STEVEN FIELDING

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Taking Rapid Prototyping of Precision Components To the Next Level with 'Production Proof' Models

The more you can think through all the details of part design and the production process on the front end, the fewer problems and limitations you will have downstream and the more options you can explore. 'Production Proof' prototyping gives you those choices.

The concept of rapid prototyping has established its value in any number of fields. In the arena of discrete part and precision component manufacturing, appearance models built with traditional stereolithography and other polymer-based 3D printing technologies provide "instant gratification" of design aesthetics. Functional models—often made of the same material to be used for the final part—allow testing of form, fit and function before tooling investments are made. Now the rapid prototyping process (RP) is being more fully exploited with the use of "Production Proof" prototype models.

The "Production Proof" prototype incorporates into the functional model all the unique characteristics of the production tooling, such as knock-out pads and pins, parting lines, flash zones, etc. Taking the RP process to this level provides a more complete look at how the projected part will perform in the application, and as important, how it will interact with fellow components in an assembly. This third dimension of insight into potential failure modes with assemblies and/or objectionable cosmetics often yields meaningful benefits, well worth the small incremental cost to develop the production prototype model.

In this article we will look at the product development process of three miniature parts—one die cast of zinc, one injection molded plastic and one two-part assembly of zinc and plastic—and how the use of Production Proof prototype models helped save costs, improve ultimate part design and functionality, and eliminate costly errors before they were able to occur.

Functional Prototypes in Zinc and Plastic

Stereolithography and other 3D part printing techniques generate appearance models quickly and economically. But, only by going to the next step—the functional model—can you begin to answer key design questions, like: have I designed this part for functionality and manufacturability? Is it going to perform at the appropriate level of safety and reliability? How will it mate or interact with other components? Etc.

Used as sacrificial parts for investment casting, spin casting or injection molding, soft 3D printing models yield multiple functional components for testing and even short-run production. Depending on the process used, quantities of functional prototypes available range from six to 12 for investment casting, 25 to 100 or even 500 with spin casting, and up to 500 with short-run injection molding. Of the three, investment casting is the most precise, and with proper care it is possible to get higher tolerance results than are typically quoted for RP processes. Very often, quoted tolerances will be in the ±0.005" to ±0.010" range, which is too much variation for most small part appli-

Photos courtesy of Fielding Manufacturing.

Figure 1
A good example of the value of producing production prototype models. The part is a mounting bracket for a fiber optic cable housing. At less than 2 cm wide, it incorporates some fairly complex geometry, very tight tolerances and even has a 000-80 thread hole on the upper face.

Figure 2
Knock-out pin shapes and the runner system with attached cap were shown on the Production Proof (upper right) of this pivot insert and cap assembly.

cations. However, as resolution holds better for small parts than it does for much bigger parts, most small part features can often get down in the ±0.003" or ±0.004" range.

As for mechanical strength, investment or spun cast prototypes for zinc die casting are typically about 85 percent of the strength of the actual die cast part. Thus, if the prototype passes your mechanical application testing, the actual die cast part will only be that much stronger.

In plastic, if the actual material is used, including color concentrates, fillers, etc., the prototype part strength is truly going to be representative of the production process of injection molding. Costs can be kept down by using frames and inserts instead of complete molds, and some manufacturers actually continue to use these tools for initial production, until sales levels are better known and the capital risk of building multiple cavity production tools can be reduced.

Dealing with Thin Walls

A frequent problem with prototyping for zinc die casting is wall thickness. Typically, the minimum prototype wall must be 0.070" to 0.080", although, depending upon geometry, they can sometimes get as low as 0.055" to 0.060". The problem is that with the die cast version, walls can be much thinner.

Die casting injects much faster and under pressure, so you can fill thinner walls. Typical NADCA recommendations are approximately 0.025" thick walls, but some walls have gone as low as 0.010" on some miniature parts where the tooling and gating have been designed to maximize flow through those zones.

