University Turbine System Research (UTSR)
Gas Turbine Industrial Fellowship Program
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Design Engineer End of Fellowship Report

Prepared for:

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Introduction

The design engineer is tasked with the development, research and investigation of design techniques and applying them to create a useful product that meets and/or exceeds customer requirements. This entails taking customer ideas as inputs, using engineering best practices in the design process and achieving a product as an output. To be cost effective as well as achieve a quality product, it is imperative that the design engineer executes his priorities with the utmost proficiency and efficiency. I was fortunate to work with GE as a design engineering intern through the University Turbine Systems Research (UTSR) Gas Turbine Industrial Fellowship Program provided by the Southwest Research Institute (SwRI) and was exposed to the intricate details in the design process for the compressor rotor of a gas turbine. I was assigned priorities that enabled me to apply the knowledge I have acquired as a student, learn a lot about the gas turbine, and grow both personally and professionally. Any confidential information will be left out of the report.

Priorities:

In assigning my priorities, my team leader managed to make it such that every task had a goal beyond the internship. Each task was challenging enough to inspire desire to think out of the box, lean on team members for guidance and elicit curiosity leading to discovery all while accomplishing the GE goal of providing the world's largest, most efficient, flexible 60Hz gas turbine with the lowest cost conversion of gas to electricity. My immediate priorities were;

i. Run transient mission analysis on assigned missions
ii. Perform Low Cycle Fatigue analysis
iii. Own a couple compressor wheel rotors through review and release

i) Run transient mission analysis

Transient mission analysis is used to evaluate how a system responds to fixed and/or varying boundary conditions over time. In this case, the speed of the compressor in radians per second and compressor discharge pressure are used, given a set of timepoints that are selected using the eRotor software as well as a spreadsheet tool for comparison.

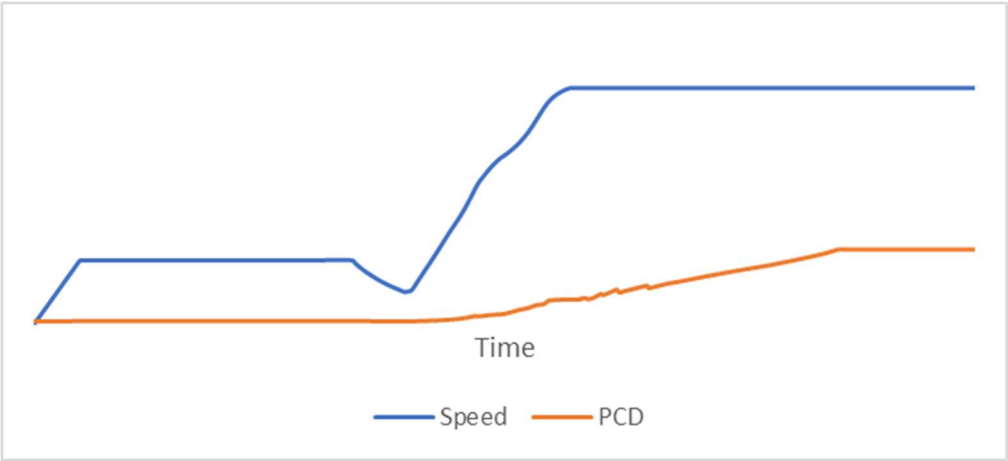

Fig 1. Typical compressor discharge pressure and speed versus time. (Graph not to scale due to confidentiality)

Our team received about 900 timepoints from the heat transfer team and from that I had to use timepoint selector to down select these to about 300 timepoints critical to the mission. This was critical to improve efficiency in processing by reducing storage requirement for the results obtained and time for running any given mission. Critical timepoints are used to create rundata files that are used as inputs for running the transient mission. Rabbet loads, thermo-elastic contacts together with frictional heat generation are applied and simulation is done on Ansys to model transient states for the given load steps. The results are then used to extract stresses and perform fatigue life calculations from startup to failure.

ii) Low Cycle Fatigue (LCF) Analysis

LCF analysis is characterized by high amplitude, low-frequency plastic strains and is useful especially in gas turbines where the materials operate in temperature varying and cyclic conditions. Mechanical and thermal loading lead to the development of high stresses greater than the material yield strength. After a startup and shut down, high tensile stress is developed in the hot compressed area as the material gets cold.

