Enhancing Learning using Gas Turbine Engine Simulation and Analysis (Work in Progress)

Adeel Khalid
Kennesaw State University

Abstract

In this research, two students that are enrolled in the Aircraft Propulsion class also take part in a research project. The project entails working on gas turbine engine simulator to gather engine performance metrics. The low by-pass ratio engine is designed for light general aviation business or private jet aircraft. Tests are performed at various flight conditions. Input parameters like outside temperature, altitude, velocity etc. are changed one variable at a time. Outputs like thrust, efficiency, fuel consumption etc. are measured for various flight conditions. Temperatures and pressures are also recorded at various stages of the engine. Temperature and pressure are used as inputs for physics based analytical engine cycle analyses. The metrics measured from test bench are then compared with the analytical analyses learned in the class. It was observed that the student showed more interest in the class, spent more time in the lab and overall performed better than their counter parts.

Keywords

Gas Turbine Engine, Test Bench, Retention, CFD, Hands-on

Introduction

Students learn and retain better with hands on learning. One of the best ways to ensure long term retention is working on a project with one's hands. In this study, the idea is to get students excited about engineering research at an early stage. Typically, given that students in their first or second year have not yet taken the core engineering courses, researchers find it somewhat challenging to employ these budding engineers at that early stage and get them to do valuable research. In this summer long study, three undergraduate students at an engineering school are introduced to their first research experience. Basic theory is introduced to them, they are given access to laboratory equipment and other tools to conduct the study and are given a timeline to conduct the work and produce presentable results. Student experiences are captured, their reflections on the process are noted and their feedback is presented. The study involves conducting a comparison of performance of a low bypass ratio turbo fan engine using an engine simulator, analytical parametric cycle analysis, and Computational Fluid Dynamic (CFD) analysis. All three students are involved in each study. The results show a comparison between the three methods of performing turbine engine cycle analysis. Experimental data is acquired using the Price Induction engine test bench. The simulated DGEN 380 gas turbofan engine is designed for small private aircraft. The theoretical aspect of this research includes performing a parametric analysis by using a combination of equations that compute specific data for different portions of the engine for the ultimate goal of computing the overall thrust and efficiency. CFD analysis is performed on individual engine components. This research is performed as part of the second year Peach State Louis Stokes Alliance for Minority Participants. As a result of this study, students indicated that they understood the challenges and rewards of conducting research. They appreciated the value of time and resources. They got excited about the results and wanted to present the material at local and national levels. At least one of the students continues to do more work on this topic and has indicated that they want to pursue this area of research in graduate school.

Methodology

For this research a parametric analysis study is performed for a turbofan engine in order to compare the results of the test bench, theoretical calculations, and CFD. A parametric analysis is a mathematical approach where a variety of equations are used to analyze a low by-pass ratio gas turbine engine – specifically for this research an engine called DGEN 380. The physics based parametric equations use the temperature and pressure inputs, which are based on the flight conditions that the aircraft is in. Parametric analysis includes calculations of the total uninstalled thrust, propulsive efficiency, thermal efficiency, overall efficiency, specific fuel consumption. Once the results are obtained a comparison of the results from each of the flight conditions is performed. Parametric cycle analysis is broken into stages: First step would be the overall total temperature and pressure of the engine. The second step includes performance analysis of different components of the turbofan engine. The following equations are used to perform the parametric analysis for a turbofan engine:

$$F = \left\{ \frac{a_o}{g_c} \frac{1}{1+\alpha} \left[\frac{V_9}{a_o} - M_o + \left(\frac{V_{19}}{a_o} - M_o \right) \right] \right\} \dot{m}_o$$

$$\eta_P = 2M_0 \frac{{V_9}/{a_0} - M_0 + \alpha({V_{19}}/{a_0} - M_0)}{{V_9}^2/{a_0}^2 - {M_0}^2 + \alpha({V_{19}}^2/{a_0}^2 - {M_0}^2)}$$

