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## Abstract

To facilitate experimental research on flow dynamics within jet engines, a cost efficient test stand is being detailed in this p. In particular, a Westinghouse J34 jet engine was converted to allow for investigations in flow structure, stall dynamics, as well as active flow control in jet engines. The jet engine consists of an axial flow compressor section, a valve controlling and added plenum, and an electric motor drive system. The electric drive motor incorporates a pulley system that manipulates the rotational speed of the J34. The drive input utilized the J34's lubrication gearbox system as an input with an added external gearbox in order to avoid interfering with the airflow of the jet engine. The test stand is instrumented to capture the flow in the axial compressor subsystem. In this way, the test stand allows for research to investigate compressor stall inception, rotating stall dynamics, and active flow control to prevent stall. A 10 horsepower General Electric AC motor is used as the electric drive motor and is controlled by an Allen Bradley 1336 Plus Variable Speed Drive. Airspeed, pressure, shaft speed, and torque are measured using sensors that are strategically placed around the jet engine. Using these sensed values, the axial compressor section can be characterized by evaluating pressure rise coefficient, flow coefficient, and efficiency of the compressor. A plenum connected to the exhaust behind the combustion chamber is used to simulate the throttle characteristics. In addition, the system is modeled using SolidWorks™. To support the modeling of the interior dynamics of the engine, a virtual reality simulation is created using the physics engine in Unity by Unity Technologies™. Utilizing proprietary software called AxSTREAM by SoftInWay, the flow within the jet engine can be computed and simulated. This is of particular interest in places where no physical measurement is possible. Measurements from the original test stand are used to validate the simulation results. In the future, AxSTREAM will allow us to optimize blade geometry and other flow influencing parameters. These measurements will allow researchers at the MCERC to design control strategies in order to prevent or remedy compressor stalls.

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## Introduction

- Due to the stall phenomenon, it was decided to create a test platform in which a J34 Westinghouse was mounted to perform research. This research will try to create the Axial Compressor Characteristic Curve undergoing stall similar to Figure 1.
- The research is conducted by measuring the pressure, airspeed and RPM while monitoring efficiency using temperature and torque sensors in Figure 5.
- Compression system instabilities are generally caused by one of two phenomena known as rotating stall and surge.
- Axial compressor systems must be operated at a safe region away from the peak of their performance curves to accommodate flow disturbances during operation. A number of different control strategies have been proposed to mitigate the instabilities and increase the efficiency without jeopardizing the operational safety of the system. [1]
- The proposed control strategies to limit the instabilities are based on active control schemes, where actuation helps to safely move the operating point further up along the performance curve.[2]

## Simulation/Modeling

- Modeling and simulation were completed using SolidWorks, Unity, and AxSTREAM.
- Geometry from the J34 Westinghouse Jet Engine is fed into SoftInWay's AxSTREAM software. A 3D model of the compressor is created in SolidWorks.
- AxSTREAM outputs information such as mass flow rate, velocity, pressure, etc. Using this data, C# can be used to program objects in Unity and create a visualization of the phenomenon.

