Prospectus

Computational Fluid Dynamics Simulation of Impeller and Seal Rotordynamics
(Technical Topic)

CAD Usage in Modern Engineering and Effects on the Design Process
(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

As technology changes and advances with the passing of time, the way that technology is developed or designed is evolving at the same time. Computer aided design (CAD) modeling is becoming more and more widely used in solving engineering problems. Computer simulation can save money and time when problem solving, as experimental rigs or physical experiments don't need to be conducted

The technical project in this thesis focuses on fluid simulation using a computer software called ANSYS CFX, and validating the simulated results using experimental ones. ANSYS provides a cheaper and more efficient option for analyzing fluid flows in machinery as opposed to using a large, physical rig for testing rotating machinery operating at high rotating speeds. By comparing the simulated results from ANSYS against physical results from existing experimental papers with the same input conditions, the accuracy of the computer simulations can be confirmed.

The STS research project portion of this thesis dives into researching how CAD modeling affects engineers, the way they work, and how technology design happens. This portion of the thesis evolved from the technical project as the technical portion exclusively uses a CAD interface to conduct research on machinery that previously would have had to be physically tested. Computer aided design and simulation is inevitably changing the way that engineers interact with their work environment, as they switch from entirely physical testing to simulations on a computer screen. With CAD, the cost of simulating experiments has dropped dramatically, as simulation software increases accessibility for engineers to problem solving for complex situations that would otherwise be costly to replicate physically.

As technology increases pace in development, engineers must adapt to new ways of designing constantly, and this will inevitably have an impact on how engineers work and how the design process occurs. This leaves a window open for study: researching how engineers are adapting and reacting to their work environment as CAD becomes more integrated into the engineering profession. This research will be conducted between the end of the Fall 2020 semester, and the beginning of the Spring 2021 semester, ultimately producing a final thesis upon graduation

Technical Topic

The technical portion of the thesis is on research that is being conducted under Dr. Cori Watson-Kassa (UVA ROMAC Lab) on rotating turbomachinery and fluid flows and rotordynamic forces in rotating machinery during operation. This research uses ANSYS CFX engineering software to simulate fluid flows. To perform the computational fluid dynamics (CFD) analysis, the fluid region of machinery components is what must be modeled. After a fluid region is simulated, studies can be done after boundary conditions are set and a mesh is generated on the geometry. The results of a simulated computational study on a fluid region can be compared to experimental results in order to validate the computation results.

There are currently two types of machinery being studied in this research: impellers and seals. The research on shrouded impellers is being based on two existing experimental papers, where physical rigs were used to test impellers (Song, 2019 & Soldatova, 2017). Experimental impellers from both papers have been modeled using CAD in ANSYS, and the experimental results of the impeller in the Song paper have already been validated. The simulated model from the

Soldatova paper must still be validated against the experimental results for rotordynamic coefficients.

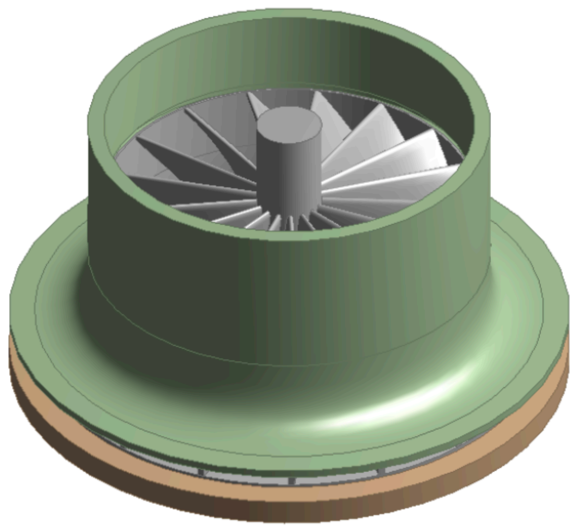

Figure 1: The simulated model of the Song et al. paper's impeller is shown.