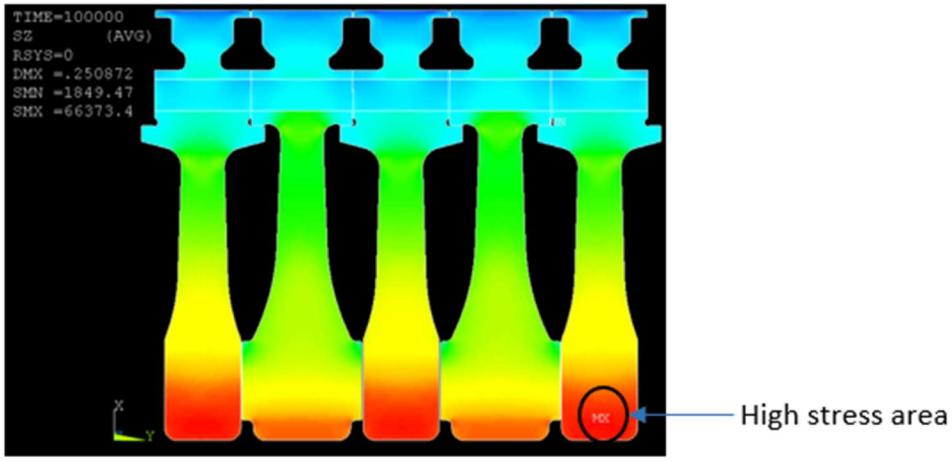

Fig 2: Ansys plot of a high stress area

Conducting LCF analysis leads to identifying areas under high stress which can experience microscopic crack that, if not identified, could get larger over time. LCF is therefore used to determine the lifetime of the component by plastic strain amplitude where the larger the amplitude, the shorter the life of the part. It should be noted that LCF is a factor of both strength and ductility.

As an aircraft mechanic, I performed calendar inspections and part replacements due to life without knowing why the time period for the inspection and/or replacement was selected.

Performing LCF lifing and mission mixing enabled me to understand why these times are important for maintenance and the life of the component.

iii) Own compressor wheel rotors through review and release

A drawing design review is critical in a product development process. It is used to evaluate the product against its requirements and engineering intent in order to verify the physical outcome of the drawing before committing to actual production. Failure to meet the design requirements can lead to huge losses in time and labor, which ultimately means financial losses.

Thorough inspection is performed using MBEWeb views which can be compared with existing, already approved drawings (typically similar/comparable-to drawings). An important consideration to make when doing a drawing review is staying in constant communication with the team. When an error is detected, letting the team know as soon as possible saves time as opposed to performing the entire review before sharing your findings. This ensures that the error is fixed while other parts of the review is still in progress if possible.

It is important to be familiar with Geometric Design and Tolerance (GD&T) symbols when performing drawing reviews. A dimensioning error could be easily overlooked as depicted in the picture below. At first glance it would appear that the first and second image are identical, ignore my scribblings on the first image. However, closer inspection shows that the profile of surface CJ to CK is a lot larger compared to the same profile on the right. This could lead to a subpar product being manufactured and failure to meet the engineering intent.

