Thermodynamics Demo Unit 1B

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Abstract

A Brayton Cycle consists of compressing air, as the working fluid, into a heating section and finally an axial turbine section to capture energy and convert into rotational energy. In this project, the rotational energy is immediately converted into electrical energy through the means of a brushless DC motor.

Introduction

Purpose: **To design and manufacture an operational Brayton Cycle for educational purposes in an introductory thermodynamic class.**

Method: **3D printed CAD to house axial blades for the use in a Brayton Cycle. Temperature and pressure points will be acquired through the use of pressure transducers and thermocouples. Utilizing airfoil analysis, each blade was optimized to perform at its peak [1].**

Conclusion: **Acquiring the pressure and temperature states at each subsection of the cycle, a p-v & T-s diagram can be produced to analyze the work output in an educational setting.**

Requirements

Table 1: Customer Requirements

Customer Requirements	Weighting	Justification
Collect Data	5	The fundamental principles behind teaching the Brayton Cycle to future students
Safety	5	No damage or deterioration of model over time to ensure functionality
Functionality	3	Must be operational for a maximum of 15 minutes to simulate a Brayton Cycle
Rigorous Design	4	Team designed blades, casing, and data acquisition
Analysis	5	Turbomachinery design and Brayton Cycle
Cost	3	Maintain low cost for entirety of project
Visibility	4	To visually illustrate the processes of a Brayton Cycle

Table 2: Engineering Requirements

Engineering Requirements	Target	Units	Justification
Work Output	20 Watt	$Watt$	Production of power from turbines will turn on a light bulb connected to the system.
Aerodynamic	>.3	C_d	Minimizing aerodynamic drag will increase the power produced from turbines
Thermal Capacity	100	K/m^2	Implementation of a heat exchanger, will provide the data for interactive graphs
Volume	<.5	m^3	Constant volume measurements for each process of cycle is required for P-v diagrams
Data Acquisition	Pressure and Temperature	Pa, K	To create a realtime chart for T-s & P-v diagrams to simulate a Brayton Cycle

