settle the issue in a practical way because customers usually don't relate well to drawings or renderings. This leaves the decision process resting solely on personal opinion, which could deadlock the project.

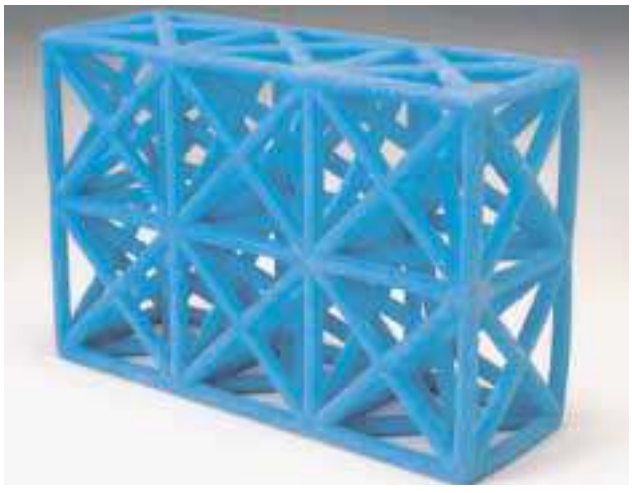
Changes in direction and rework. Critical mistakes often survive unnoticed in digital models for weeks and only appear when a project approaches production. One project, for example, was held up for a month when someone finally detected that a late-stage change made to internal components would force a rerouting of the wiring and cause a one-month delay. This problem existed in the digital data for weeks but was only found when the project went to late-stage modeling. If the rewiring conflict were caught earlier, the delay could have been avoided completely.

Sometimes it's the end customer who finds a mistake late in the process. On a design project for a handheld medical device, the basic grip design was tested by several nurses late in the process. The grip turned out to be extremely uncomfortable if held for several hours, a long but not unusual period of use for the tool. This left the design team to choose between delaying the product release for weeks or going to market with a product that would appeal to only 75% of the target market.

MAKING A DIFFERENCE WITH PROTOTYPES

Three-dimensional prototypes put engineers, managers, manufacturing staff and marketers on equal footing in evaluating designs. All the interested parties can see, touch, and handle the design, just as the ultimate customers will.

Some companies take the extra step of including end users in the process by using prototypes. One product developer, for example, prototyped 12 different concepts of a handheld device in one day then convened a test panel of likely users to evaluate the design. They identi-



fied the best features from each, and the company quickly created a hybrid that captured them.

Prototypes also clarify communication, spanning distances and disciplines. For example, Graco Children's Products, a leading manufacturer of child-safety products, uses RP to communicate between its design facility in Pennsylvania and its production facility in China. A leading automotive company uses RP to communicate between engine designers and the foundry.

Adidas uses concept models to rapidly create new sole designs and then immediately broadcast these models around the world to sister facilities. They e-mail CAD data and prototypes are "printed" at the remote sites, creating a "3D fax" capability.

Prototypes are also effective project-management tools. On a recent project, a sensor design company produced prototypes after each design iteration. They sent copies to the marketers, management, and a focus group of end users several times each month. This let designers stay close to the customers' needs while letting managers closely monitor the project's progress. Management and marketing met to review options and establish a given direction for designers, along with goals for the next review. Regardless of technical training or access to specific hardware, each member of this design effort had the same information at the same time in the form of the 3D prototype.

Prototypes also are handy at design reviews. The prototype need not embody all of the product's final qualities; it is only important the model convey information clearly. At a recent design review for a component on an upcoming Mars lander, for example, a working prototype quickly drew attention to problem areas such as a piece not thick enough to survive the landing impact.

Other companies, like ExpressCAD, a design services firm, use RP to force a project along. In one instance, ExpressCAD used RP to go from initial concept for a skateboard wheel assembly to finished parts in just 10 days. They placed themselves on the regimen of a model a day, and at the end of each day, new models were delivered to the client. The client sent back their reactions and gave ExpressCAD an idea of where to focus the next day's activities.

Most companies can't see final designs in product form until tooling is produced. New concept-stage RP technologies can provide dozens of snapshot views of the final product at a fraction of the time and cost of traditional RP systems. This lets designers watch as the product evolves and lets them take more chances and be more creative as less time, effort, and ego are invested in each model.

For example, engineers at Giostyle, a European housewares manufacturer, use RP to fully explore a wider range of possibilities. "Many other companies are trying to reach the same customers we are, and some have far lower labor costs. If we are to succeed, we must give the customer products that are clearly better and to do so we must be more daring than the rest. Concept modeling helps us do that," says a company spokesperson.

