Spark Ignition Engine Lab

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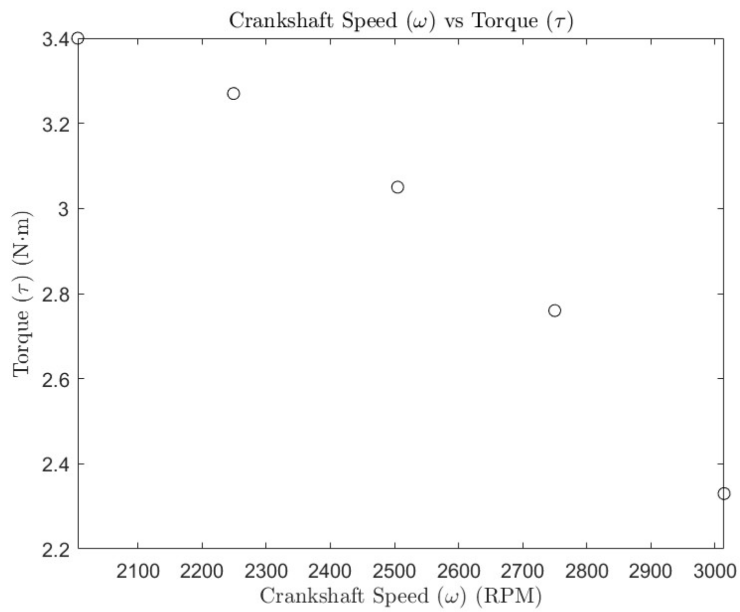

Figure 1a. Measured torque versus crankshaft speed for the spark ignition engine at fully open throttle.

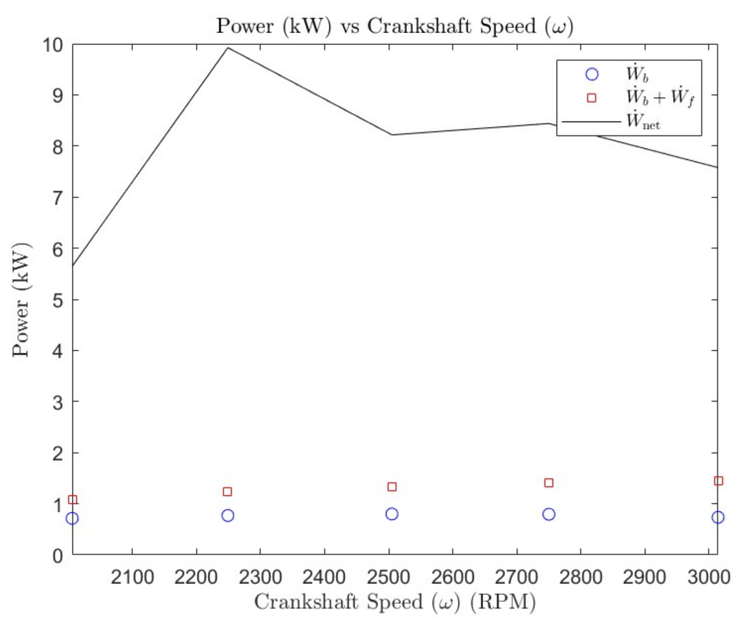

Figure 1b. Brake power and total power versus crankshaft speed for the spark ignition engine at full throttle. The markers indicate the experimental measurements. The black line represents the total theoretical power available, based on the Otto cycle using the air-standard model at the same conditions as those measured in the experiment.

