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RAPID PROTOTYPING APPLICATIONS AT SANDIA NATIONAL LABORATORIES

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ABSTRACT

In an effort to reduce the cycle time for producing prototypical mechanical and electro-mechanical components, Sandia National Laboratories has integrated rapid prototyping processes into the design and manufacturing process. The processes currently in operation within the Rapid Prototyping Laboratory are Stereolithography (SL), Selective Laser Sintering (SLS), and Direct Shell Production Casting (DSPC). These emerging technologies have proven to be valuable tools for reducing lead times and fabrication costs. Sandia uses the SL and SLS processes to support internal product development efforts. Their primary use is to fabricate patterns for investment casting in support of a Sandia-managed program called FASTCAST that integrates computational technologies and experimental data into the investment casting process. These processes are also used in the design iteration process to produce proof-of-concept models, hands-on models for design reviews, fit-check models, visual aids for manufacturing, and functional parts in assemblies. The DSPC process is currently being developed as a method of fabricating ceramic investment casting molds directly from a CAD solid model. Sandia is an Alpha machine test site for this process. This presentation will provide an overview of the SL and SLS processes and an update of our experience and success in integrating these technologies into the product development cycle. It will also provide a lead-in for a tour of the Rapid Prototyping Laboratory, where these processes will be demonstrated.

BACKGROUND

A responsibility of the Manufacturing Technologies Center at Sandia is the manufacture of prototype mechanical and electro-mechanical components using state-of-the-art manufacturing processes. These processes have evolved, over the years, from labor intensive, manually operated machine tools to computer-aided machining centers and wire-feed electrical-discharge machines. The integration of rapid prototyping processes into the design iteration process has had a significant impact on the product development cycle. In 1989, a new program called FASTCAST was initiated at Sandia. The goal of FASTCAST is to reduce the cycle time necessary to produce a high-quality casting. In support of this goal, a method for rapidly producing wax patterns was needed. Using CNC multi-axis machining centers, we began machining investment casting patterns from billets of machinable wax. This method was effective in reducing lead times and

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patterns were dimensionally accurate, but the cost of the patterns was excessive. Subsequently, the acquisition of rapid prototyping processes has had a significant and timely impact on manufacturing prototype parts, particularly regarding casting patterns.

THE RAPID PROTOTYPING LABORATORY

The Rapid Prototyping Laboratory is a fully operational facility and is located in Sandia's Process Development Laboratory. The rapid prototyping processes currently in use are a stereolithography SLA-250² and selective laser sintering Sinterstation 2000TM³. An SLA-500 was recently purchased and will be installed in January 1994. The direct shell production casting Alpha⁴ machine is located in the investment casting laboratory. The hardware and software used to support these processes are two Silicon Graphics work stations and Pro-engineer modeling software. This facility is an integral part of Sandia's manufacturing capabilities.

RAPID PROTOTYPING APPLICATIONS

At Sandia, the product development begins with a conceptual design based on customer requirements. The design is developed using a computer work station and CAD modeling software to create a three-dimensional solid model. Using solid modeling in the design process has many advantages. The designer can perform engineering analysis, can fit-check mating parts, see a three-dimensional representation of the design, change the design as necessary, document changes immediately, and retain the design information indefinitely.

After a design is established, the designer may choose to have a prototype part built. If the design is final, manufacturing may begin using traditional methods such as machining or casting. If the design is not final, the design iteration process begins and a replica of the CAD model is built quickly using a rapid prototyping machine. The CAD model data is translated to a standard machine readable format called an STL file. The part is then fabricated using the Stereolithography Apparatus (SLA-250) or the Sinterstation 2000TM Selective Laser Sintering (SLS) machine. The SL process produces acrylic or epoxy models. It is a layer additive process and uses a laser to scan and solidify a thin layer of photo-curable liquid resin. Each layer is .005 inch to .020 inch in thickness and represents a cross section of the part geometry. The SLS process produces polycarbonate, nylon, or wax models. This process is also a layer additive process and uses a laser to scan and melt a layer of powder to the previous layer until the part is complete. The SL or SLS models can be used for proof-of-concept, design review, fit-check, visual aid for other methods of manufacturing, or as patterns for producing investment casting molds. The advantages of using these processes for fabricating prototypes are: 1) ease of fabricating complex geometrically shaped parts, 2) increased design flexibility, 3) reduced lead times and fabrication costs, and 4) more efficient design iteration.

When the design iteration process is complete and a production-like prototype is ready to be fabricated, it is necessary to determine the proper method of manufacture. Typically, the proper method of manufacture for the prototype is the same as for the production part. If traditional machining methods are used, the CAD model data is translated into a manufacturing data file and tool paths are generated. At Sandia, if the method of manufacture is investment casting, the

² The SLA-250 Stereolithography machine is manufactured by 3D Systems, Inc., 26081 Avenue Hall, Valencia, California 91355

³ The Sinterstation 2000TM Selective Laser Sintering machine is manufactured by DTM Corporation, 1611 Headway Circle, Building 2, Austin Texas 78754

⁴ The Alpha Direct Shell Production Casting machine is manufactured by Soligen Inc., 19408 Londerius St., Northridge, California 91324

part enters the FASTCAST process. The designer transfers the CAD data over a computer network to a FASTCAST engineer, who modifies the part's solid model geometry for investment casting. The modified CAD data is transferred to the Sinterstation 2000™, or the SLA-250 where a pattern for investment casting is built. If the casting pattern is built using the Sinterstation 2000™, the pattern material is wax or polycarbonate. Wax is the traditional pattern material for investment casting; however, polycarbonate patterns build faster, are more robust, are dimensionally stable, and parts require no support structure during the build process. If the SLA-250 is used, the pattern is built with epoxy resin and Quickcast build style. Quickcast is a software package that permits a lattice-like structure, rather than a solid structure, to be built for investment casting patterns, thus easing the pattern burn-out phase of mold preparation.

Once a pattern is fabricated (by SL or SLS) and post processed, it is sent to the investment casting area where gates and vents are assembled to the pattern to guide the flow of metal into the mold. The entire pattern assembly is then dipped into a binder material and covered with ceramic powder and allowed to dry. This step is repeated several times until the resulting ceramic shell is the required thickness. Next, the shell is placed in a furnace or steam autoclave; and the pattern is melted from the shell, leaving a mold cavity the shape of the pattern. After firing, the completed ceramic mold is taken to Sandia's Liquid Metal Processing Laboratory for pouring of the specified metal.

There are many advantages to using SLS and SL processes to fabricate patterns for investment casting. The traditional method of fabricating wax patterns requires the acquisition of an injection mold. This can require several months of lead time and cost thousands of dollars. If the part design changes, the mold becomes obsolete. Using SLS or SL, we are able to fabricate a pattern within five days after receiving an STL file. The designer can now request more complex geometrical shapes, optimize the part design to meet customer requirements, and change the design if necessary. Complex parts can be cast to near-net shapes and be finish machined. Prototypes can be manufactured and tested by the same methods as production parts.

CONCLUSION

The integration of rapid prototyping processes into the design and manufacture of prototype components has significantly reduced the product development cycle time and cost. Sandia has had success in fabricating prototype investment casting patterns and design verification models using these processes. Recent developments and implementation of new software and hardware have increased part accuracy and surface finish. As these and other processes continue to evolve and as new materials and applications are developed and found, they will have a greater impact on the product development cycle.

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