University of Portland SHILEY SCHOOL OF ENGINEERING

ME304 – FINITE ELEMENT ANALYSIS

The Turbine Project

Assigned date: Sept. 9th, 2019 Due Date(s): Sept. 25 and Oct. 7, 2019

Description

Students calculate the tip deflection of a turbine blade from a Rolls-Royce engine by setting up their own version of the Finite Element Method. The project requires students research the design of the Rolls-Royce turbine engine and develop of a numerical simulation to solve the problem. Students also gain experience at conducting a professional meeting with a lead engineer through a meeting that they lead with their professor.

Learning Objectives

After completing this assignment, students should be able to:

- Explain the methodology behind the Finite Element method
- Describe what is meant by a convergence study
- Solve an engineering problem with a high degree of ambiguity
- Create a meeting agenda for a design review
- Conduct a meeting with a lead engineer in a professional manner
- Calculate the approximate tip displacement for a Roll-Royce compressor blade
- Describe the general design of a Rolls-Royce turbine

Time Requirements

Students should expect to spend approximately 8-12 hours working on this project. My break down is based on the following estimates:

- 1-2 hour researching
- 2-3 hours developing an analytical model
- 1 hour for meeting, meeting prep, and meeting follow-up – the above is due by Sept. 25
- 3-4 hours coding and debugging
- 1-2 hours preparing final report out – final report is due Oct 7.

DATE: September 9th, 2019
TO: Members of ME 304 Section A and B
FROM: Kenneth E. Lulay, Ph.D., PE
RE: Radial blade-tip displacement analysis

Welcome to Rolls-Royce and congratulations on your first engineering job! As your lead engineer, I am asking you to analyze the radial blade-tip displacement on the Boeing 787 *single-stage HP turbine* (a major component of the turbofan engine) when it is under normal operational conditions. Details as we have them are attached. Feel free to use Excel to solve this problem.

You may think that the engine used on the 787 has been completely designed; but nothing is ever *completely* designed. Design is iterative, always improving. Therefore, even though our product is currently being used by Boeing, we are continually improving the design.

Jet engines are very precise machines with about 30,000 individual parts, operating at extreme temperatures and stress. Some of the components, such as the HP turbine, spin at high speeds. Clearance between the tip of the turbine and its stationary housing is a ***critical*** feature; having serious impact on engine performance and efficiency (more efficient = less fuel burned = a valuable contribution achievable by good engineers).

Right now, we are trying to optimize the radial dimensions of the compressor section. Several other departments (materials and combustion physics group) are working on the design as well, and I will be sharing data as I have it. Your main input to this process is going to be developing a way of predicting the turbine blade tip deflection.

Please familiarize yourself with the design of our *single stage HP turbine* and develop a method for predicting tip deflection. Feel free to work with three or four of your peers towards a solution. When you feel you have made sufficient progress, schedule a check-in meeting with me. Please provide an agenda for the meeting at least two days in advance of the meeting. I have attached our company's standard meeting agenda template. These kinds of meetings are a regular and critical part of our design process here, and your professionalism is appreciated. As incentive, your performance review will be heavily weighted on how well this meeting is conducted.

After this meeting we will expect you to have a well-formulated method for solving the problem, so please come prepared. We are expecting you to solve this problem: that's what we're paying you for.

A few of our engineers have put together a few points for working here. Make sure you take the time to read through this, as it has some helpful tips for first-timers.

Again, welcome to Rolls-Royce! Glad to have you on the team!

Meeting Agenda

Subject:
Date: *Location:*
Participants:

Item	Description	Assigned	Time
1	*<item 1>*	*<person>*	*<time>*
2	*<item 2>*	*<person>*	*<time>*
		Total Time	

Required Items and/or Resources

- *<responsibility 1>*

…

Action Items:

- *<action item 1>*

…

Understanding the Basics

As with most engineering projects, solving the problem is not the biggest task, but ***understanding*** the problem is! That is probably the situation for this project. Before beginning your analysis to determine blade-tip displacement, it would be advisable to have some understanding of what a turbofan engine is, what an "HP turbine" is (HP=high pressure), and what a turbine blade is. What are the basic operating conditions (loads, temperature, etc.) for the blades and what materials are typically used to make turbine blades (hint, it sure isn't aluminum!). It would also be advisable to learn something about the specific Rolls-Royce/787 engine. You are very familiar with using Google –that's a good thing! Wikipedia can be a valuable resource to engineers! You should not use such sources for detailed engineering decisions, but they can be very valuable educational resource. In other words, do not be afraid to use online resources, but do use them with a critical eye. The information from the OEM websites (*original equipment manufacturer*, in this case, Rolls-Royce) tends to be good sources of information as well.