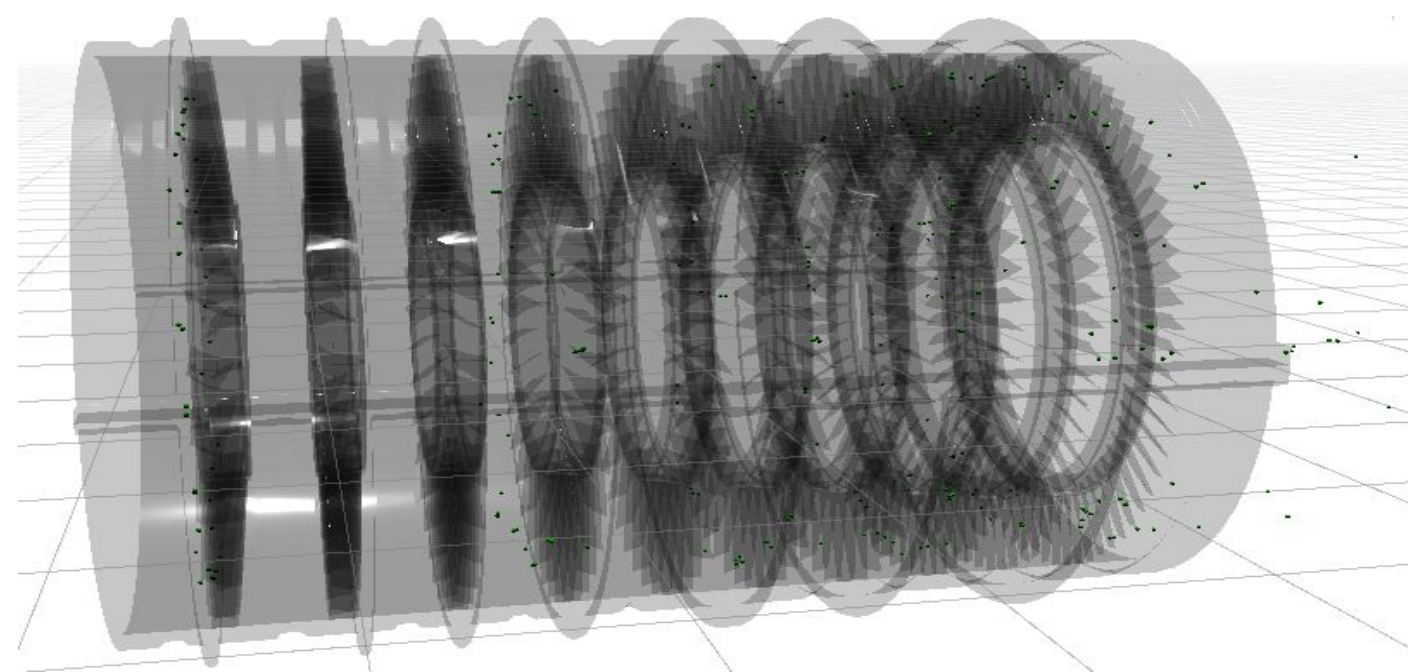


Figure 2. J34 Compressor Flow Visualization in Unity



Figure 3. J34 Test platform and Test Stand

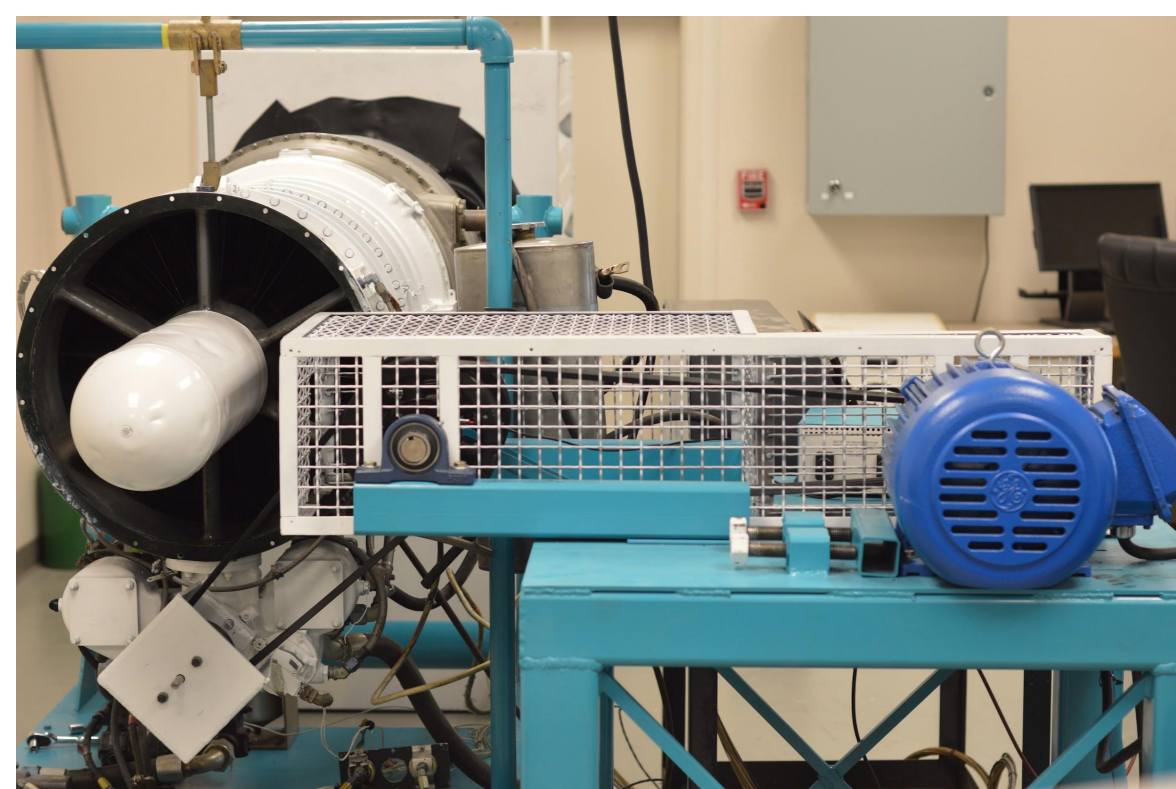


Figure 4. Motor and Pulley System

## Future Objectives

- Identify the flow dynamics within a single blade passage and provide research infrastructure to Idaho State University for future students to benefit from.
- Create a PSD analysis to measure pressure in the casing above the blade passage, and then determine the signature frequency band. Signature frequency band will follow the graph in Figure 8 and the sensors will be placed on the blade like Figure 9.
- The implementation of a test stand which will include a single sensor that will be incremented through sensors 4 to 6 in Figure 9 above the first blade passage. Sensors 4 to 6 indicate the most sensitivity in terms of changes in PSD magnitude within the signature bandwidth

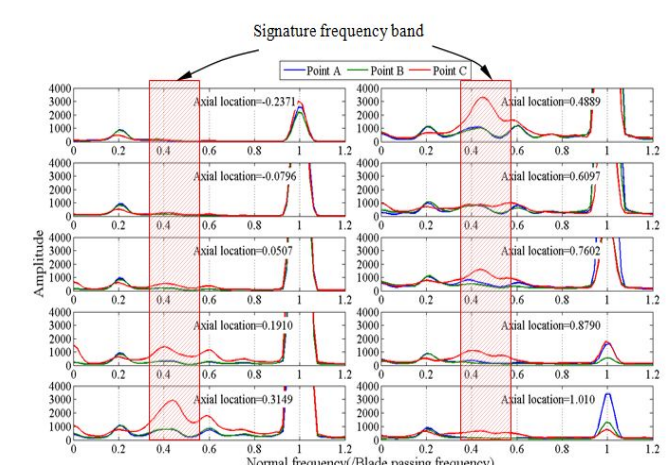


