A DESIGN-VALIDATION-PRODUCTION WORKFLOW FOR AEROSPACE ADDITIVE MANUFACTURING

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EXTENDED ABSTRACT

With the advent of 3D printing and additive manufacturing, manufacturing designs previously thought difficult to produce can now be generated quickly and efficiently and without tooling. In the aerospace industry, weight is often tied directly to cost and is thus of great importance to any engineering design. Traditionally, the design process often involves much iteration between the designer and the analyst, where the designer submits a design to the analyst, and then the analyst completes his or her analysis and sends recommendations back to the designer. The process is repeated until a valid design meets the analysis criteria. The design is then handed to the manufacturing team which then may have additional constraints or concerns and iterations can continue. Additive manufacturing coupled with topology optimization allows the design and analysis loops and manufacturing iterations to be reduced significantly or even eliminated. The critical step is to ensure that the part will perform as simulated.

This paper outlines a process by which these technologies can be used to significantly reduce the time to design, analyze, and produce an aircraft component while significantly reducing the weight of the component. The example chosen was a 172 Cessna rear elevator bellcrank. The project goal was to optimize the part for weight based off the maximum allowable load input while ensuring the part had a Factor of Safety of 2. To perform the optimization study, the Altair solidThinking Inspire™ structural optimization software was used to generate the conceptual design.

Prior to the optimization, a mid-stage validation of the simulation was performed using a carefully conducted test on a 3D printed

standardized Cornell bike-crank which was not the actual part but contained features that could probe the quality of the simulation. Stress-strain measurements on printed specimens of the actual printed material provided real material data. The Matereality CAEModeler was used to generate an elastic-plastic piecewise (matx36) material model.

The 3D printed Cornell crank used for the validation was simulated using the Optistruct solver and the elastic-plastic piecewise (matx36) material model. Through the use of digital image correlation (DIC), images of the strain field on the face of the Cornell crank were gathered to compare to the simulated strains to evaluate fidelity of the simulation to the measured data.

With a measure of confidence in the simulation now established, an optimization of the elevator bellcrank was commenced using the Altair solidThinking Inspire™ structural optimization software. The resulting conceptual design achieved a mass reduction of 45% which is significant for any structure and especially for aerospace structures where minimizing weight is critical.

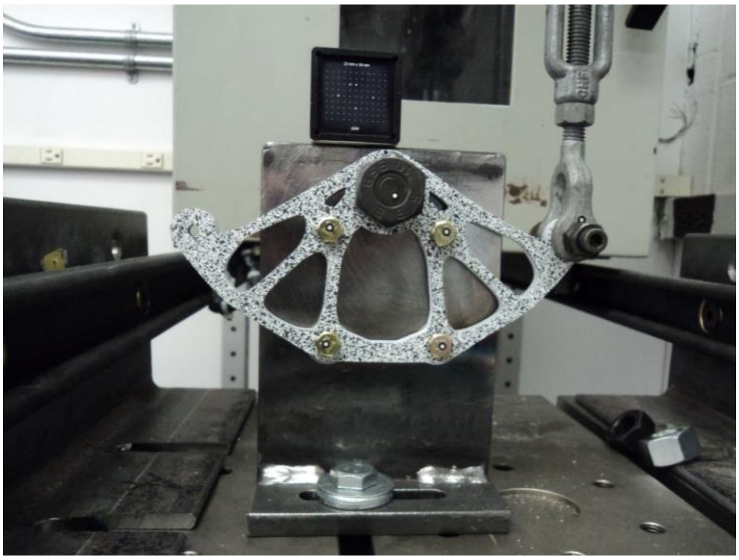

Figure 1 Optimized bell crank being tested with DIC for strain measurement

Three cranks were printed in the XY plane. The printing was performed by Incodema 3D, Inc. Ithaca, NY through direct metal laser sintering of EOS Aluminum AlSi10Mg gas atomized powder from EOS GmbH. A 370 W, 100-500 μm variable diameter Yb fiber-laser on an EOS M280 was used to sinter the 30μm layers. The laser traversed the pattern at a 1300mm/s scanning speed with a hatching distance of 0.19 mm. For each layer the scanning path was rotated 66°. After cooling, specimens were cut away from the bed.

To confirm that the cranks performed as designed, the optimized printed part was deformed in a real-life test again using DIC to measure surface strains. The resulting strains were compared to those obtained in the optimization simulation.

Conclusions

This paper illustrates how a company can go through the design, analysis and optimization, build, and test process for an aerospace component. Incorporating a mid-stage validation into the production workflow is required to confirm the efficacy of the solver and material model prior to use in real-life parts. The produced part will generally have lower weight through an optimized design that will not increase manufacturing costs. Additive manufacturing coupled with topology optimization provides significant opportunities to the aerospace industry because of these benefits.