Once you have some idea of the big picture problem, you will then need to go deeper. I recommend you team up with your peers and help each other understand the problem, determine what information you need to solve it, and develop a plan of attack (identify what you plan to do to answer our question). While you will work as a team, ultimately each of you will be responsible for your own work and final report. The report will ***not*** be a team effort; one report per student.

How to Interact with your Lead Engineer

Part of the purpose of this project is to help you develop good professional interaction skills. Many freshly graduated engineers find it difficult to learn to walk the fine line between asking too many questions and too few. An appropriate approach is for you to spend reasonable time thinking about the question and looking for answers and keeping good notes. When you believe you are no longer being productive and need some help, then ask well-thought out questions that you have **written down**. For this project, you should be able to find some of the necessary information from online resources such as Wikipedia and Rolls-Royce web page; however, not all data will likely be found. Once you feel you have done a reasonable search, make a list of what you have found, and what information you believe you need but were unable to find.

Although this is not a team project (everyone has to do their own project) I am asking that you form teams to meet with your lead engineers (Lulay). The team should meet before meeting with the lead engineer to determine who "does what" during the meeting. Everyone needs to play an active role during the meeting. As a team, create an agenda for the meeting.

Leading a productive meeting is an invaluable skill, and very appreciated in the professional world. Try to provide the agenda well in advance of your meeting (two business days for this project) so that your lead engineer can familiarize them self with what you are doing and what they might need to help you with. When formulating your agenda, always keep in mind the purpose of your meeting. While you may have done a commendable amount of leg-work, the main goal is to solve the problem, not demonstrate how much work you've already done. Consider what needs to be covered, who will lead the discussion, how long each item should take, and what it has to do with the purpose of the meeting. Provide background information as it is needed to further the discussion. Sometimes the most productive means of providing background is to provide a list of responsibilities so that you can have a productive meeting.

You may find the following items helpful in planning and conducting your meeting:

- A clear problem statement (you do this on every homework problem)
- A concise summary of any general information you have obtained (engine type, what is a turbofan engine, purpose of an HP turbine, general operating conditions, etc.). Photos can be very helpful.
- Specific technical information you plan to use in your analysis including Free Body Diagrams of a turbine blade.
- bibliographic information for the source of your information (such as URL's)
- a list of questions you have including what information you still require
- your plan for solving this problem.

Keep in mind: **bulleted lists are easy to read – long paragraphs take a lot of time to read.**

Completion Requirements

While it is expected that you work with other students on this project (including the meeting with Lulay), you will be responsible for your own individual submission. For completion of this project, each student will submit a hardcopy of their work. This hardcopy will include the following:

1. A technical letter or memo (12 pt, Times, 1 page, max, references may go an additional page) providing an overview of your work.
    a. Concise introductory remarks (greeting, problem statement, and brief statement of conclusion)
    b. Background (1-2 paragraphs max)
    c. Overview of method
    d. Conclusion and qualifying statements (treatment of assumptions)
    e. Closing remarks
    f. Signature and List of attachments (all attachments should be referred to, except for the agenda)
    g. List of references (IEEE format)
2. A signed agenda from your check-in meeting (which means all students need to bring a hardcopy of the agenda to the meeting). You will need to meet with Lulay before September 25.
3. Miscellaneous documentation
    a. Clean and unambiguous FBD's of the problem (readable, labeled, all elements present)
    b. Clear solution methodology (follow the HW format)
    c. Programming Flow-diagram with attached code.
    d. Organized background material
    e. Any other appropriate miscellaneous items (to be covered in check-in meeting when appropriate)

Rubric

This is one of two projects in the ME304 syllabus. The grading rubric closely reflects professional practice – either your work is professional or it's not acceptable.

MARK	PERCENTAGE	DESCRIPTION
A	100%	All required elements are included. Professional quality in both submission and conduct. Clear, concise, and well-reasoned.
B	87%	All required elements are included. Some elements were lacking, such as the technical letter or the conduct of the check-in meeting.
C	75%	Lacking in one or two elements which required a resubmission.
D	65%	Lacking in several elements which required a resubmission.
F	0%	Work would not be acceptable in the work place. Requires significant rework that was not completed.