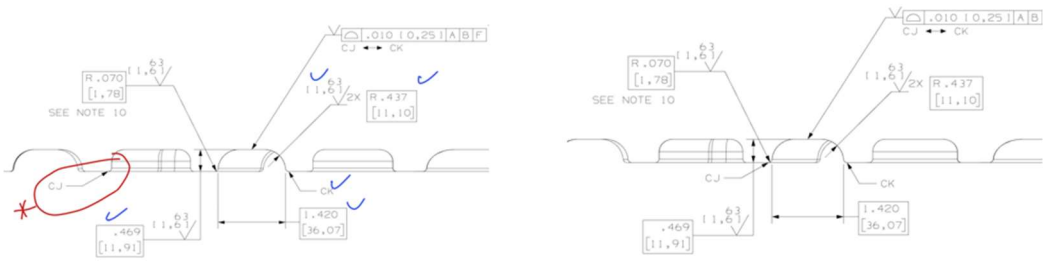

Fig 3: Dimensioning error over surface profile CJ-CK left image compared to the right

CAD models are also inspected, and checks made to ensure they are as expected. This is done on NX where the CAD model, together with other similar CAD models (as was in the case of MBEWeb comparison) are used to compare each other. The CAD models are loaded as layers on NX where one model is layered over another on the same axis with the same orientation. The model can then be sectioned and then viewed closely to check for unwanted differences.

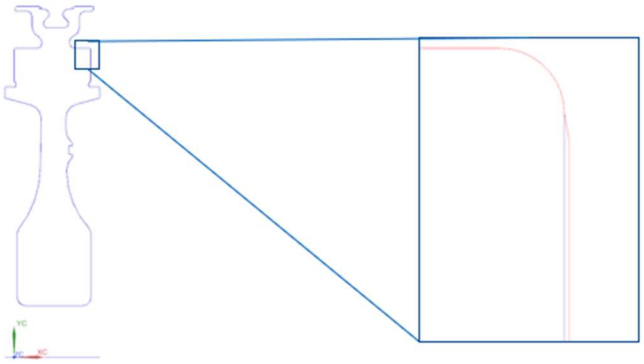

Fig 4: NX model overlay with closeup

While performing maintenance as a mechanic, I regularly used engineering drawings to assemble, disassemble, troubleshoot, or even check a part for conformity before accepting them. It is therefore very crucial that the design engineer performs a thorough drawing review, not only for internal success of the company but the success of others that use the part.

iv) Miscellaneous assignments

a) Runout analysis

Runouts measure the variation in measurement of a feature or features to a reference point when the part is rotated about an axis. Runout controls are used for concentric alignment of rabbets and parallelism of flanges. Runout limits are put in place such that the piece part limits are tighter than assembly level. My objective for this assignment was to identify the trend in assigning limits from the piece part to the assembly level of 7 Units. This was accomplished by identifying the runout limit and matching the runout location for the piece part with the compressor or turbine rotor and then to the unit rotor where applicable. A tech-table was then created for comparison of multiple engines which will be used in engineering design practice.

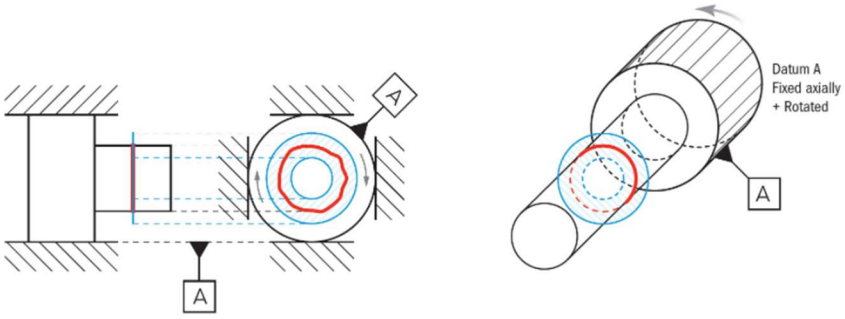

Fig 5: Runout feature measurement[i]

b) Gravity sag comparison

Gravity sag comparison was performed on three units to check how much difference in sag was present on the models. This was accomplished by identifying the cg location from the data collected through ANSYS, the total weight and peak deflection with respect to the axial length. It was expected that the sag would be comparable in every case since the units are treated as beams

fixed at both ends with uniformly distributed load. However, I found that one of the units had a deflection that was approximately 0.0015 inches higher than the other two units. This was due to the difference in axial cg location.

