Experimental Gas Combustion Turbine

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Design of an experimental assembly capable of imitating the operation of a turboshaft gas turbine in a laboratory, with particular interest in the exploration of novel technologies for the reduction of the formation of oxides of nitrogen within the combustion chamber (such as the injection of water into the combustion zone).

Background

Greenhouse gases, such as CO_2 and NO_x are seen to exacerbate the effects of global warming. There is therefore a strong drive to reduce these emissions, linked to fossil fuel combustion. This project looks particularly at reducing the production of NO_x during gas turbine combustion.

In order to combat the production of NOx in the combustion chamber of gas turbines, a number of combustion control techniques exist. The method of water injection into the combustion zone is a novel technology that claims to be able to reduce emissions of oxides of nitrogen by 20-25%, with an industrial associated cost of 2-3$/kW of installed capacity, for gas turbines used for the generation of electrical energy [1]. Table 1 summarises a variety of combustion control techniques.

Combustion Control Technology	NOx reduction (%)	Capital Cost ($/kW)
Low NOx burner	40-60	2-4
Close coupled over fire air	30-50	4-7
Separated over fire air	40-60	5-10
Induced flue gas recircultaion	30-40	3-5
Forced flue gas recirculation	40-50	5-10
Water/Steam Injection	20-25	2-3

Table 1: Comparison of combustion control technologies [1]

Engineering Problem Statement

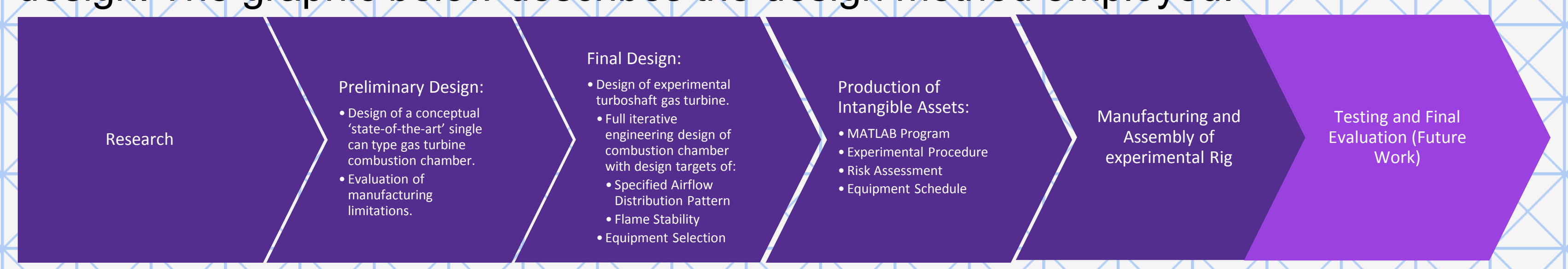
“Facilities at the faculty of engineering are limited with respect to permitting the physical testing of novel technologies on the performance of a gas turbine. The creation of an experimental assembly of a turboshaft gas turbine will be able to permit physical investigations and design evaluation of a variety of systems and techniques, in particular techniques (such as the injection of water) used to reduce the production of greenhouse gasses (such as oxides of nitrogen) within the combustion zone.” [2]

Project Aim

"To design, manufacture, and evaluate for performance; an experimental assembly of a turboshaft gas turbine engine capable of demonstrating the physical effect of novel technologies particular to the combustion processes (such as the injection of water into the combustion zone) on a variety of overall performance parameters. In particular looking into the effect on the reduction of the production of greenhouse gasses such as oxides of nitrogen, with a negligible effect on system performance.” [2]

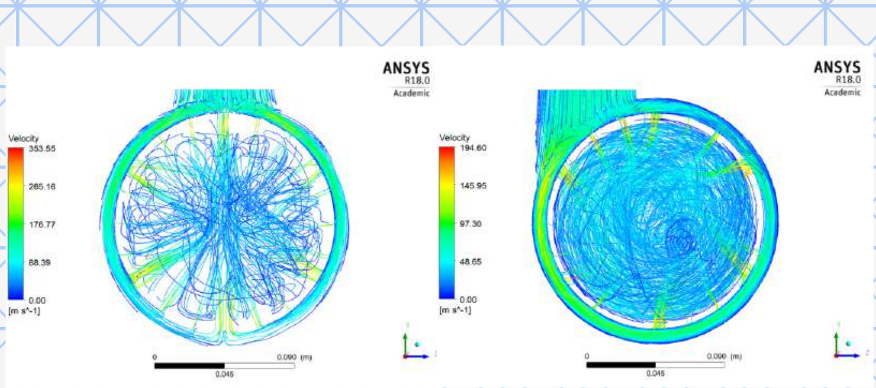
Design Approach

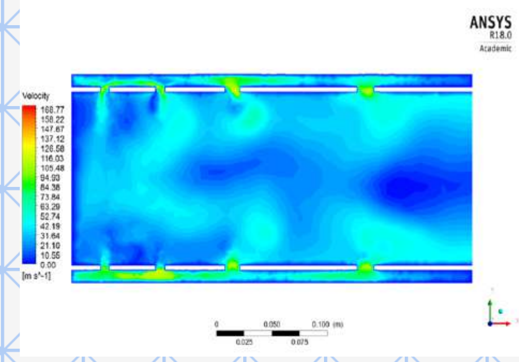
The design was approached in two main phases: preliminary design and final design. The graphic below describes the design method employed.