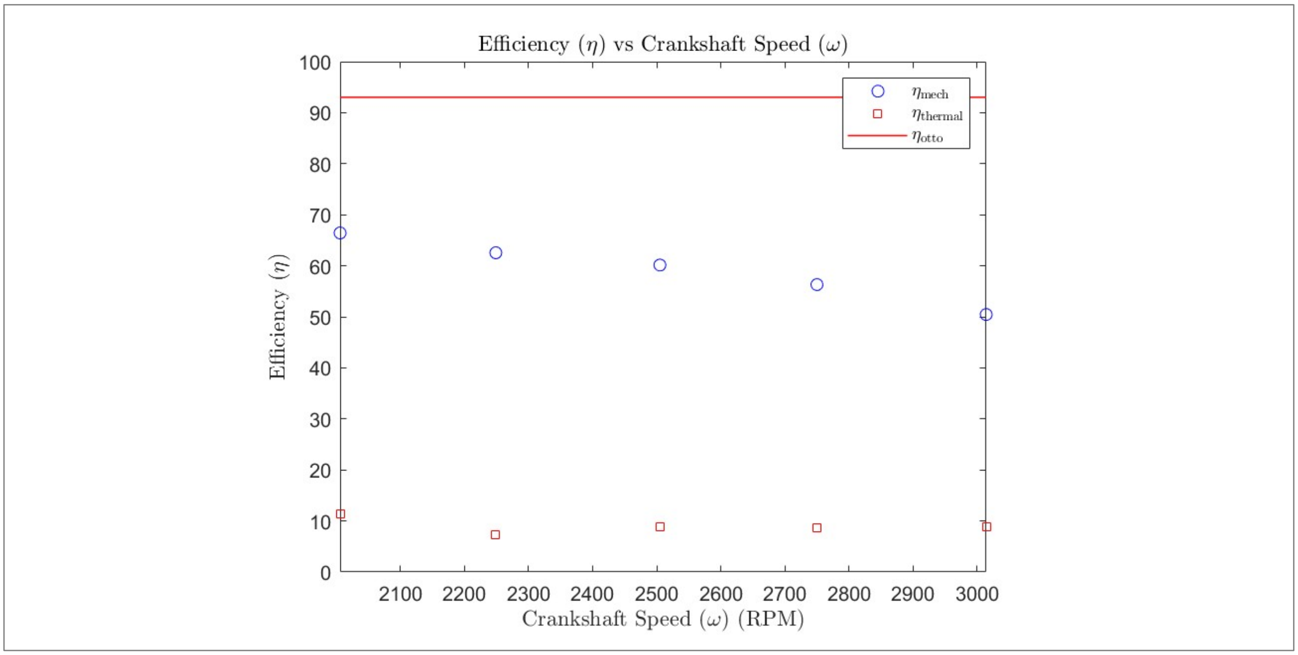

Figure 1c. Thermal efficiency versus crankshaft speed, comparing the measurements and theory. The theory is based on the Otto cycle using the air-standard model at the same conditions as those measured in the experiment.