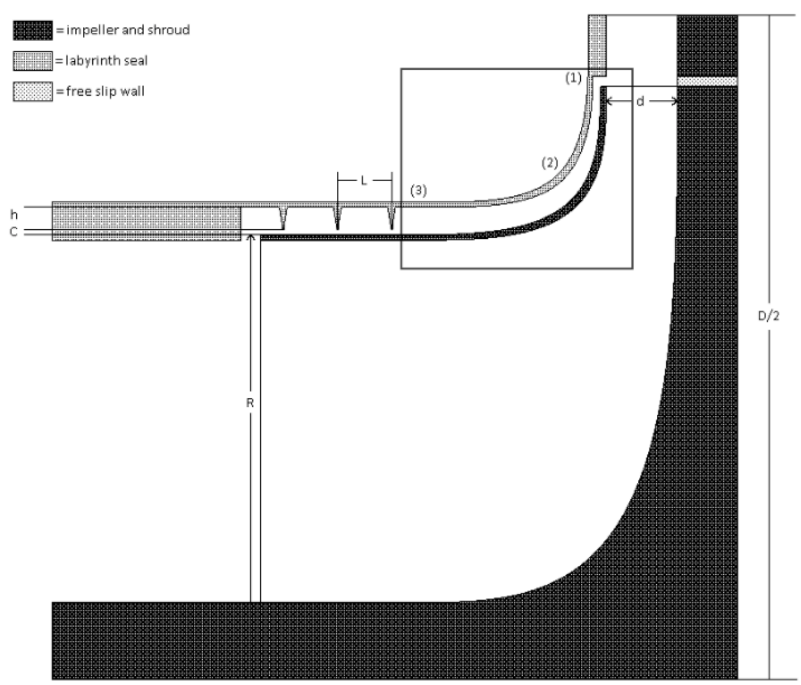

Figure 2: This figure shows the cross section of the simulated impeller based on the Song et al. paper.

Ongoing research on the impellers also studies the effect of surface texturing on the shroud of the impeller. This surface texturing, in the gap between the rotating impeller and shroud, could potentially reduce the leakage from impellers. This reduction in leakage could improve the efficiency of rotating machinery and centrifugal compressors. The effects of this surface texturing are still being studied. As this is a new line of research, there are no experimental studies to compare these results against, so the surface texturing must be added to the existing models from the Song and Soldatova papers after those base models are validated.

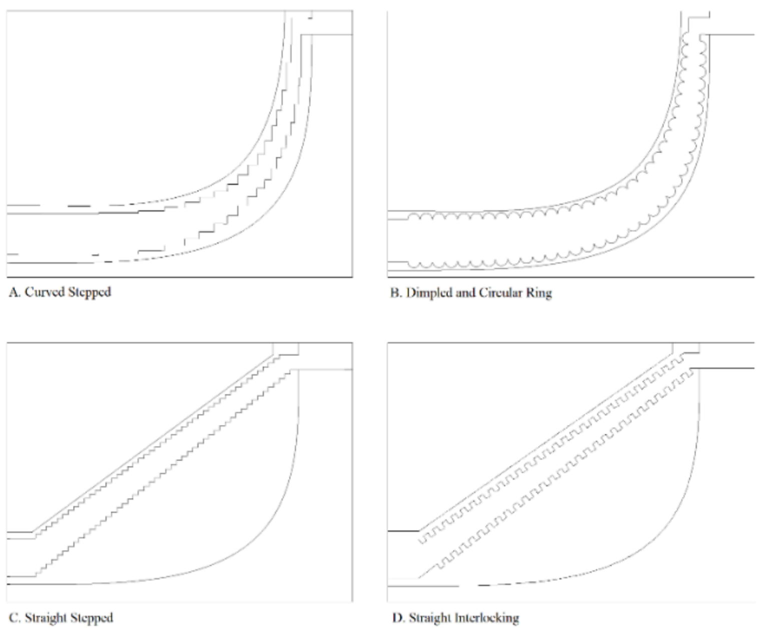

Figure 3: The types of surface texturing being applied to the shroud cavity are shown on the cross section of the model.

The other piece of research, which studies the rotordynamic forces in seals, is also based on two experimental papers which studied smooth seals operating either with water or gas as the working fluid (Jolly, 2018 & Childs, 1995). The results from these simulated models will ultimately be compared to the experimental ones. These will verify that the computation model is accurate, and that there is an effect from eccentricity in a seal on the generated rotordynamic coefficients.

With a comparison to existing, experimental results, computer simulations can be validated and proven to be accurate. The results from current research being conducted in the ROMAC lab will be verified this way, and the effects of surface texturing on the shroud of the impeller can also be studied after the initial rotordynamic coefficients are verified against existing experimental results. The technical research portion of this thesis is being conducted entirely using CAD through the software ANSYS. Before the prevalence of CAD, research on such rotating turbomachinery would have had to be conducted using an expensive, bulky, physical rig. CAD has affected the design process in this research, as simulations can now be validated against experimental results and shown to provide accurate results at a much lower cost and in a shorter time.