Evaluation

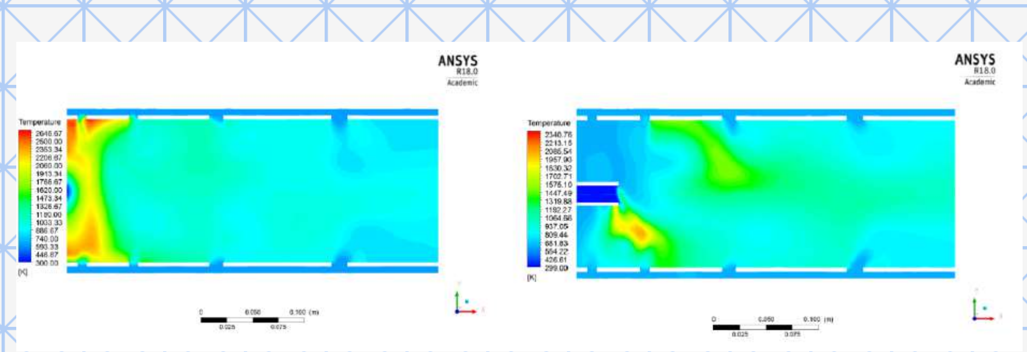
Top Image: The tangential inlet of the air flow into the combustion chamber through the casing (right) presents a much stronger axial vortex than the radial inlet (left).





Left Image: The holes (size and location) drilled into the liner were designed in an iterative manner to give the required airflow distribution of 50-20-30% into the primary, secondary and dilution zones of the combustion chamber.

Bottom Image: The flame holder was designed to encourage flame stability within the combustion chamber. The flame holds a much more uniform shape with the flame holder (right) than without the flame holder (left).



Experimental Gas Turbine

1. Flame Holder: The flame holder is designed to encourage flame stability within the combustion chamber.

2. Igniter: A traditional spark plug assembly is used to ignite the engine.

3. Temperature Sensing: K-type thermocouples will be inserted though bosses on the casing, secured with compression fittings.

4. Casing: Made from an NPS Schedule 10 6” pipe, the casing surrounds the liner and houses various bosses for the integration of measurement devices. The air inlet position encourages the generation of an axial vortex though the combustion zone for mixing.

5. Water Injection Position

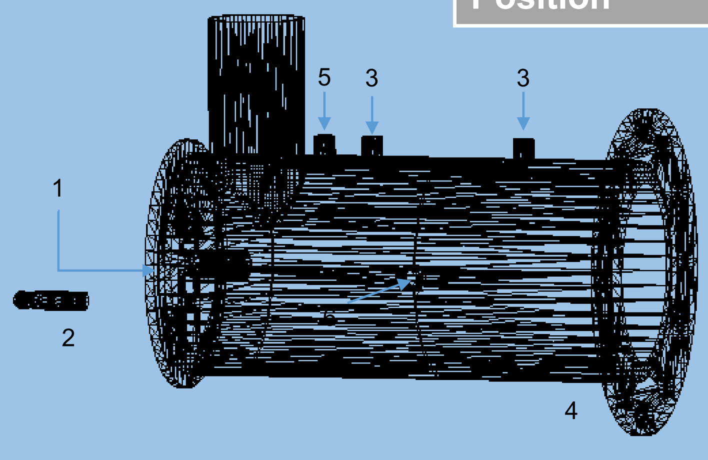
6. Pressure Sensing: Glycerine filled mechanical pressure gauges will be fitted to the engine, with pressure siphons being used to protect the devices where high temperatures will be experienced.

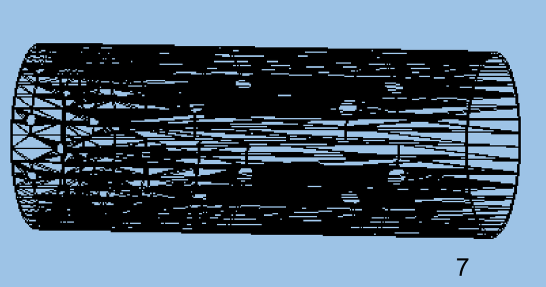
7. Liner: The liner is designed to be removable, being supported by a small sleeve at either end of the combustion chamber (machined onto each end flange). The liner has holes drilled though it to precisely distribute the airflow though the three zones of the combustion chamber (primary, secondary, dilution) as required for effective combustion. Made from NPS Schedule 10 5” pipe.