The solution is to make the prototypes with excess material—i.e., in the 0.070"/0.080" range—then machine that back down to the required dimensions for testing. The trick is not to alter the design, but to alter the model for the prototype process.

The Need for "Production Proof" Prototype Models

The problem with functional prototypes most often lies in what vendors don't know. In today's highly proprietary, multi-vendor manufacturing environment, "black box" design mentality often limits the amount of information vendors are given about the components they are to manufacture. Vendors are given a part print along with a list of specifications and told simply to meet them.

Often, the design engineer in charge is not thoroughly familiar with the vendors' processes and has not considered all eventualities. Frequently, there are mating components or other requirements not known which affect the part being made. Conversely, the requirements of the manufacturing processes—zinc die casting or injection molding—can also impact the part in ways the design engineer may not have considered—ways which may cause difficulties with the overall component assembly, or which may even have the potential to save money and/or improve the overall assembly.

If the vendor is working blind, it is very difficult to communicate these issues until (or after) parts reach the production stage. Hence, the value of the "Production Prototype" model.

Fielding Manufacturing (Cranston, RI) has been involved with rapid prototyping for more than a dozen years. Founded in 1962, the company specializes in the manufacture of high-precision miniature die-cast and injection-molded components. Fielding provides a full-service solution that includes design for manufacturability, RP, tool design and reliable parts production, as well as a range of secondary operations and finishing. They have a strong reputation for quality, service and dependability, and have experience in a wide range of industrial markets, including telecommunications, fiber optics, hardware, electronics/electrical, automotive, fasteners/threaded components, appliance and consumer.

Fiber Optic Mounting Bracket

The part sequence shown in **Figure 1,** is a good example of the value of producing production prototype models. The part is a mounting bracket for a fiber optic cable housing produced for a high-end OEM. At less than 2 cm wide, it incorporates some fairly complex geometry, very tight tolerances and even has a 000-80 thread hole on the upper face. Pictured are the green 3D print model, initial production prototype model and the final zinc die cast piece.

Fielding Manufacturing was told the part mated with "four or five" other parts, but was not allowed to know what those parts were, what they were made of, or how they mated with this part. All they were told was that one piece was to "nest" with the base of this part, and that the geometry was specifically designed to facilitate that.

This left Fielding Manufacturing in a bit of a quandary. In order to die cast the piece, they had to position ejector (KO) pins in the tool to "knock out" the parts from the mold. The best place to put the KO pins was where they would strike against this underside. Here, they had two options: they could curve the ends of the knock-out pins to conform to the convex curve on the underside of the part—a complex and expensive proposition as it meant the pins would also have to be kept from rotating—or they could make little indents in the part and use standard pins.

But not knowing exactly how the mating part "nested," they had no idea whether there would be any interference. By incorporating the knock-out pin flats into the 3D print and Production Proof model, the customer was able to see and, if necessary, test, whether these flats would cause any problem with his nesting part without Fielding ever knowing anything more about it.

As it turned out, the knock-out pin flats made no difference and Fielding was able to use the less expensive production method. However, when the assembled components were tested, it was found that the geometry of the two nesting parts was not sufficient to prevent them from wiggling. They were able to eliminate this problem by designing a nesting groove around the periphery of the part, which can be seen in the final production part on the right in Figure 1.

Pivot Insert and Cap

A similar example—a ruggedized housing which provides wire strain relief for high end microphones—is shown in **Figure 2,** where knock-out pin shapes and the runner system with attached cap were shown on the Production Proof (upper right). The cap was designed to easily snap on after wires were inserted through the main barrel and hold long enough for the parts to be encapsulated by overmolding with plastic. Also of interest in this application was that 90° core pulls were used to create a 94° angle on the part, and the inherent ductility of zinc allowed the attaching cable to be crimp-fitted, eliminating additional parts and assembly.