Final Design

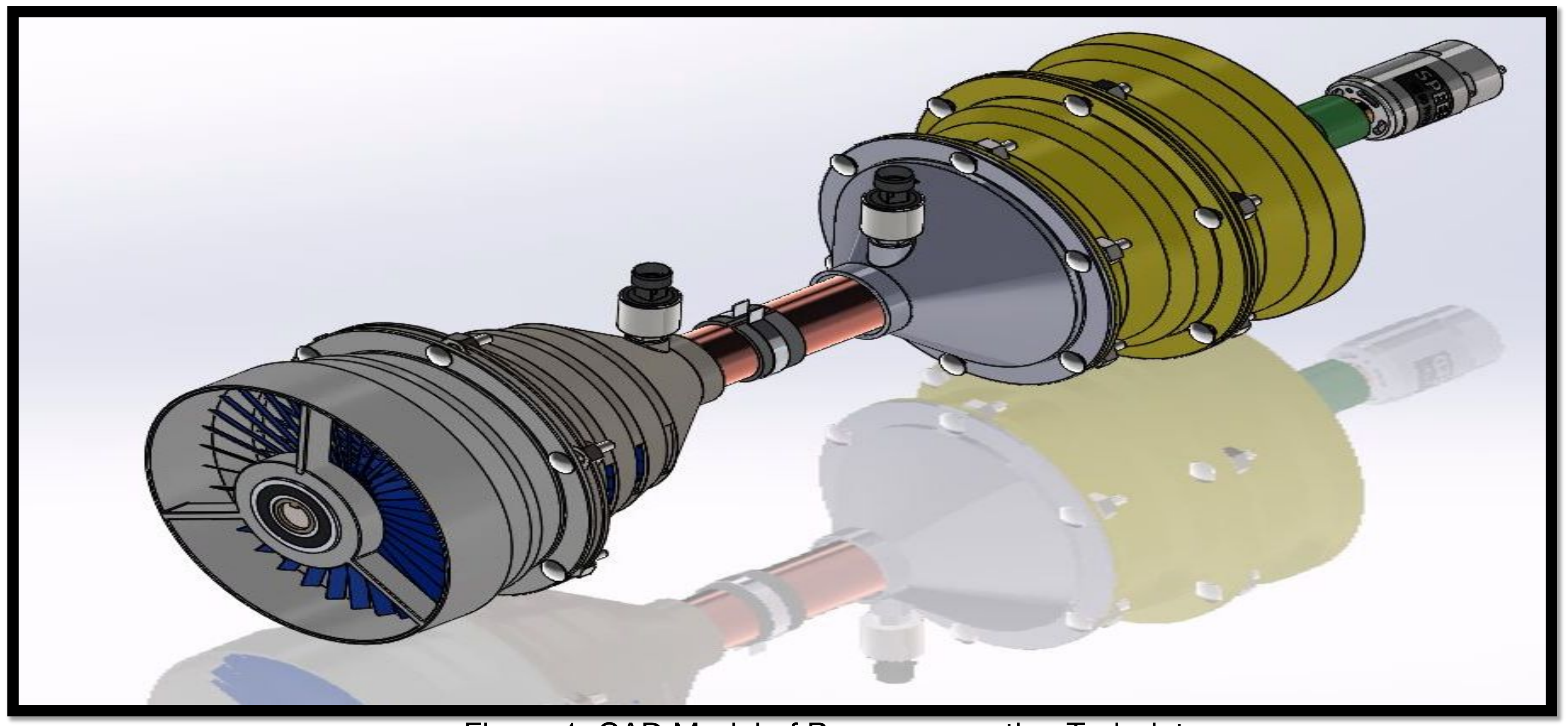

Figure 1: CAD Model of Power generating Turbojet

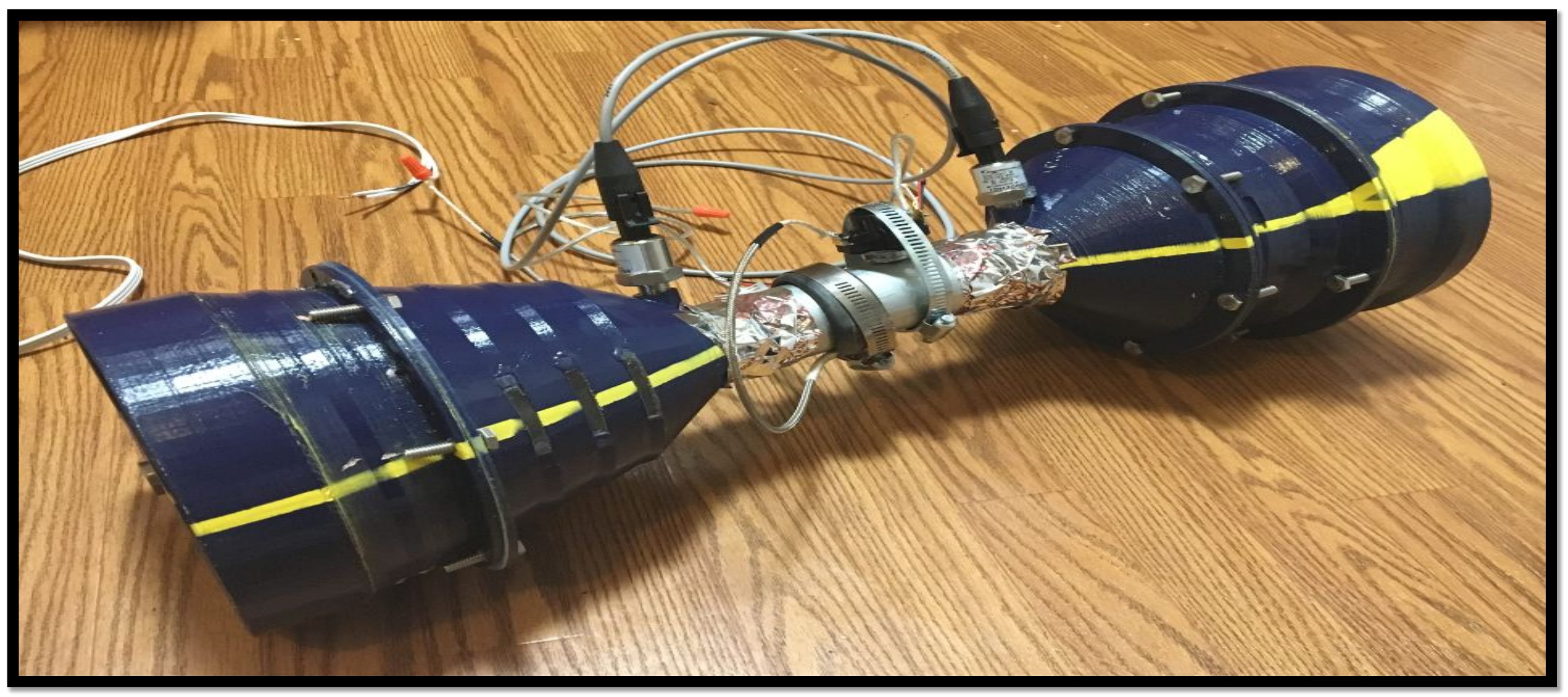

Figure 2: Model of Power generating Turbojet

Design Changes

Original designs for the operating Brayton Cycle consisted of larger 3D printed material to allow for the compressor section to operate. All subsections of the system has been updated to include less material while maintaining operational efficiencies at a minimum.

