Procedia Manufacturing

Volume 5, 2016, Pages 1119–1127

44th Proceedings of the North American Manufacturing Research Institution of SME http://www.sme.org/namrc

Implementing the Digital Design Process for the Development of a Centrifugal Fan Impeller in the Undergraduate Engineering Curriculum

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Abstract

For the past two years, Mechanical & Aerospace Engineering students at the University of Florida have been designing and manufacturing impellers for a centrifugal fan. The method is taught in our Thermo-Fluids Lab and Design class and involves using Euler's Turbomachine Equation and creating velocity diagrams to predict performance. A limitation of the Euler Turbomachine Equation is that it is based on a finite control volume analysis which prescribes blade angles at the entrance and exit of the impeller, but provides no information on the number or geometry of the blades within the impeller. Another limitation of the equation is that it assumes an infinite number of blades of zero thickness that results in uniform flow at the inlet and the exit, while a real impeller has a distinct velocity profile in between each blade that leads to losses not predicted by the equation. A Digital Design Process has evolved whereby students create an initial design using the Euler method, and then create a digital model using Solidworks, and then follow that up with a computational fluid dynamics (CFD) to optimize their design. After optimization, the students manufacture a prototype of their impeller using a 3-D printer, and then test the impeller in the lab fan performance apparatus. The results of their efforts as well as the issues involved in managing such a project with about 125 students per semester will be discussed in this paper.

Keywords: Turbomachinery, CFD, 3-D printing, Centrifugal Fan

1 Introduction

The Department of Mechanical and Aerospace Engineering Department has the largest enrollment of any department at the University of Florida with approximately 1700 students. The goal of the Bachelor of Science degree is to produce leading engineers for the 21st century. Those engineers must excel in designing and manufacturing useful items for society. Besides learning the underlying theory, we believe the students need to have practical knowledge and experiences to build upon so that they can make the maximum positive contributions.

Selection and peer-review under responsibility of the Scientific Programme Committee of NAMRI/SME

doi:10.1016/j.promfg.2016.08.086

Many manufacturing industry leaders believe that a crucial aspect of manufacturing leaders of the 21st century will be the productive and effective use of a digital thread through the design and manufacturing process. As an example, the USA federal government has awarded a $70 million grant to build the Digital Manufacturing & Design Innovation Institute in Chicago to develop and transfer such technologies. Therefore, we have developed an integrated design/manufacturing project which is required of all undergraduate mechanical engineering students and some aerospace engineering students. This paper describes the current state of the project.

In this paper, we describe a senior-level project for students who have already completed the majority of their courses, including courses on design, manufacturing, and fluid mechanics. The students will also have had various experiences in using theory, computational approaches, and experimentation to analyze engineering systems. This project will allow them to tie together these courses and experiences into a project which is more representative of the integrated nature of contemporary engineering practice. The project also gives them an initial experience whose lessons learned they can apply in the senior design capstone course.

The students are given a task to design a centrifugal fan which is to have particular performance characteristics. The project uses their knowledge of fluid mechanics and mechanical design to design a fan with that desired performance with solid modelling. They then use a computational fluid mechanics computer program to study and improve their design. When they are satisfied with the predicted performance, they then rapid prototype the fan and test its performance in the laboratory.

2 Designing the Prototype Impeller using Traditional Techniques

A performance curve, i.e., head vs flow rate, is specified by the instructor for each design team. There are about thirteen to sixteen teams per semester with six to eight students per team. The students are seniors in Mechanical & Aerospace Engineering, and have previously taken courses in fluid mechanics, thermodynamics, and instrumentation. The design process for the students begins by applying the Euler Turbomachine Equation and using velocity triangles to determine the inlet and exit blade angles for the impeller, and then adding the blades to a template of the impeller hub provided by the instructor in the 3-D computer aided design (CAD) program Solidworks® as shown in Figure 1a. Ultimately, the final product will be installed into the existing housing shown in Figure 1b, but there is much analysis left to be performed before the final product is built. At this point in the design process, only classic design guidelines have been applied.

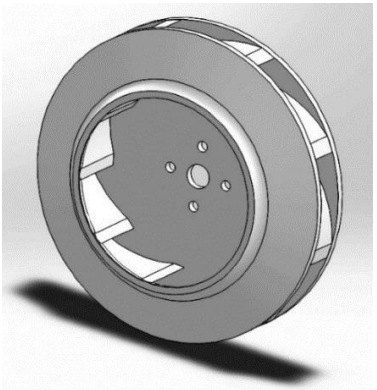

Figure 1a. Solidworks drawing of an impeller

Figure 1b. Blower Housing in test rig