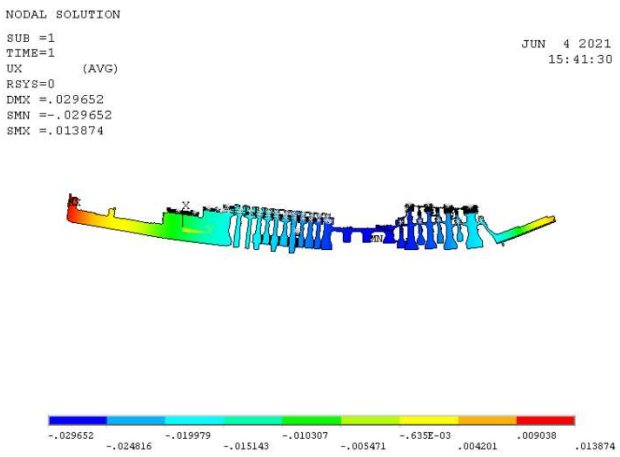

Fig 6: Ansys plot of a unit gravity sag model

Conclusion

I learned a lot about the turbine in general and compressor rotor in particular. The compressor inlet sucks air into the compressor which is then worked on by the 14-stage compressor. This is immediately followed by the combustion section where the gas temperature is increased at constant pressure before moving to the turbine section where the air is expanded and blown out of the exhaust.

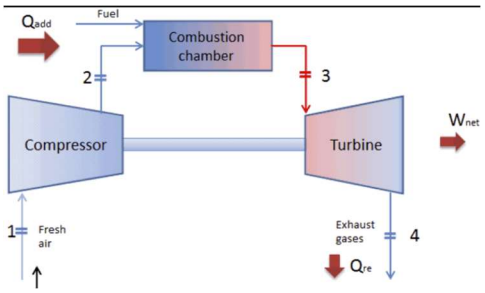

Fig 7: Flow diagram of the turbine engine

I said earlier that the priorities I was assigned had a goal beyond my internship. While performing my tasks, I learned a lot about the gas turbine especially the compressor wheel. The different configurations of the bucket loading slots and their purpose was very intriguing. Another thing that I found interesting was the use of shot peening to reduce stress and fatigue failures and prolong the life of a compressor wheel.

Learning about the fundamentals of Gas Turbine led me to revisit thermodynamic principles that I learned in class and the critical role it plays in design and operation of the engine. In designing the gas turbine, the engineer has to think beyond his scope of work and collaborate broadly with other engineers to the end user.

Acknowledgements

There was not a dull moment during my stay at GE. The rotors team was very welcoming and inclusive in every aspect of my tour. I would like to thank JaNet for working with me through the process of being a part of GE this summer. I also thank Prakash, for his leadership and continued support throughout my internship. I loved that he made learning about gas turbines a priority number one. It is easy to dismiss the basics, yet they are key to understanding the more complex nature of the why and what we do as design engineers. I will always fall back on his advice of not forgetting the simple stuff. I also want to thank Matt for the lessons and encouragement he had with me. He taught me not only about cool tips and tricks for an efficient job, but about GE as an organization and the internal relationships within departments and the city of Greenville in general. My internship would be incomplete without my office buddy Joe. It was always nice to walk up to him and ask questions in the office. He always had detailed explanations about the assignments he gave me which helped explaining the why I had

mentioned earlier. He had jokes that were always included in the learning process and the big picture attitude in problem solving that he introduced me to which made learning that more enjoyable. Thanks to the entire GE team for making my experience memorable and successful and the SWRI team for making this experience possible.

[i] Runout feature, Runout | GD&T Basics (gdandtbasics.com), www.gdandtbasics.com/runouts, accessed 10/02/2021