A major company in the handheld communications market also uses RP to accelerate creativity. Rather than following the normal practice of prototyping only until the major design

direction is established, they begin by turning out 10 prototypes representing ten different design approaches. They solicit feedback on these and select the best features of each, and then turn out a new series of hybrid designs in just a few days. As they describe it, they give themselves "the luxury of presenting customers with a variety of possible combinations and gaining early insight into niche-focused concepts." Rather than taking leaps of faith toward their customer's preferences, they pursue what they call "the scientific process of design."

RP ADVICE

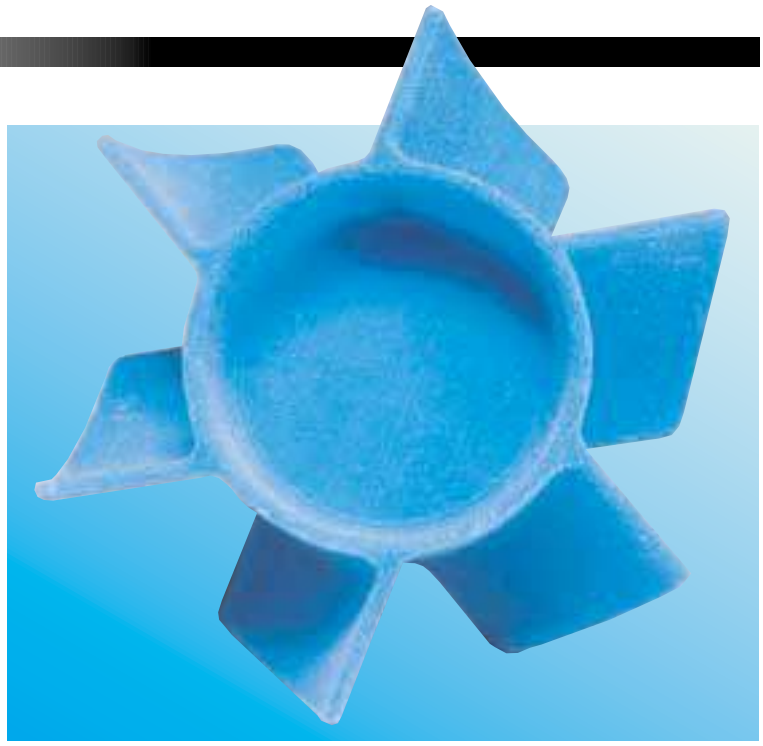
The examples above only scratch the surface of what can be done with RP to improve and shorten product development. Here are some suggestions for helping other companies change their design styles to take full advantage of RP:

Every prototype should be aimed at a specific question that needs answering. When RP was expensive and slow, engineers could only afford to use prototypes that tested several ideas at once. Now they can afford to test ideas individually, then mix and match later. Consequently, to assimilate this new behavior, explicitly plan to use each prototype to test only one idea or assumption. It's good scientific practice to test hypotheses independently, and now engineers can afford to do it.

Prototypes should be only elaborate enough (strength, surface finish, etc.) to answer this question. In later stages of development, where models have traditionally been cost justified, designs were mature and well refined, so refined models seemed appropriate. When models are used early in the product-development process, such refinement is wasteful. Engineers should build prototypes with just enough detail to answer the specific question at hand. When you have this answer, toss the prototype away and move on. This prevents money and time from being wasted polishing models in ways that won't move the project forward.

Be advised that everyone, including the accountants, will have to get used to seeing wastebaskets full of models that have served their purpose. To help you with this, you might consider the much-ballyhooed paperless society that computers were to bring us. So far, paper usage is actually rising. Why? Because we *can* produce high-quality documents more easily and at much lower cost than ever before, and these documents help us run the business more effectively.

If you think of multiple alternatives, build multiple prototypes in parallel. Everyone is aware of the speed advantages gained by proceeding on multiple activities in parallel. Now we can afford to do it with models. If designers or engineers think of alternative ways to solve a design problem, make prototypes of each option rather than presupposing the best solution and modeling only one. With prototypes of the alternatives, new combinations may become apparent.



Make decisions as questions are answered. Don't wait until the final prototype appears. This is probably the most difficult habit to change, but it is also the most crucial. This change will affect others in the organization, such as marketers, people in manufacturing, and top management.

The trick to progressing quickly with RP is to move forward incrementally with small but sound steps. But if the final decision makers continue to wait until the final, "perfect" prototype appears before making any commitments, there will still be lots of second guessing, indecision and rework. And there will be no real improvements in the process. This behavioral change is essential if RP is ever to grow beyond the "cute toy" stage.

The faster you can make prototypes, the faster you can develop the product. Making the best use of RP is predicated on making small but sound steps quickly. Thus, the process accelerates to the extent technology will let us make and assess models more quickly. But it won't work if a company still makes conceptual prototypes by sending them out for processing at service bureaus, still ships prototypes to decision makers the same way they used to, or management still takes as much time to make decisions as before. Success depends on the ability to shorten the iterative product-development loop. ■

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