Figure 8. Signature Frequency band for 10 sensors (Li)

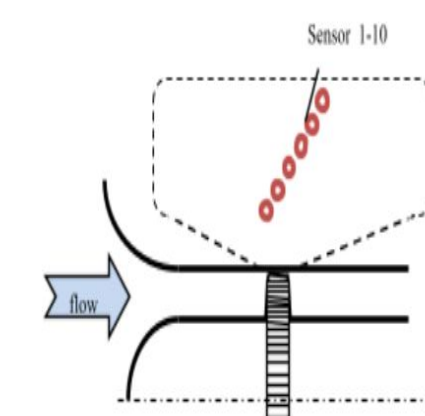


Figure 9. Figure caption

## Conclusion

- The J34 Westinghouse Jet Engine Axial Compressor Test Stand was constructed with the intent to simulate stall and surge phenomena.
- Geometry from a tangible jet engine can be processed into computer graphics for more helpful observations.
- The implementation of the PSD analysis through incrementing sensor positions 4 to 6 will measure the stall and surge pressure phenomena.

## References

- [1] Vo, H. D., Tan, C. S., and Greitzer, E. M. (2008). Criteria for Spike Initiated Stall, ASME J. Turbomach., 130(1), 011023.
- [2] Williams, J.E. and Huang X.Y. (1989). Active stabilization of compressor surge, Journal of Fluid Mechanics, 204, pp. 245-262.
- [3] "Axial compressors," Axial Compressors - an overview | ScienceDirect Topics, 2019. [Online]. Available: <https://www.sciencedirect.com/topics/engineering/axial-compressors>.