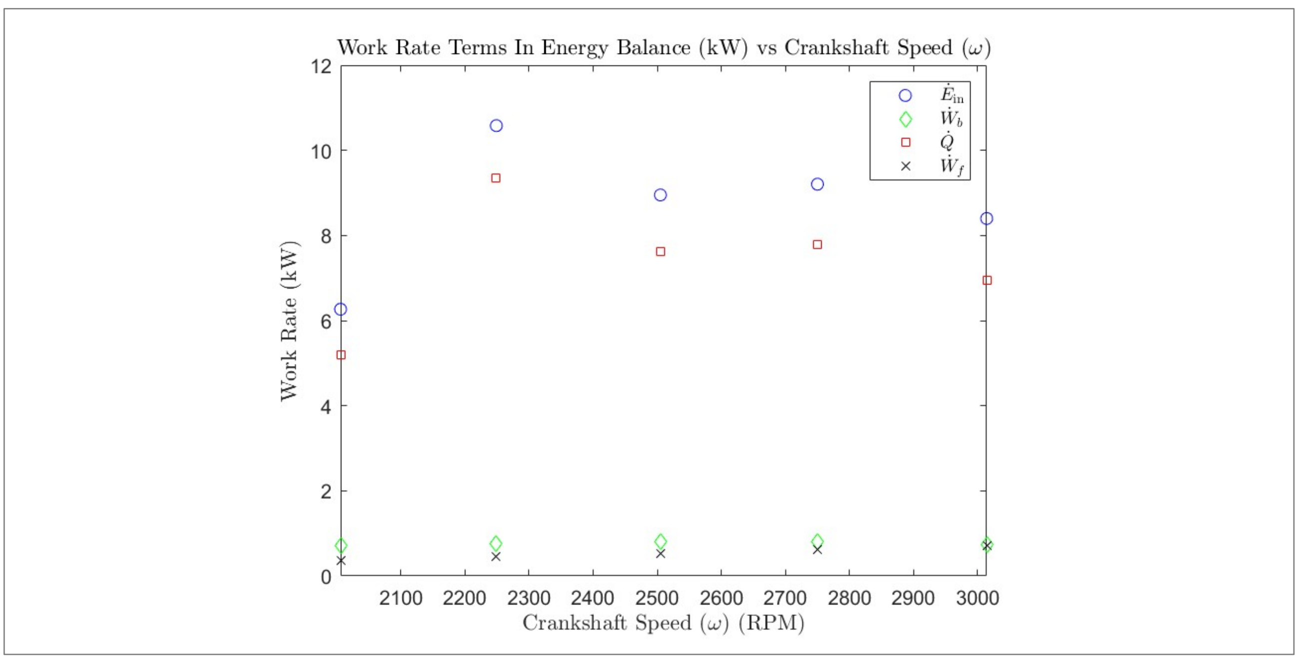

Figure 1d. Work rate terms in the energy balance of the engine versus crankshaft speed, as based on the experimental measurements.

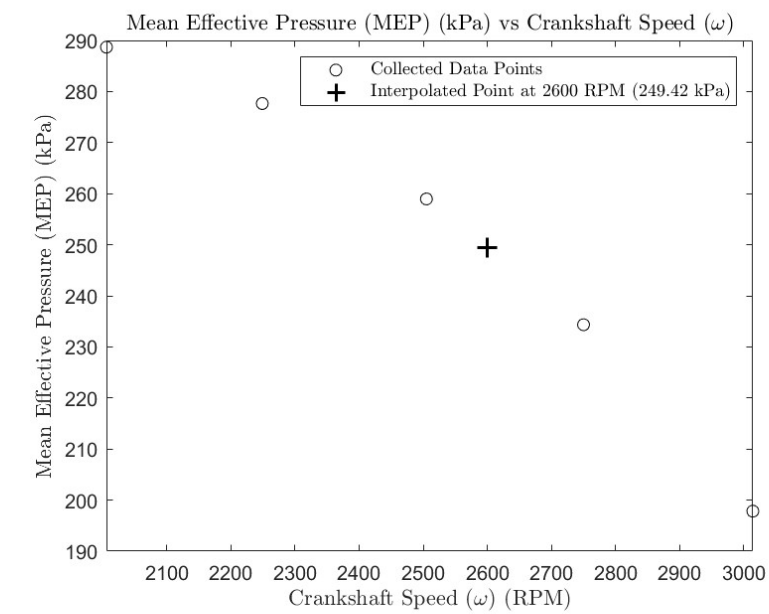

Figure 1e. Mean effective pressure acting on the piston head versus crankshaft speed, as based on the experimental measurements.

Short-Answer Questions

2a. *State the value of the following energy ratios (in terms of a percentage) averaged over the entire range of engine speeds examined: $\dot{W}_b/\dot{E}_{in}$, $\dot{W}_f/\dot{E}_{in}$, and $\dot{Q}/\dot{E}_{in}$. Discuss how the frictional/inertial loss compares to the miscellaneous heat lost to the surroundings, and how this affects the overall thermal efficiency of the engine. [2–4 sentences]*

From calculations, the energy ratios averaged over the entire range of engine speeds examined are: Wb/Ein = 9.0019%, Wf/Ein = 6.2682%, and Q/Ein = 84.7299%. In terms of how frictional/inertial loss compares to the miscellaneous heat lost, it is clear to see that the main loss of energy that the engine experiences is from the heat lost to the surroundings, and that a very small amount of energy (less than 20%), is lost due to frictional/inertial loss. This result also seems to match up with the analysis of thermal efficiency of the engine, 1c, where the approximate average efficiency shown is 9%, which is very low compared to the mechanical efficiency, which is, on average, 59.1784%.