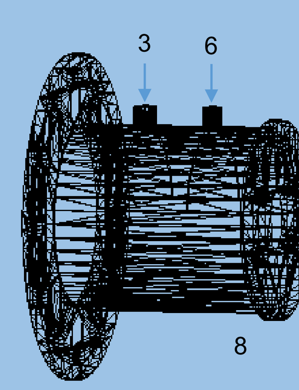
8. Exhaust Manifold: The exhaust manifold is similar to the casing, designed to cool and transport the combustion products travelling form the combustion chamber to the turbine inlet. This part is also manufactured form an NPS schedule 10, 5” pipe – and contains bosses for the integration of measurement devices.

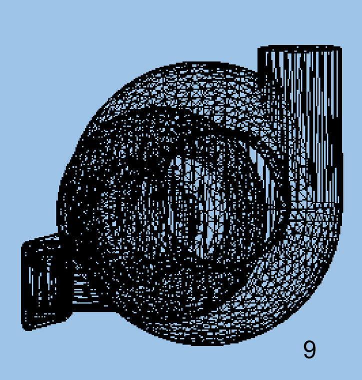
Material: All manufactured parts are made from Stainless 316L due to the high temperatures exhibited within a gas turbine engine.

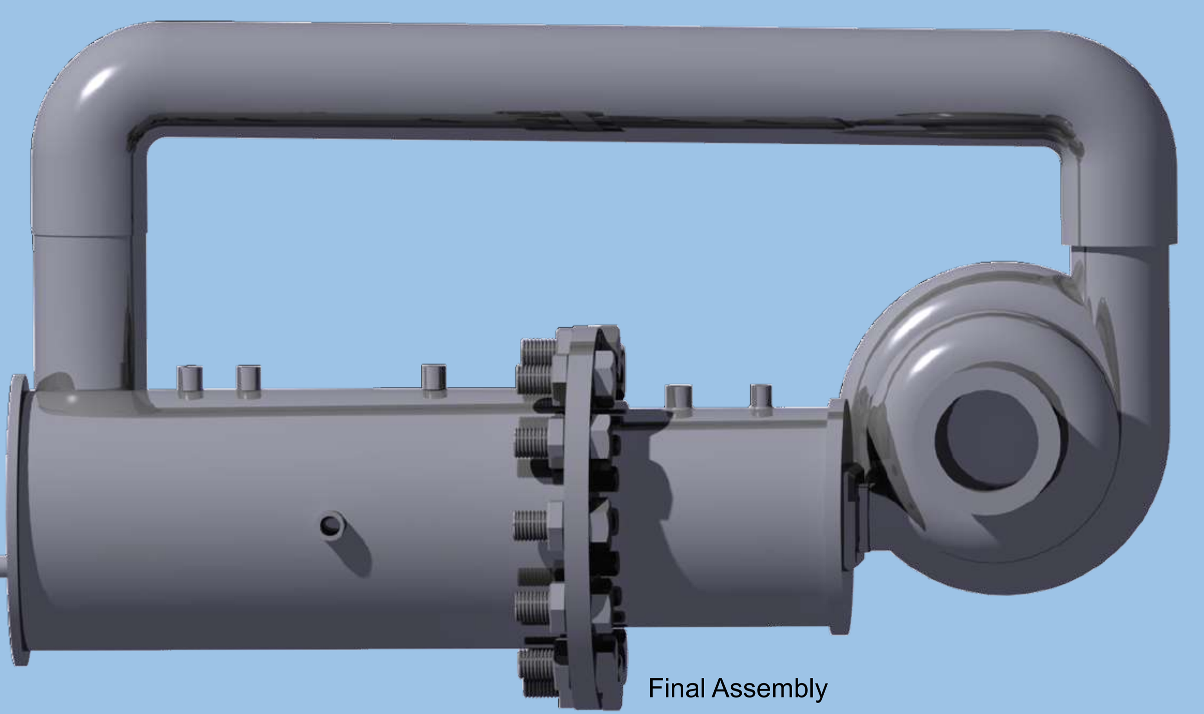
9. Turbocharger: A Garrett GT3582 RS Turbocharger was chosen to preform the compressive and expansive duties, acting as the engine’s compressor and turbine.











Final Assembly

References:

1. Bell, R.D., Associates, M., Fred, I. and Buckingham, P. (no date) AN OVERVIEW OF TECHNOLOGIES FOR REDUCTION OF OXIDES OF NITROGEN FROM COMBUSTION FURNACES. Available at: http://www.mpr.com/uploads/news/nox-reduction-coal-fired.pdf (Accessed: 30 October 2016).
2. Final group report

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