PRELIMINARY COMPONENT INTEGRATION USING RAPID PROTOTYPING TECHNIQUES

by

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ABSTRACT

Rapid prototyping is a very important tool that should be used by both design and manufacturing disciplines during the development of elements for the aerospace industry. It helps prevent lack of adequate communication between design and manufacturing engineers (which could lead to costly errors) through mutual consideration of functional models generated from drawings. Rapid prototyping techniques are used to test hardware for design and material compatibility at Marshall Space Flight Center (MSFC).

BACKGROUND

As used in this paper, rapid prototyping refers to a collective set of solid freeform fabrication technologies used to build physical models directly from computer aided design (CAD) data. These fixtureless processes operate in an additive fashion, wherein each model is built from the bottom up by adding thin horizontal layers of material.

MSFC maintains a unique rapid prototyping laboratory equipped with all rapid prototyping technologies that are domestically available. These seven processes include:

1. Stereolithography, a liquid-resin based technology that employs an ultraviolet laser to selectively cure epoxy into the shape desired.
2. Selective Laser Sintering (SLS), a powder-based process that uses a laser to melt cross-sections of polymer or semi-metallic powders into the shape desired.

3. Laminated Object Manufacturing (LOM), a solid-based process which adheres layers of paper, plastic, or composite and then cuts each cross-section with a laser.
4. Fused Deposition Modeling (FDM), another solid-based process that extrudes a semi-molten thermoplastic through a moving X-Y orifice.
5. Multi-Jet Modeling, a process that builds solid wax patterns by printing layers of hot wax directly through standard print jets.
6. Three Dimensional Printing prints layers of binder into a polymer powder matrix.
7. Laser Engineered Net Shaping deposits a thin bead of metal powder into the focal point of a high-powered laser, while the part is moved in the X-Y plane below to form cross-sections.

These processes are used in a variety of concurrent engineering tasks, including concept modeling, assembly verification, fit-check analysis, flow functionality testing, and investment casting pattern making.

RAPID PROTOTYPING APPLICATIONS AT MSFC

Shooting Star Experiment

Prior to the procurement of rhenium hardware, rapidly produced absorbers were cast from a superalloy to be used during initial thermal experiments. Within days, early designs of the solar thermal engine housing and absorber inserts were rapid prototyped in an investment casting wax, and the parts were investment shelled and cast on-site within 4 weeks.

These inexpensive hardware castings continue to be tested extensively by thermal elevation and cycling in the MSFC Test Stand Area. The data allowed early analysis of the functionality of the engine design, as well as saving just under $300,000 and 6 to 12 months of lead time on the project. (See Figures 1 and 2.)

Simplex TurboPump

The use of rapid prototyping also proved valuable during the manufacture of a complex impeller for a high-pressure experimental turbomachinery design known as the Simplex TurboPump. Preparations had been made for five components to be machined at a cost of $60,000 each, with drawings delivered to the machine shop and tooling-up already underway. However, a rapid prototyped plastic model fabricated using the stereolithography apparatus (produced at a cost of approximately $1,000) revealed that the blueprints had reversed the correct designation of the impeller blades. This information allowed alterations to be made prior to production, for a cost savings of approximately $300,000.

Throughout the life of the Simplex program, additional savings in cost and time were obtained by using rapid prototyping and investment casting to provide castability verification of candidate materials, fabrication planning, and continuous auditing with functional models and hardware. (See Figure 3.)

Space Shuttle Main Engine Fuel Ducts

During a redesign of the Space Shuttle Main Engine (SSME), it was determined that replacement of existing supply and drain fuel lines would reduce weight and increase safety and reliability. Previously, the steel lines had been fabricated by welding variously shaped sections together, in order to access all required inlet/outlet ports of the engine. The new design called for continous feedlines to be custom-formed from tubing, in order to reduce the weight of the welds, optimize flow, and decrease the probability of fuel leakage. Unfortunately, the first hot gas duct fabricated didn't integrate properly after additional hardware was attached to the engine during assembly, requiring a costly and time-consuming process to correct the problem.