Figure 3
For the production prototype of this two-part plastic/zinc nozzle assembly, it was important to use the actual plastic material specified for the final production part, and also to match the actual conditions of high volume injection-molding as closely as possible.

Figure 4
These parts all have identifying numbers or assembly instructions molded in. Done upfront, as part of the prototyping process, it's a no-brainer. If not done, or done later, it can cause difficulties in production, and add cost to the process.

Variable Air Flow Nozzle

Another example is the variable air flow nozzle shown in **Figure 3**. This two-part assembly for a major HVAC OEM consists of two small plates, approximately 1 cm in diameter, one plastic, the other zinc, and joined with a flexible snap post. A feedback mechanism rotates the zinc part by means of its geared rim to control air flow. Key to the design was the functionality of the snap hub and the lubricity of the plastic disk which needed to withstand hundreds of thousands of cycles. The customer also wanted 50 sets of parts not only for a wide range of mechanical tests, but also for their marketing people to give to selected customers for additional design feedback.

Thus, for the production prototype, it was important to use the actual plastic material specified for the final production part, and also to match the actual conditions of high-volume injection molding as closely as possible since things like barrel residence time can affect material properties, like lubricity. But the problem was, that without investing in the cam-action mold needed to produce the snap post—the prototype tool used a little hand-loaded insert with two core pins—they would not be able to achieve anything close to the cycle times of actual production.

The solution was to use a smaller machine—the smaller barrel held less material, thus reducing residence time per shot—so Fielding was able to simulate production molding conditions to achieve the levels of lubricity required. But again, the key to success was to provide the customer with a set of fully functional production prototypes which matched the final part and manufacturing conditions as closely as possible.

Left and Right Hand/Labeled Parts

The final example is very simple but often overlooked and is emblematic of this whole process of 'working blind.' It involves engraving part numbers, logos, patent numbers, even instructions on molded parts. Done upfront, as part of the prototyping process, it's a no-brainer. If not done, or done later, it can cause difficulties in production, and add cost to the process.

Several cases in point are the mechanical OEM hardware components pictured in **Figure 4,** which all have identifying numbers or assembly instructions molded in. In the case of the connector pin (upper right), the manufacturer used the same connector for both U.S. and European equipment. That meant that the threads for the connecting screws had to be in U.S. measure on one set of parts and metric on another. However, the two were impossible to distinguish visually, leading to considerable confusion in assembly. The simple solution was to imprint the thread size onto the landing post where it would be visible to the assemblers, but unobtrusive to end users.

However, if issues of marking/labeling are not addressed in the prototype stage, problems can result. If not designed into the tool initially, the only option (other than welding the tool, which is better to avoid) is to engrave the tool, i.e., take away steel. This means when casting the parts, the labeling features are raised, not recessed, and suddenly the issue of placement becomes more sensitive: a raised label can cause interference on a functional surface.

Whatever type of label is added—part number, patent number, logo, instructional symbol—doing it at the wrong point in time limits your options as to where you're going to put it, and how deep and how big it's going to be. You have fewer choices.

The more you can think through all the details of part design and the production process on the front end, the fewer problems and limitations you will have downstream and the more options you can explore. 'Production Proof' prototyping gives you those choices. **TCT**

Steven P. Fielding *has been president of Fielding Manufacturing (Cranston, RI) since 1989. A graduate of Villanova University, he is a member of the Society of Plastics Engineers, the Society of Manufacturing Engineers, the American Society of Mechanical Engineers and the North American Diecasting Association. He is also a Founding Member and Past President of the Rhode Island Plastics Partnership Council, and has served as a Board Member or Executive for a number of industry/education and RI State Governmental Advisory groups such as the School to Career Subcommittee, the Worker's Compensation Advisory Board, the Manufacturing Partnership, the Economic Policy Council, Business Education Roundtable and Slater Center for Environmental Technology. He can be reached at stevenf@fieldingmfg.com.*