Aggie Innovations: Waste Heat Recovery System

Kyle Harris, Luke Lerick, Ben Robbins, Sarah Thiele

Undergraduate Marine Engineering Technology

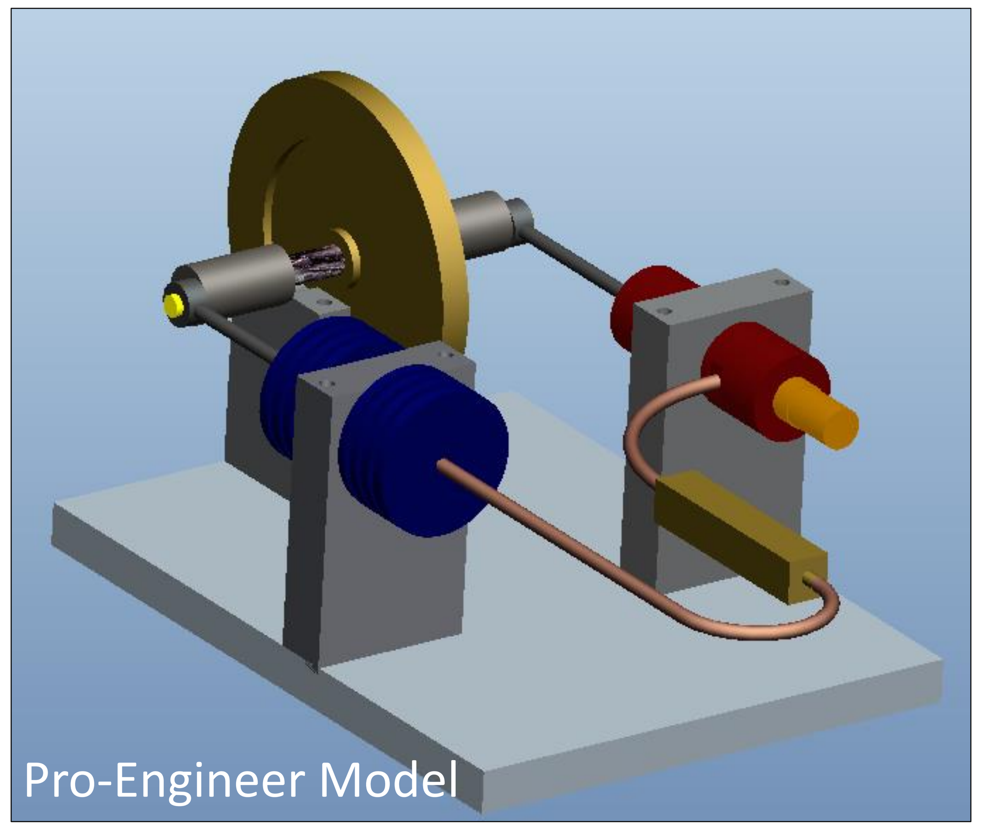
Project Goal

Design and build a Stirling Heat Engine to efficiently recover waste heat from the exhaust of a diesel engine generator.