A decision was then made to fabricate rapid prototyping patterns for the remaining five ducts, in order to verify that they would fit correct. Each duct was approximately 7 feet long and 6 inches in diameter, with a complex three-dimensional curvature and precisely placed junctions. The prototypes were fabricated in 12-inch sections using the laminated object manufacturing process at MSFC, with the entire set completed in 2 to 3 weeks. The engine contractor designed each section with dissimilar boss-and-socket alignments for proper assembly. These prototype lines were shipped to the engine contractor facility, where they were assembled and mounted to an actual main engine to verify the designs prior to manufacture of the remaining lines. It is believed that the use of these models resulted in an overall savings of about $175,000 (or $35,000 per line), as well as several months of lead-time. (See Figure 4.)

Meteorite Patch Kits

Rapid prototyping is also being used to support a project that applies meteorite patch kits, which requires precise mixing of a two-part solution to obtain adhesive properties required for composite material bonding. A special funnel was designed to provide accurate delivery of each component of the adhesive mixture. However, due to the low number of funnels required (approximately two to four every year), it is not considered cost-effective to have them mass-produced. Instead, the funnels are being directly fabricated using rapid prototyping techniques. The materials used are compatible and provide adequate strength and density to prevent permeation or breakage. The funnels are chemically cleaned and reused several times prior to disposal. (See Figure 5.)

Space Shuttle Main Engine Fuel Seals

After a recent design change, an SSME fuel line no longer matched up properly with its associated pump. A flexible seal, (about 9 inches in diameter, with a 270-degree rotation of an eccentric nature) was required to correct this problem. The MSFC rapid prototyping lab produced several solid prototypes of the flange, which were used by the pump contractor to make molds for the new seals.

SUMMARY

At MSFC, the use of rapid prototyping technologies continues to yield significant savings in cost and time to NASA projects. Increased use of these technologies is anticipated to cater to a concurrent engineering environment realized due to decreased funding allocations and project time constraints mandated throughout the Agency. Similar applications and successes are seen throughout the private manufacturing industry, as well, where profit margins and a highly competitive market drive companies to deliver products quickly and efficiently.