2b. *Write one sentence for each of the items below related to engine efficiency. [3 sentences total]*

→ *State the average mechanical efficiency of the engine (averaged over the range of crankshaft speeds measured), and compare this value with the typical mechanical efficiency of an electric motor having an equivalent power rating (1–2 hp).*

→ *Write a statement that compares the calculated thermal efficiency with that of an ideal Otto cycle, by quantifying the discrepancy (ϵ) with a percentage, as follows*

$$\epsilon = \frac{\eta_{\text{Otto}} - \eta_{\text{th}}}{\eta_{\text{Otto}}} \cdot 100$$

→ *State three things that were neglected in the ideal model of the Otto cycle that might contribute to such a discrepancy.*

The average mechanical efficiency of the engine averaged over the range of the crankshaft speeds measured was approximately 59.178. According to the U.S. Department of Energy, an electrical motor having an equivalent power rating, and operating at a 100% load has an approximate maximum efficiency of ~85%. However, efficiency typically tends to decrease dramatically below about 50% load.

The calculated thermal efficiency (average over the different crankshaft speeds) was approximately 9.0019%, which resulted with a discrepancy of 90.3231% difference between the thermal efficiency and the ideal Otto cycle.

In the Otto cycle, there are multiple assumptions made, including that the air is the working fluid, and considered to be an ideal gas, the combustion process is replaced by a simple heat addition process, and the exhaust process is replaced by a simple heat rejection process. This means that the real world behavior that the engine exhibits might not be fully captured, and a lot of the losses are neglected in the ideal cycle that causes a greater theoretical efficiency than the real thermal efficiency.

2c. *Based on your calculations for the mean effective pressure (MEP), estimate the average force acting on the piston head during the cycle when the engine is operating at 2600 RPM. State your answer in units of both N and lbs. Include this calculation in your Matlab code and have the code display the result to the screen. [1 sentence]*

Based on the calculations for the mean effective pressure, the estimated MEP for an engine operating at 2600 RPM was 249.42 kPa. This results in an estimated average force that acts on the piston head during the cycle of approximately 830.2052 N, or 186.6376 lbs.

2d. *Carbon dioxide (CO_2), a greenhouse gas, is released into the environment from the exhaust of spark ignition engines. A diagram of the carbon lifecycle is shown below, illustrating how auto emissions tend to alter the natural balance by creating excessive carbon dioxide in the atmosphere. Spend some time to research (using the internet, textbooks, or other sources) solutions for reducing CO_2 gas emissions from combustion engines. For example, some technologies can help increase engine efficiency, thereby reducing CO_2 emissions. State one operation or hardware modification that could be implemented to improve the efficiency of a spark ignition engine, such as turbo-charging, inner cooling, split-fire spark plugs, variable valve timing, etc. Explain how this modification works to improve engine efficiency and describe some of the challenges associated with implementing this modification in practice. [4–6 sentences plus at least one reference]*

One hardware modification that can be implemented to improve the efficiency of a spark ignition engine would be turbo-charging. The way that turbo-charging an engine works is that a physical piece of hardware, a turbocharger, is added into the air-intake process. Turbochargers compresses the air flowing into a combustion engine, allowing the engine to squeeze more air into the cylinder, and by increasing the amount of air that can go within the cylinder before combustion, means more fuel that can be added. This results in more power from each individual explosion within the cylinder. This casues more power available to the combustion engine, resulting in more time between refuels. However, there are some issues with turbocharging an engine, including both physical and software limitations. With air being pumped into the cylinders, there is a danger of knocking, which is the phenomena when a compression ratio is high enough to alter the ignition temperature of the fuel, causing your fuel-air mixture to explode independelty without the spark ignition from the spark plug. This means that cars with turbochargers may need to run on higher octane fuel to avoid knocking. When it comes to software, modern vehicles rely on oxygen sensors in the exhaust to determine if the air-to-fuel ratio is right, and wthe cars system will automatically increase the fuel flow if a turbocharger is added. However, if a turbocharge that causes to omuch boost is added, the system may not provide enough fuel. That could be because the controller in charge might not be programmed to allow it, or the pump and injectors are not capable of supplying the required fuel flow. In either case, the modifications will have to either be reverted to make your old system compatible with changes, or the systems in charge of the other aspects of the fuel injection process will have to be modified.g

[1] K. Nice and K. Hall-Geisler, “How Turbochargers Work,” *HowStuffWorks*, Dec. 04, 2000. https://auto.howstuffworks.com/turbo.htm

[2] C. Woodford, “How do turbochargers work? | Who invented turbochargers?,” *Explain That Stuff*, Jun. 27, 2018. https://www.explainthatstuff.com/how-turbochargers-work.html