STS Topic

The STS portion of the thesis will research and address how computer aided design has changed the modern world of engineering and how engineers perform problem solving. This line of research evolved directly out of the technical portion, where only CAD is used to conduct research on rotating machinery.

Engineers are forced to interact with CAD software in different ways from physical experiments or models. Unlike physical experiments or testing, an interface that is purely digital must be dealt with differently, and will, as a result, prompt different responses from the operator. The STS research will provide a clear idea of how CAD simulation is impacting engineering and the design process and illuminate how computer interfaces can be improved to better integrate engineers with their work. This research will be conducted by examining existing studies and papers on CAD, how engineers interact and emotionally react to it, and how the design process is noticeably changing along with the evolution of technology.

Research can be conducted on how computer software has affected the engineering design process through the way that engineers perform as operators. A prior case study examined the use of computer tools by an engineering team (Robertson, 2009). The problem-solving process and how CAD affected it was studied in this source. It was accepted that the usage of CAD tools by engineers and designers in their work environment must be having an influence on how they solve engineering problems. Research like this can be used to improve the design of CAD tools themselves, and therefore improve the experience of engineers using them and how they integrate into a system together.

The emotions and reactions of engineers can be studied to reveal more about how they connect with a CAD interface (Liu et al., 2014). There is a different emotional reaction to using simulation software as compared to a physical rig, or even when compared to simulation software with different interfaces. This emotional reaction can be used to develop better software interfaces so that engineers can work even more efficiently.

Although CAD can allow engineers to perform work they would normally need a large physical rig for, it also has limitations (Heikkinen, 2018). The limitations of CAD are different from what previously existed when simulation had to be physically done. The way that engineers interact with a CAD interface can produce even more limitations than the software purely existing alone, without human interaction or operation. Unintuitive design of a software prevents engineers from immersing themselves in work, like would be possible when setting up a physical simulation. CAD software is now being used as a carrier for information, so there is a developing disconnect between geometric modelers that use CAD, and other users that may have to add information to the interface before a simulation can run accurately.

Computer aided design also suffers limitations with regards to having to tradeoff between mesh design, model accuracy, and result accuracy, as well as how much engineers interact with their model or prototype physically (Brown, 2009). With a physical model, there is no need to generate a mesh on a model before physically simulating something. CAD modeling is most efficient when the model is most simplified, and therefore has the most simplified mesh possible. Engineers must now evaluate that tradeoff between efficiency when running the simulation, and accuracy in the results, as an oversimplified CAD model will provide potentially meaningless results. There is also a change in the design process regarding the reduction of time between initial design and prototyping. With the arrival of CAD came also the development of 3D printers to quickly produce prototypes, eliminating the portion of the design process where engineers physically assemble their work. There is room to research how this elimination of physical assembly and instead the quick generation of a 3D model directly into a physical form with a printer impacts engineers and how they work.

Compared to a physical rig, there is more background knowledge of software and evaluating required from the CAD operator with regards to mesh generation and model simulation when using computer software. If CAD software can be even more automatized, fewer, or even simpler, user inputs could be required to accurately simulate an experiment (Elm, 2003). There have been studies into how CAD software can be better integrated between disciplines, to connect programs so that the number of inputs required from an operator can be reduced. In even further CAD integration, there is evidence to suggest that the engineering design process can be further simplified and more effectively and efficiently used.

As the design process changes, and engineers adapt how they work, it seems that the CAD system is an expanded region where engineers can interact with problems at a greater level than physically (Suchman, 2005). Computer design can provide a representation of a physical model, while also integrating with other systems such as documents and discussions, ultimately allowing for a system of technology that allows engineers an even greater role in the design process and increased problem-solving ability.

This research is important because it can show how engineering has evolved into the modern form now, where CAD is used extensively. More research can also show where engineering is headed, how engineers will continue to adapt to CAD technology, and how interfaces can be better designed to integrate with an engineer as they work and optimize the designs they produce and test

Next Steps

In the following research and thesis, the technical and STS portions will be continued to investigate the impact of CAD on how modern engineers work. The technical portion will be continued to validate the simulated results from ANSYS software against existing experimental papers results.

For the continued STS research, I will focus on sources that collect data on how engineers interact with CAD interfaces and address how this evolving world of engineering and computer aided design can impact society as a whole through how technology is developed and tested. This research provides a potential for improvement in the design of CAD interfaces and the operation of engineers' problem solving in the modern world.

Between the time period of the end of the Fall 2020 semester, and the beginning of the Spring 2021 semester, I will research and review papers on the modern nature of CAD in engineering design, and on the interactions between engineers and their workspace as CAD use increases.

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