ACKNOWLEDGEMENTS

REFERENCES

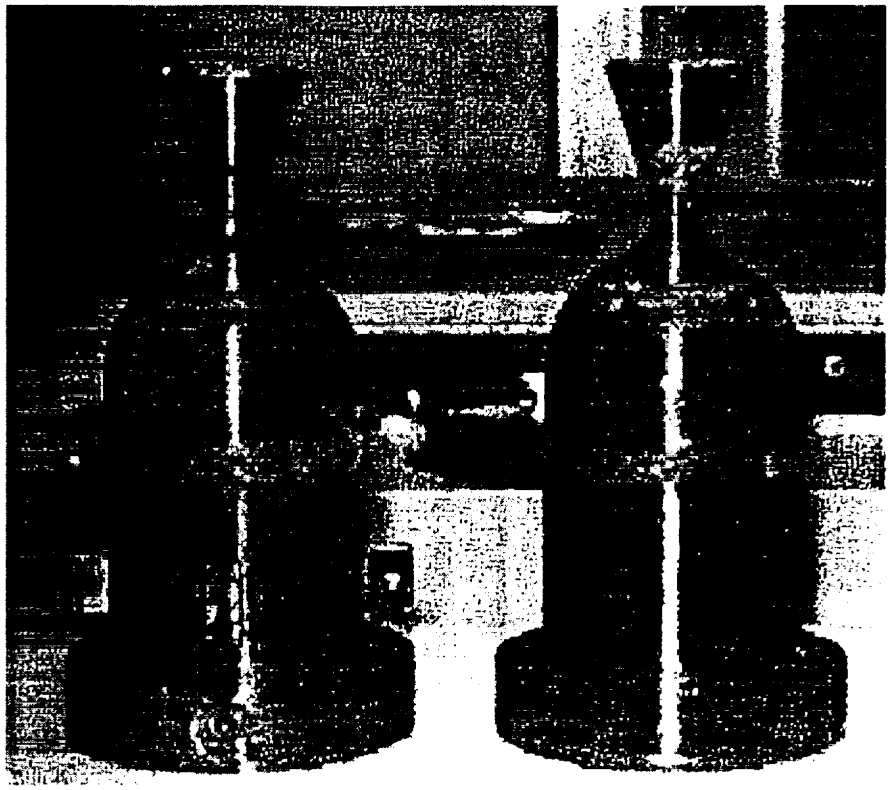

Figure 1 – Investment casting waxes for Shooting Star absorber

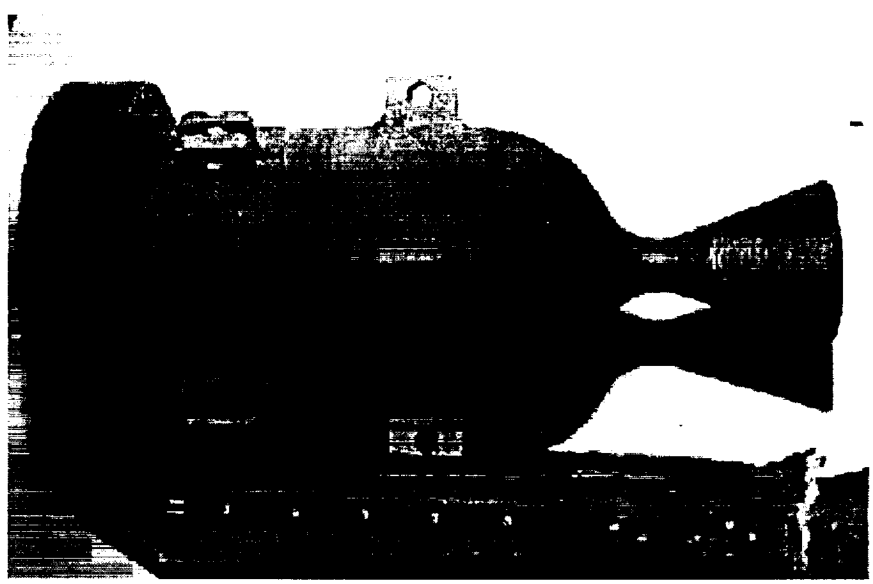

Figure 2 – Hardware casting for Shooting Star absorber

Figure 3 – Inducer model produced for Simplex TurboPump

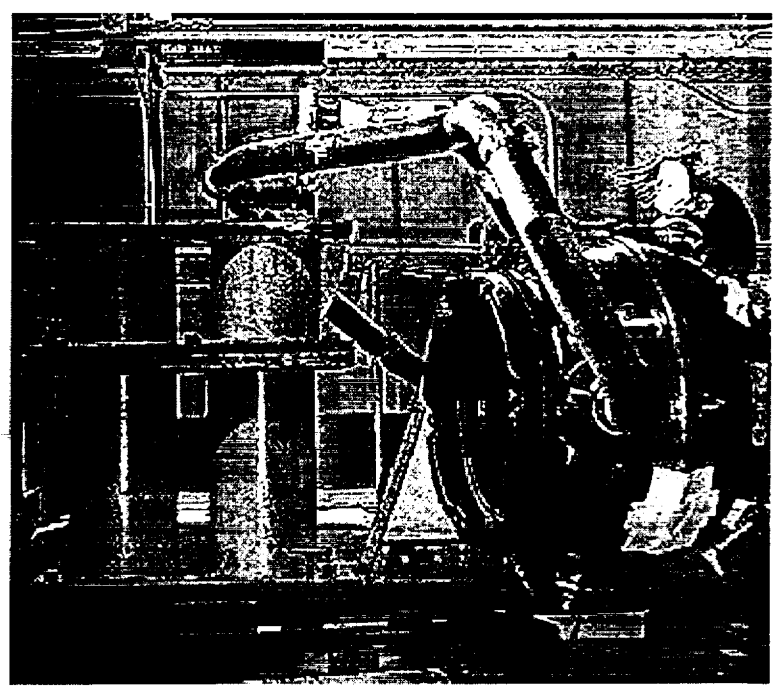

Figure 4 – Prototype for SSME fuel duct

Figure 5 – Funnel for meteorite patch kits