Where

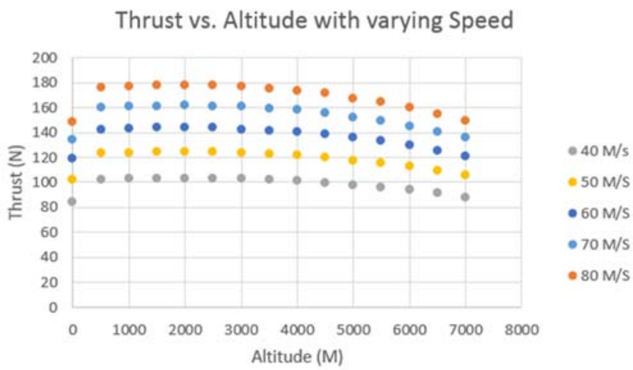
$$a_o = speed\ of\ sound = \sqrt{\gamma R g_c T_o}$$

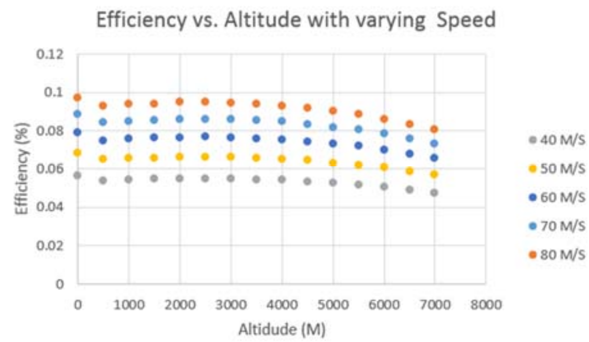
$$g_c = gravity = 9.81\ m/s$$

$$\dot{m}_o = initial\ mass\ flow\ rate$$

$$V = Flow\ Velocity$$

$$M = Mach\ Number = \frac{V}{a} = \frac{V}{\sqrt{\gamma g_c R T}}$$





Pedagogy

This ongoing study allows three undergraduate students to go through a complete engineering design analysis. They start with a baseline gas turbine engine and calculate the cycle parameters using analytical methods. The values are then compared with a corresponding engine test bench. Validation is performed to ensure that the CFD software is calibrated (in progress). Various flight conditions are changed and corresponding performance parameters e.g. thrust and efficiency values are calculated. This activity allows the undergraduate students to experience a complete engineering research process. The participating students have indicated that as a result of this work, their confidence in pursuing engineering studies and research has increased; they are now interested in pursuing graduate work and hope to continue to do more of the same or similar work into the future. It is expected that as part of this study the students will continue to work on the project and look at the effects of varying the blade aspect ratio, chord, type of airfoil and taper on the engine thrust output and efficiency. Possibly future explorations include designing various components and full assembly of the low by-pass ratio engine and conducting a full motion based Computational Fluid Dynamic analysis and comparing the results with the analytical and experimental results. The overall performance of the three students has been by far better than most other students in the related aircraft propulsion class they are both enrolled in in the fall semester.

References

1 P. Induction, "DGEN Engine | Price Induction", *Price-induction.com*, 2016. [Online]. Available: http://www.price-induction.com/dgen-engine/. [Accessed: 30- Jun- 2016]

2 K. Liew, E. Urip, S. Yang, Y. Siow and C. Marek, "Parametric (On-Design) Cycle Analysis for a Separate-Exhaust Turbofan Engine With Interstage Turbine Burner", *NASA*, 2016.

3 Y. Şöhret, Ö. Turan and T. Hikmet Karakoç, "Analysis of Combustion Efficiency for Turbofan Engine Combustor Using MATLAB", *IJET*, vol. 7, no. 2, pp. 86-90, 2015

4 "Design of a Tapered and Twisted Blade for the NREL Combined Experiment Rotor", *National Renewable Energy Laboratory*, no. -500-26173, 1998

5 "High Fidelity Turbofan Engine Simulation (NASA) | :: AP Solutions, Inc. ::", *Ap-solutions.com*, 2016. [Online]. Available: http://ap-solutions.com/capabilities/analysis-and-design/cfd-application/high-fidelity-turbofan-engine-simulation-nasa/. [Accessed: 28- Jul- 2016]