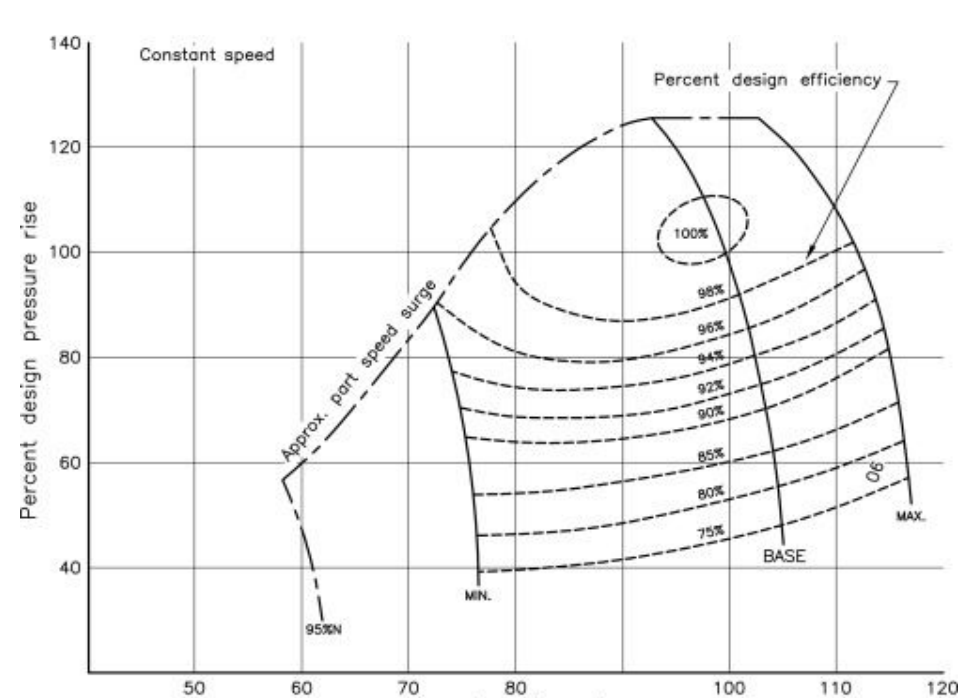


Figure 1. Axial Compressor Characteristic Curve undergoing stall  
Source: [3]

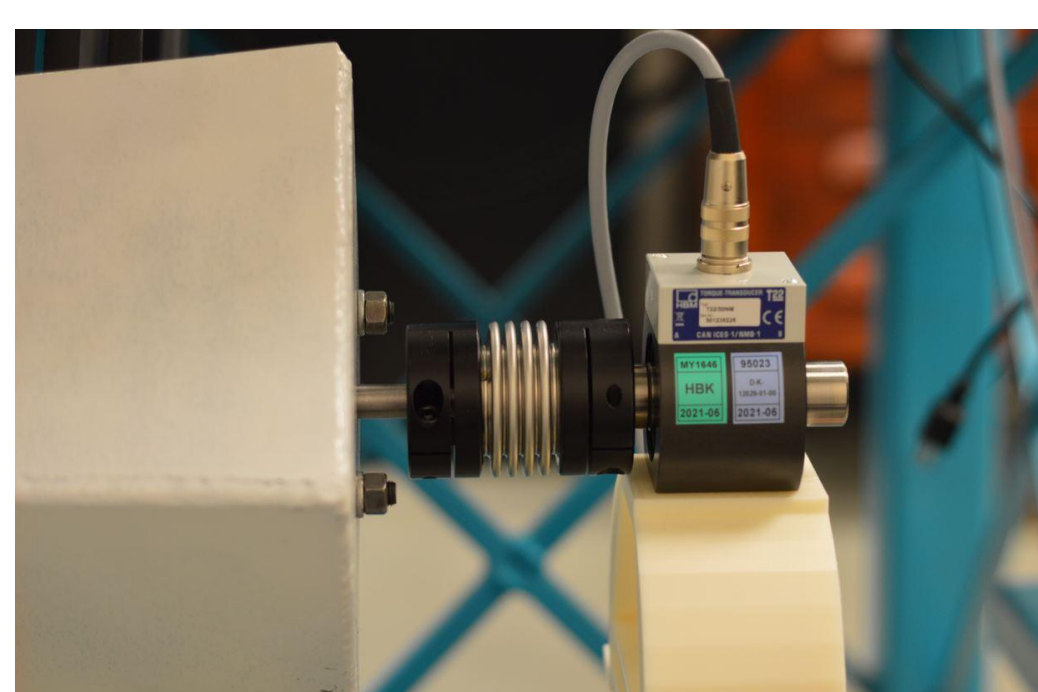


Figure 5. Torque Meter (adjacent to Gearbox)

