Diesel Engine Laboratory Report

Course: **Energy Conversion Lab**

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Introduction

In the Diesel Engine Lab, a diesel engine will be ran on a dynameter while data is collected to determine performance metrics. The purpose of this lab is to gain an understanding for how the diesel thermodynamic cycle is functions through studying the performance of an internal combustion engine. The engine will be ran at different speeds and recorded against engine torque output. Other engine diagnostics such as exhaust gas temperature will be recorded to calculate the efficiency of the engine. At the end of this lab, students will be able to utilize dyno plots and have a functional understanding of internal combustion engines.

Apparatus and Testing Procedures

Below is a view of the configuration used to collect data from the diesel engine module:

The procedure is as follows for data collection:

Connect the engine power supply. Check that the “EMERGENCY STOP” button is released. If it’s not released, pull the button until it clicks into place. Turn on the master switch. Ensure the air hose and exhaust hose are connected, with the outlet of the exhaust hose leading outdoors. Verify that the fuel line to the engine and the measuring tube on the CT 110 test stand are filled. Make sure the fuel valve for draining the measuring tube is closed. Turn on the “IGNITION” switch on the CT 110 test stand. Set the speed regulator to “START” and the speed adjusting knob for the asynchronous motor to approximately 5. Set the torque adjusting knob to a maximum torque of 10. Press the “IGNITION” button to start the engine. Turn on the asynchronous motor by pressing the green “Starter/Brake” button on the CT 110 test stand. Gradually reduce the speed until the engine runs steadily with the torque indicated on the CT 110 test stand at approximately 0. Allow the engine to warm up without load for approximately 5 minutes at idle speed. Use the fuel regulator button to top up the fuel. Allow the engine to warm up further before starting experiments. Record the readings for engine speed, torque, inlet air temperature, exhaust gases temperature, and time for 1 cm (about 0.39 in) of fuel consumption. Set the engine to a different speed and repeat the procedure. Reduce the speed using the engine rack. Adjust the speed of the engine using the speed regulator to about 50% of the maximum speed. Turn off the engine by switching off the "IGNITION" on the CT 110 test stand. Open the valve at the bottom to drain excess fuel back into the tank. Deactivate the engine test stand with the master switch. Set the speed regulator on the engine to the "STOP" position.

Theory

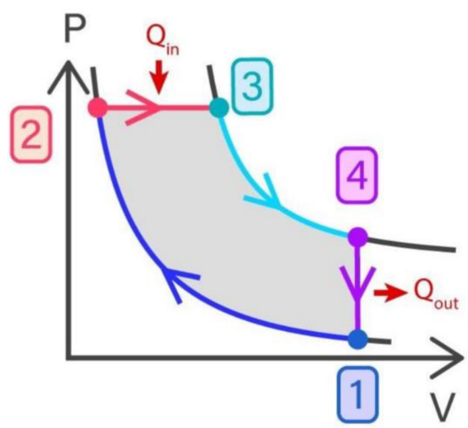
The diesel cycle is one of the most common thermodynamic cycles used for internal combustion engines. An ideal diesel cycle can be represented by four process as shown below:

1 – 2: Adiabatic compression

2 – 3: Constant pressure heat addition

3 – 4: Isentropic expansion

4 – 1: Constant volume heat rejection



Determining the power output and efficiency of the diesel engine begins with calculating the power as a function of torque and engine speed,

$$P = 2\pi NT$$

in which P is power, N is the engine's revolutions per minute, and T is the output torque recorded by the dynameter.

Next, the mass flow rate of fuel must be calculated as a basis for fuel economy. Fuel mass flow rate is represented as:

$$m = \frac{\rho_f V_f}{t}$$

where m is the fuel's mass flow rate, rho is the density of the fuel, V is the volume of fuel, and t is the time that the fuel was injected.

The specific fuel consumption is represented as the ratio of fuel used per unit of power output by the engine:

$$Specific\ Fuel\ Consumption\ = \frac{m}{P}$$

The thermal efficiency is ratio of heat generated in the engine from combustion vs the power output of the engine:

$$\eta_{th} = \frac{P}{Hf}$$

Where P is the engine power and H_f is the heat of combustion.

Data

The data below was collected across 6 different trials of the use of the diesel engine. The top 3 trials were given to us from previous years' experiments, and the bottom 3 were hand collected by our group using the software and manually from the diesel configuration.