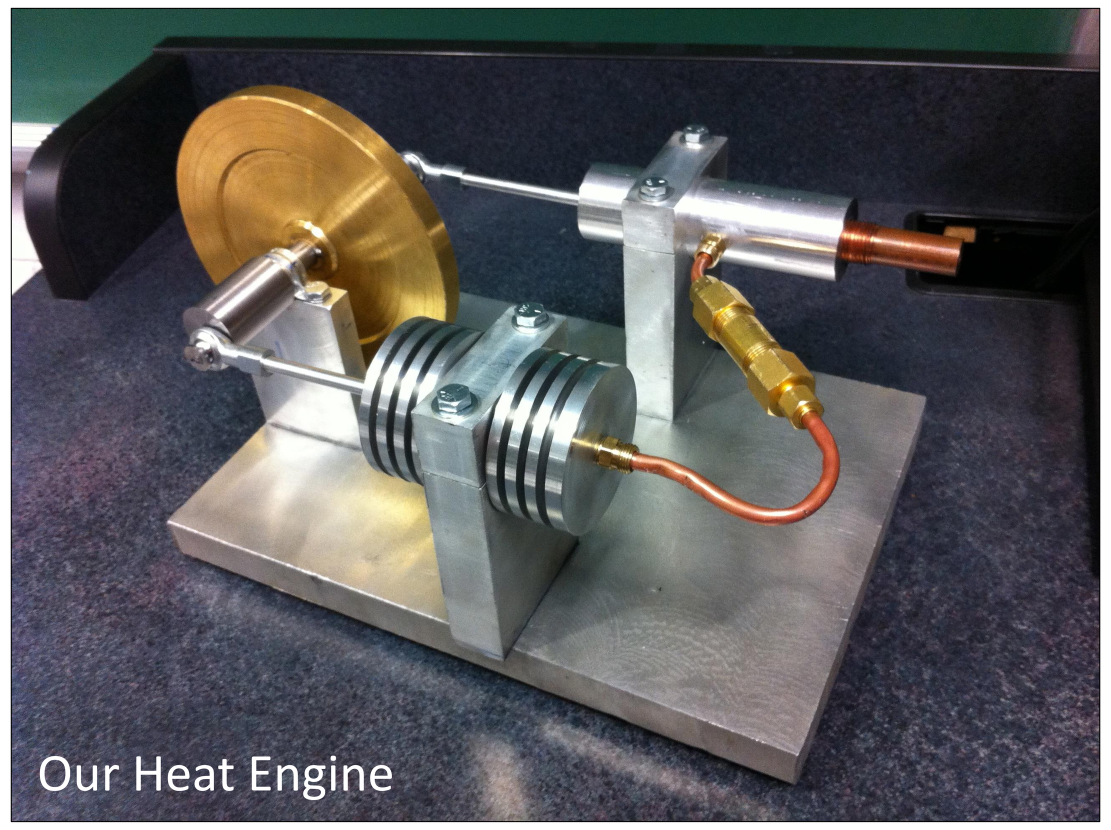
Abstract

Combustion engines are used to convert thermal heat into useful work, however much of this heat is rejected through the engine's exhaust. Aggie Innovations is working on a method of recovering some of this waste heat and using it to create additional useable energy. Aggie Innovation's Waste Heat Recovery System is composed of a Stirling engine that converts the exhaust heat from a diesel engine generator into power by means of a flywheel. The benefits of utilizing this waste heat are immense, in modern engines more than half of the heat created by the fuel is rejected as waste heat. The inherent economic advantage of increasing engine efficiency is that more power will be obtained when burning the same amount of fuel. The applications for such a system are endless.

Aggie Innovation's Waste Heat Recovery System: Alpha Type Stirling Heat Engine

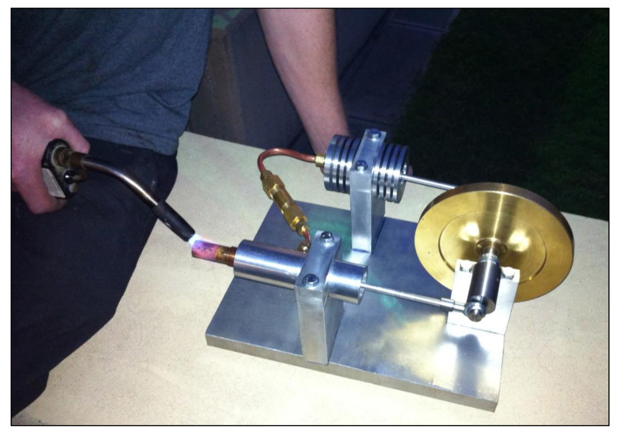


Pro-Engineer Model



Our Heat Engine

Manufacturing and Fabrication



Stirling Heat Engines

Our heat engine is a alpha type Stirling engine. It operates as a constant volume standard air cycle with air as the working fluid. Other gases may be used but air is the most attainable and will allow for ease in maintenance as we will not have to refill the working fluid any time a modification is made. Alpha type Stirling engines have two separate cylinders, one near a heat source and one in a cooler environment. The air in the hot cylinder expands as it is heated forcing the piston out and turning the flywheel. The cylinders are connected so that when the flywheel pushes the cool piston in, cool air is forced back into the hot cylinder, continuing the cycle.

Our Heat Source

Our heat source is the exhaust from a diesel engine generator. We chose this for our heat source due to its high exhaust heat (550° F) and accessibility. Existing tie-ins meant for sensors and gauges are the ideal for connecting our engine. The heat available from the exhaust is what determined the sizing for the entire system based on our desired output RPM. This allows for more opportunities for industrial applications because diesel generators are common in industry.

Component Summary

Component	Fabrication Method	Source of Material
Aluminum Cylinders	Machined	Donated – Farmers Copper
Copper Core	Machined	Donated – Farmers Copper
Aluminum Piston Heads	Machined	Donated – Farmers Copper
Graphite PTFE Lip Seals	Pre-Fabricated	Purchased – McMaster Carr
Brass Flywheel	Machined	Donated – Farmers Copper
Aluminum Brackets	Machined	Donated – Farmers Copper
Aluminum Connecting Rods	Machined	Donated – Farmers Copper
Carbon Steel Flywheel Shaft	Machined	Donated – TAMUG Machine Shop
Bolts	Pre-Fabricated	Purchased – Chalmers Hardware
Aluminum Flat Plate	Machined	Donated - Farmers Copper
Steel Rod End Bearings	Pre-Fabricated	Purchased – Applied Industrial Technologies
Regenerator Components	Pre-Fabricated	Purchased – Home Depot

Note: The majority (over two thirds) of our project materials were donated then machined in the TAMUG machine shop, keeping us well below our allocated budget.

Calculations and Theory

Our heat engine began with a conceptual design and through the use of various assumptions and calculations each part was designed and analyzed. Beginning with the heat from the diesel generator's exhaust, the heat transfer was calculated through the copper core into our cylinder. Next, thermodynamic calculations were preformed based on the assumption of a constant volume air standard cycle, allowing us to size our cylinders. We performed stress analysis to validate our cylinder, piston head and connecting rod designs. After determining a desired RPM the flywheel was sized and the energy storage calculations were performed as well as stress analysis. The most extensive stress analysis was performed on the flywheel shaft in terms of static and dynamic failure methods. The flywheel shaft was assumed to be the critical link of the system and therefore the most likely to fail.

Acknowledgements

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References: Borgnakke, Sonntag, Fundamentals of Thermodynamics, 6th Edition, John Wiley & Sons, Inc., NJ, 2009. Budynas, Nisbett, Shigley's Mechanical Engineering Design, 8th Edition, McGraw-Hill, NY, 2008. Pro-Engineer, Parametric Technology Corporation (2012) [computer software].