Gas Turbine Hot Gas Path Hardware Concept Design Using Additive Techniques

University Turbines Systems Research(UTSR)

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Due to the nature of the projects, many critical details have been left out due to proprietary information and property infringement. Your understanding is appreciated.

1. Abstract

The Purpose of this report is to outline the lessons and achievements learned during this fellowship in Greenville, SC. The fellowship was through a technology design team at GE Power. Before the implementation of new parts to the hot gas path of a turbine, designing, testing, and analyzing are needed to be done. Hot gas path hardware are modified to make them more efficient, stronger, and cheaper. Parts were designed through the process of CAD and created through additive manufacturing. After being created, parts are inspected using computer analytical inspection software. During those processes, finite element analysis techniques were used for mechanical testing to analyze parts for fatigue, creep, and deflections.

2. Introduction

General Electric's conceptual-design team (or NTI) is based in Greenville, South Carolina. This group works to apply new concepts and ideas to their gas turbines by brainstorming, designing, prototyping, and analyzing. This internship consisted of several projects, many of which will not be discussed in detail due to intellectual property protection. To complete these projects, certain applications and processes were utilized such as 3D printing, Unigraphics, and ANSYS.

3. 3D Printing

GE Power has recently made a push for utilizing their 3D metal printers for gas turbine applications. Over the summer, the NTI team worked closely with the additive manufacturing team to start with undisclosed new features that may be added to the hot gas path of the turbine. The additive machines utilized at GE were high power laser metal 3D printers located in their Advanced Manufacturing Works(AMW).

Printing of parts was done through a process called Direct Metal Laser Melting(DMLM). DMLM is a process that transforms metal powder to be transformed into solid 3 dimensional shapes. Additively manufacturing parts with this process is proving to have many significant benefits. One of the main benefits is being able to produce complex internal features in a single piece that may not be possible to machine out. These features may be used to save or distribute weight, create more cooling, and structurally better reinforce parts.

One of the many roles the NTI team had was to help design gas turbine parts to be additively produced and implemented into the turbine. In time, it will take a few iterations before the part will be implemented. A couple of the problems encountered while printing were building outwards at steep angles and warping from tall thin parts. These common problems can be fixed at the price of dividing the part or building supports which later have to be machined or welded.

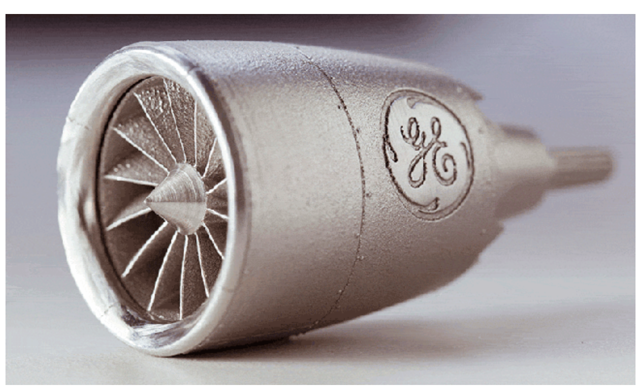

Figure 1: Capabilities of DMLM. Model of a GEnx jet engine

4. CAD with Unigraphics

The use of CAD has been prominent in the design of gas turbine parts for years. A large portion of the summer was dedicated to the use of the CAD software Unigraphics to help improve or to modify parts. Adding features to nozzles and blades were done to help increase gas turbine efficiency. Working with the complex shapes of turbine parts such as blades and nozzles created challenging projects to overcome.

5. Post-Processing GOM Inspect

Additive manufacturing with superalloy metals is still a complicated process that does not always deliver perfection. Since a laser melts powder to weld on a new layer of metal, temperatures may be at different extremes in the part while building vertically. This is a prominent cause of warping in the material. Thicker parts are less vulnerable to warping, however thin parts are prone warping when building vertically. Supports may be added, however it is not convenient and may need to be machined off later. GOM Inspect is a 3D inspection tool that compares the 3D printed model to the CAD model. To do this, the additively manufactured part is accurately scanned by a blue light scanner and the measured version is placed onto an .stl file where it may be uploaded. Both the CAD model and the scanned model are then compared for defects in the printed part. A number of printed objects were observed during this internship and it was apparent that tall thin parts warp at the top. This is a known problem with additive manufacturing. As shown in figure 2, an example of 3D measured data is shown.

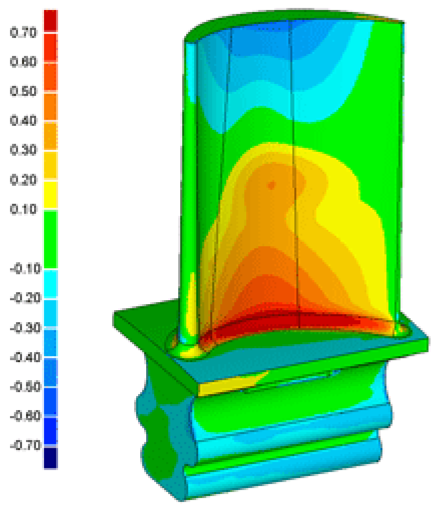

Figure 2: Example of tolerances on a blade

6. Post-Processing with ANSYS

Before real testing begins, parts must be analyzed to see if they hold up to the standards. This is done through ANSYS. ANSYS is a software used to simulate interaction of all disciplines of physics, structural, vibration, fluid dynamics, and heat transfer. Industry leaders such as GE use ANSYS to create virtual prototypes of complex products to be certain that the product is ready to be produced. Several post processed parts were analyzed for creep, fatigue, and other stress factors. These results are used to reduce risk, avoid unplanned downtime, and speed up new product development.

Over the course of this internship, parts such as nozzles, shrouds, and buckets were analyzed. Four different types of shrouds were looked at to determine which design was the best. To do this, the temperature profiles, mechanical stress, and deflections were looked at. This information will be investigated to determine the next design. Figure 3 contains an example of what Von Misis stress might look like for a hot gas path turbine blade.

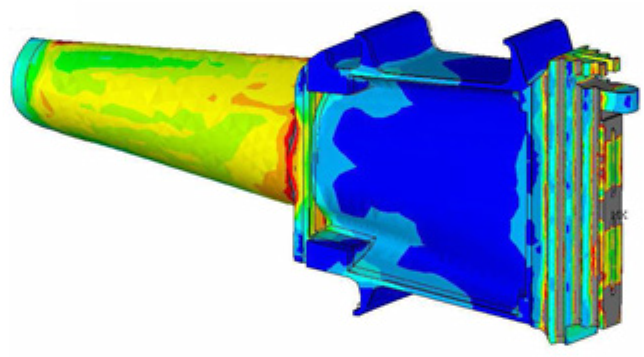

Figure 3: Example of Von Misis Stress of a blade

7. <u>Conclusion</u>

Multiple skills were developed by learning about gas turbines, additive manufacturing, and utilizing engineering programs. New skill sets were explored and developed. The internship was a success, I learned a significant amount about turbines and how real engineers work every day to push the limits of success. It has stimulated my interest for turbines and I now look forward to making connections about everything I learned this summer to my studies.

8. <u>Acknowledgments</u>

I would like to thank UTSR for the opportunity to intern at a great company such as GE. This fellowship powered me to pursue a career on gas turbines. Also thank you to all the hard working GE engineers that took their time to mentor me and present me with a great experience during my internship. This internship powered me to pursue a career on gas turbines.