Trial 1				Trial 2				Trial 3			
Engine speed (rpm)	Torque (Nm)	Exhaust air temperature (oF)	Time for 1 cm of fuel consumption (s)	Engine speed (rpm)	Torque (Nm)	Exhaust air temperature (oF)	Time for 1 cm of fuel consumption (s)	Engine speed (rpm)	Torque (Nm)	Exhaust air temperature (oF)	Time for 1 cm of fuel consumption (s)
2270	16.62	440	14	2268.555	16.4062	434.8075	13	2269.531	16.1816	440.2693	14
2477.5391	16.1621	496.8959	10	2477.051	15.8887	479.5061	12	2479.492	16.0547	483.9634	13
2684.082	15.957	494.8242	12	2689.453	15.5859	506.6267	11	2689.941	15.5762	513.344	11
2858.8867	14.7852	462.4302	13	2858.887	13.877	491.6853	10	2857.422	14.0234	503.2994	12
2977.0508	7.6758	352.1275	19	2977.539	5.127	327.3926	28	2976.563	4.6484	322.998	27

Trial 1				Trial 2				Trial 3			
Engine speed (rpm)	Torque (Nm)	Exhaust air temperature (OF)	Time for 1 cm of fuel consumption (s)	Engine speed (rpm)	Torque (Nm)	Exhaust air temperature (oF)	Time for 1 cm of fuel consumption (s)	Engine speed (rpm)	Torque (Nm)	Exhaust air temperature (oF)	Time for 1 cm of fuel consumption (s)
2128	16.67	473	15	2152	16.14	485	15	2269.531	16.1816	440.2693	14
2335	16.37	506	13.33	2354	15.62	506	13.6	2479.492	16.0547	483.9634	13
2531	15.14	533	12.77	2551	15.3	529	12.5	2689.941	15.5762	513.344	11
2741	15.21	547	12	2753	14.91	545	12	2857.422	14.0234	503.2994	12
2901	12.32	483	13.33	2913	12.25	485	11.7	2976.563	4.6484	322.998	27

The data below shows the averages of the collected data shown above and the calculations required by the procedure are also depicted to the right. Sample calculations are shown below for the first row of data and can be used to accurately quantify the thermal efficiency of the diesel engine at various engine speeds.

Averages									
Engine speed (rpm)	Torque (Nm)	Exhaust air temperature (oF)	Time for 1 cm of fuel consumption (s)	Speed	Power (W)	Power (kJ)	Fuel Flow Rate (kg/s)	Fuel Consumption (kg/Ws)	Thermal Efficiency
2183.177	16.33053	466.0897667	14.66666667	2	3731.622667	54.73046578	0.000272291	7.29685E-08	32.68115851
2389.497	16.0149	498.6544667	13.31	3	4005.338147	53.31105073	0.000300045	7.49113E-08	35.07832987
2590.647	15.33873	525.1146667	12.09	4	4159.165033	50.28430525	0.000330323	7.94204E-08	36.42552955
2783.807	14.71447	531.7664667	12	5	4287.381091	51.44857309	0.0003328	7.76231E-08	37.54843229
2930.188	9.739467	430.3326667	17.34333333	6	2987.025845	51.8049849	0.000230267	7.70891E-08	26.16005792

Sample Calculations:

Calculation for Engine Power:

$P = 2\pi NT$, where N is revolutions per second, and T is torque.

$$P = 2\pi NT = 2\pi\left(\frac{2183.117}{60}\right)(16.33) = 3731.622\text{W}$$

Calculating for the fuel mass flow rate:

$m = \frac{\rho_f V_f}{t}$, where p is the density, V is the volume, and "t" is time of fuel consumption.

$$m = \frac{\rho_f V_f}{t} = \frac{(832)(0.0000048)}{(14.6667)} = 0.000272291\ \frac{kg}{s}$$

Calculating for specific fuel consumption:

Specific Fuel Consumption= Fuel Mass Flow Rate/ Engine Power

Specific Fuel Consumption= $\frac{0.000292291}{3731.622}$= 7.2968e-8 kg/Ws

Calculating for Thermal Efficiency:

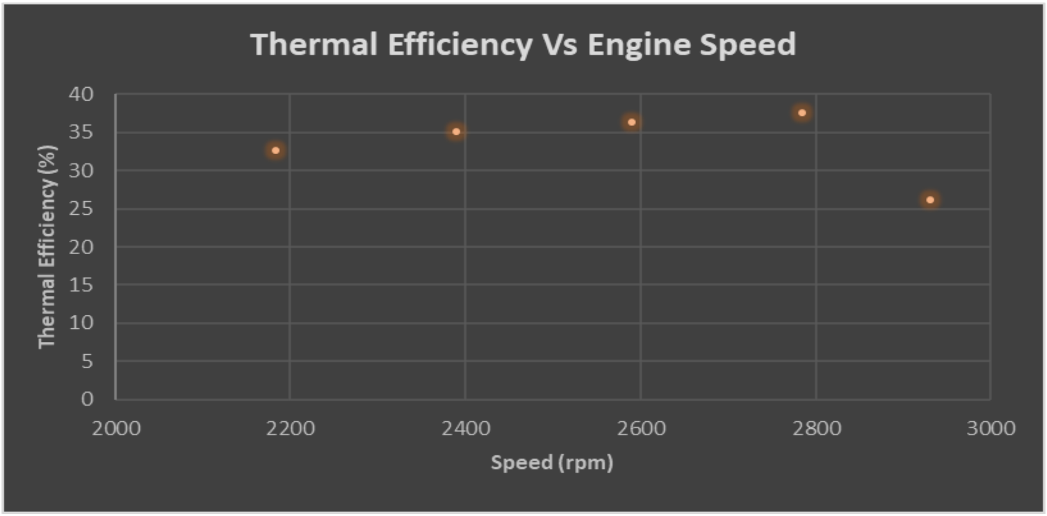
$$\eta_{th} = \frac{P}{hf} = \frac{54.73KJ}{(45.6)(0.000272291)(100000)} = 0.3268 = 32.68\%$$

The thermal efficiency of the system makes sense as the average expected thermal efficiency from the diesel cycle is expected to be between 25-40%. There are a few small sources of error that will be explained in the later sections of the lab.

Discussion

A) What variables affect the efficiency of a Diesel Engine?

Many scenarios can affect the thermal efficiency of diesel cycles. Within this experiment, the engine's speed, in revolutions per minute, the fuel flow rate and its direct connection to fuel consumption can greatly influence the efficiency of the diesel engine. As the engine's rpm increases, the graph below shows that the efficiency greatly increases before dropping back off as a certain engine speed is reached. The graph of the diesel engines thermal efficiency with respect to the engine speed is shown on the chart below:



This shows that at speeds under 2800rpm, the diesel motor generally increases in efficiency up until this point, and then a steep drops off occurs after this critical point. This proves that engine speed is the main factor in engine efficiency. In real life scenarios, it is also known that diesel engines output more power at lower rpms and lose power and efficiency at higher rpms and are used in high output powers at low rpms in most real-life applications.

B) Why do Heat Engines need to reject energy to the environment?

Heat engines necessitate the rejection of energy to the environment due to the second law of thermodynamics. This principle dictates that in any energy conversion process, some energy will inevitably be converted into a less useful form, typically heat. Heat engines, which transform heat energy into mechanical work, inherently experience inefficiencies in this conversion process. As they operate, they generate waste heat alongside useful mechanical work. If this waste heat is not expelled from the system, the engine would eventually overheat and cease to function efficiently. Therefore, to maintain operational efficiency and prevent overheating, heat engines must expel this waste heat into the environment. This process ensures the continuous cycle of energy conversion within the engine, allowing it to perform its intended function effectively.

C) Why is the thermal efficiency of the auto cycle higher than the Diesel engine? What is the reason for increasing the use of Diesel cycle instead of Otto cycle?

Conclusion

In this lab, a dynameter was used to determine the power and efficiency of a diesel engine. Data was collected to correlate other diagnostic engine parameters with performance. After analyzing multiple dyno runs, the power and efficiency of the engine ranged from 3000 – 4300 W and 26 – 38%, respectively. It was clear that as engine speed increased, power and efficiency increased until detrimental returns set in. The most effective operating conditions provided roughly 4300 W of power and 38% efficiency at 2784rpm. In conclusion, this lab provided hands on experience with a common thermodynamic cycle through the use of a diesel engine.