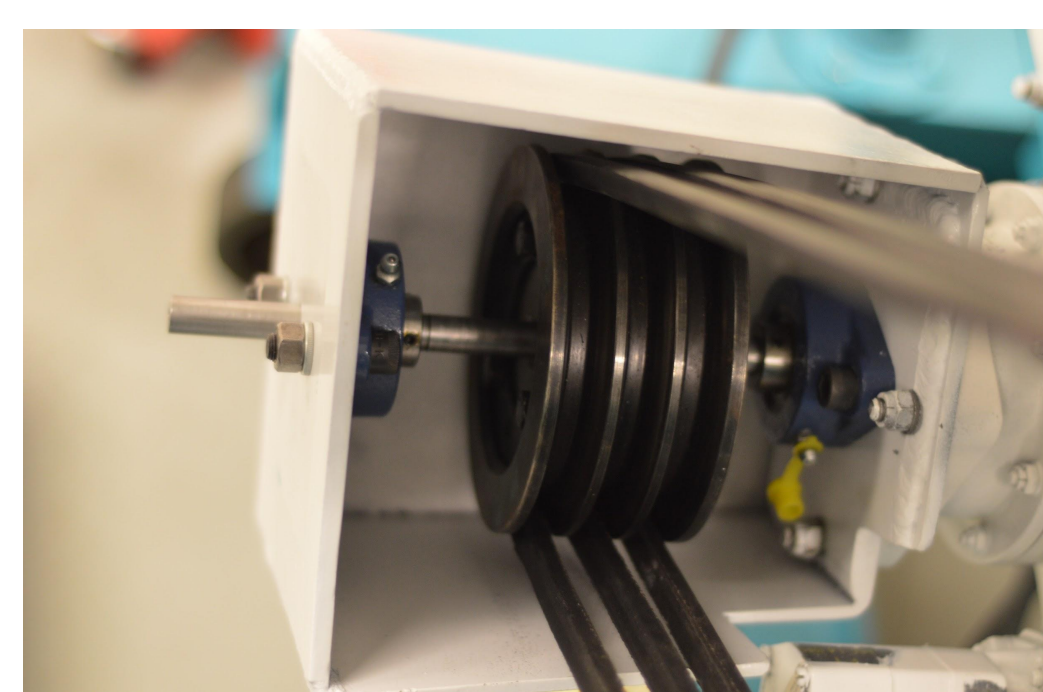


Figure 6. Gearbox

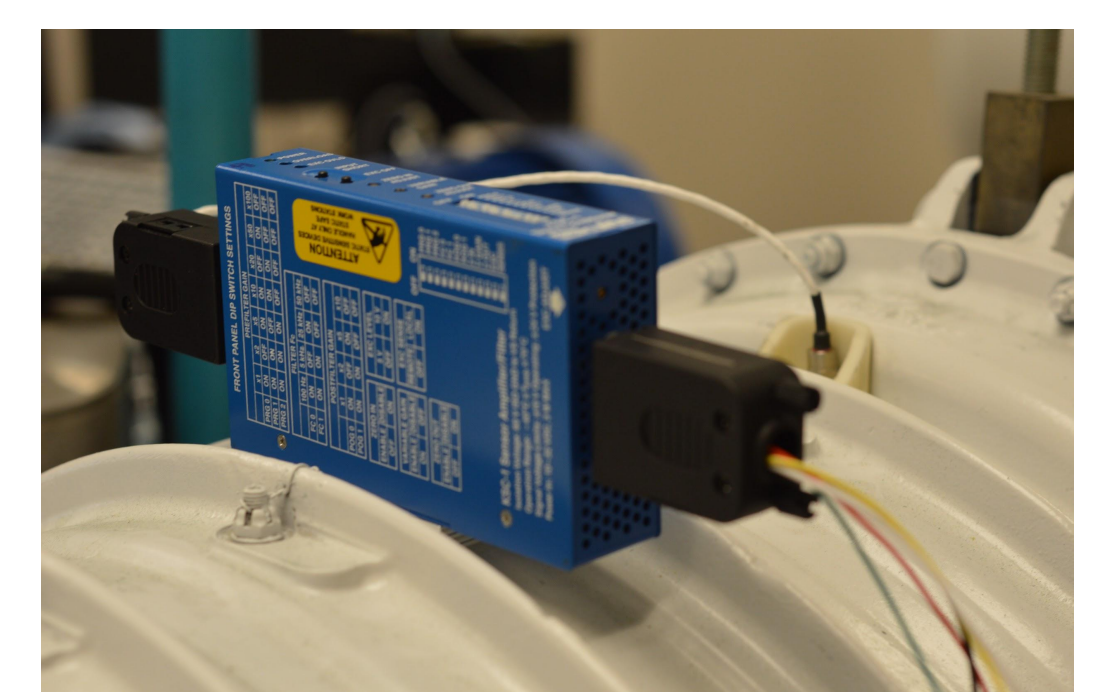


Figure 7. PSD Sensor