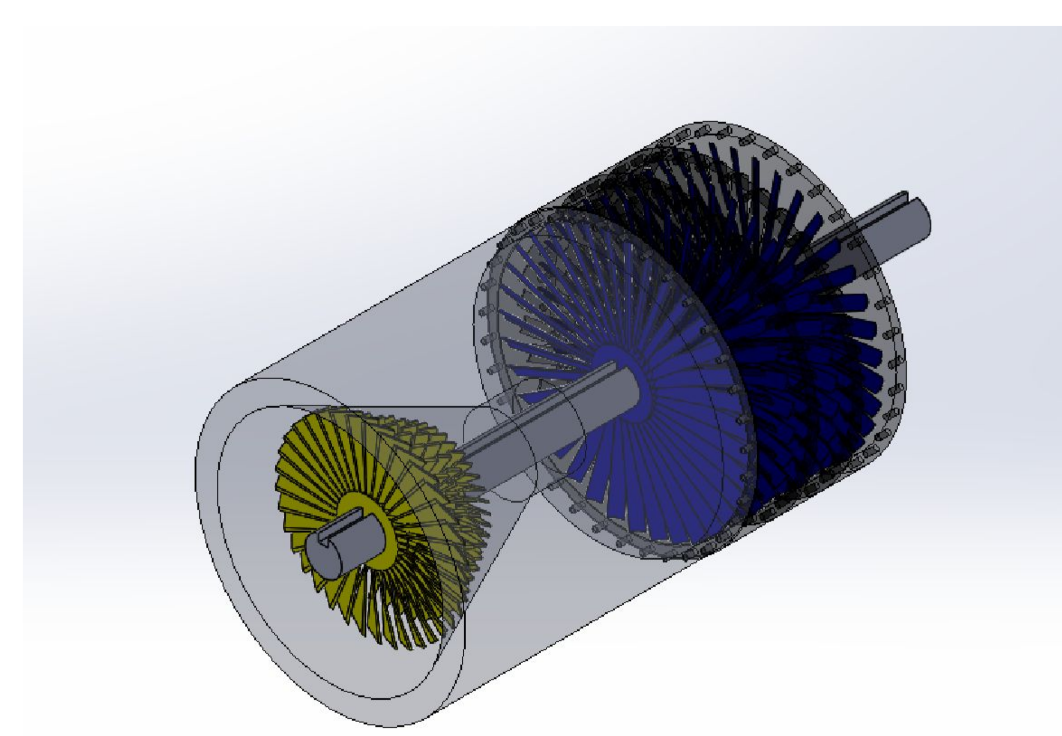

Figure 5: Previous Design

P-v & T-s Diagrams

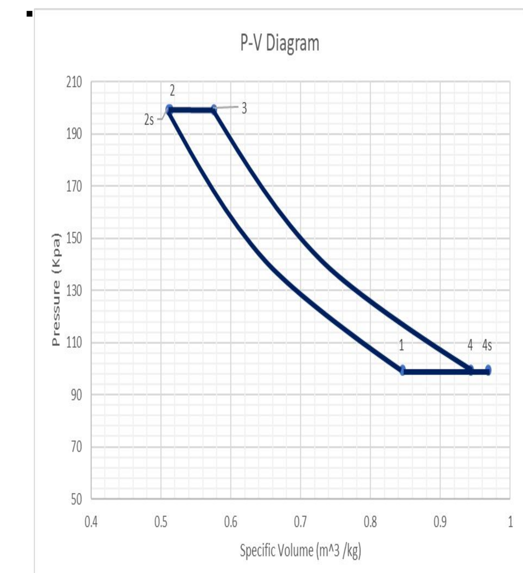

Figure 3: P-v Diagram

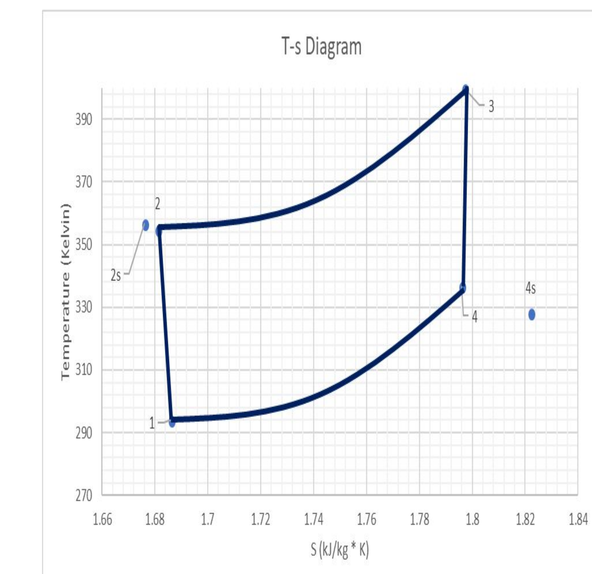

Figure 4: T-s Diagram

P-v & T-s Diagrams were produced using a compression ration of 2, isentropic efficiencies of 90% to output a power of .46 kW .

Power Output

A series of 24 Volt LED lights are attached to a brushless DC motor. To fully power the system, an analysis was performed to calculate the necessary rotation to power 4.4 Watt [2].

$$V = i \cdot R + K \cdot \omega$$

$$\omega = \frac{24\,Volts\; - (0.122\,Amps)(5\Omega)}{21.1\,mNm/A} = 110.85\,rad/s$$

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References

[1] Airfoiltools.com. (2018). *NACA 4 digit airfoil generator (NACA 2412 AIRFOIL)*. [online] Available at: http://airfoiltools.com/airfoil/naca4digit [Accessed 5 May 2018].

[2] Fox, R., McDonald, A., Pritchard, P., Mitchell, J. and Leylegian, J. (n.d.). *Fox and McDonald's introduction to fluid mechanics*.