Project 2 Descriptions and Reporting

In project 2, you are calculating, using a computer software (e.g. matlab) the indicated and brake quantities of an engine from basic thermodynamic calculations. A skeleton matlab software is given and you have to complete the code to achieve the correct results.

The basic model implemented in the skeleton code is:

- multiple cylinder engine with all cylinders being identical, i.e. there is no thermal effect from the cylinder placement
- the intake system is modeled as a single pipe with an aspect ratio L/D equivalent to ~1000. That means that once all flow restrictions are taken into account (flow turning, area changes, filters, etc) the pressure drop in the intake system is equivalent to a smooth pipe 1000 diameters long.
- Square engine (B=L), though easily modifiable to a different aspect ratio
- Instantaneous heat release
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You are provided with some geometric and gas property functions:
$V(\theta), dV/d\theta, A(\theta), \mu_{air}(T), k_{air}(T), f_{darcy}$

The code that's implemented currently has ideal (instantaneous) combustion
As a comparison point, you can use a modified version of the problem of assignment 3, problem3. You can turn off all losses (heat loss, friction, etc) and run your code to check that your answers match.

Summary of Tasks

When submitting your report, include a pdf report with the answer to the specific questions of the different tasks as well as your matlab code (the .m files or equivalent if you are using a different software).

Task 1: Implement Finite Rate Heat Release Model (the Wiebe function)

Instead of adding heat instantly, you will be adding heat over a finite amount of time, equivalent to a finite amount of crank angle. For this you will make a few changes to the code in ice_diff.m to include the actual model and in integration_driver.m to change the limits of integration and replace the instantaneous heat addition. The theory is covered in Ferguson and Kirkpatrick, section 2.6.

i. The two variables theta_s and theta_d, representing, respectively, the angle value at which you start combustion and the duration of combustion are already implemented. As a starting point, use thetas = -20 and thetad = 40 . That is, combustion starts at an angle of -20 degrees and lasts 40 degrees. This is already implemented in driver.m so you can simply use the variables as is and use them in the routines. Note that both values are defined in degrees, which is a more human readable unit. There are 2 lines to convert to radians in driver.m.

ii. Instead of integrating the isentropic compression from $-\pi$ to 0, you will be integrating from $-\pi$ to θ_s .

iii. Integrate, instead of adding heat analytically, from θ_s to $(\theta_s+\theta_d)$.

iv. Instead of integrating expansion from 0to pi , integrate from $(\theta_s+\theta_d)$ to pi .

At this point, you are performing 3 integrations: $-\pi\rightarrow\theta_s\rightarrow\theta_s+\theta_d\rightarrow pi$. You are still integrating over a full circle, just in 3 sequential steps.

v. In the function you are integrating that defines the derivatives, add the Wiebe function. In other words, change your current pressure derivative $dP/d\theta=-kPV'(\theta)/V(\theta)$ and include the heat input term. Use the constants for a 4 stroke, SI engine given in Ferguson and Kirkpatrick. In the integration function, make sure to put an if statement to check the value of angle. Specifically, if (theta<thetas) set $\dot{Q}=0$, if ((theta >= thetas) and (theta < thetas+thetad), set $\dot{Q}$ to the heat released by combustion. If (theta >= thetas+thetad) set $\dot{Q}=0$ again.

Deliverable:

(a) Plot the P-v diagram with instantaneous combustion and with finite rate heat release.

(b) What is your maximum pressure in each case? Does the maximum pressure of the finite rate model agree with the maximum pressure of the ideal cycle?

Task 2: Implement heat losses

You can now add, in the function that calculates your derivatives, the process that calculates heat losses.

i. In your derivative function, implement the instantaneous heat transfer **Annand** correlation described in Ferguson and Kirkpatrick, section 8.5.

Run your code again and show in report:

(a) Plot the P-v diagram with and without the heat loss.

(b) What is the effect on the maximum pressure in the cycle?

Task 3: Implement pressure and pumping losses

Instead of modelling the movement of gas flow in and out of the engine, you will be assuming the pressure is constant throughout the exhaust and intake phases (although not equal), so the pump work part of the cycle is a rectangle. The pumping losses are calculated in driver.m.

i. Calculate the ideal valve diameters based on the theory presented in the course slides/videos.

ii. Calculate the pressure drop in the intake from prior knowledge from your Fluid Mechanics/Fluid Dynamics courses. Recall the use of the Darcy friction factor: $\Delta P = f(\epsilon/D, \mathrm{Re})(1/2)\rho V_{\mathrm{intake}}^2 L/D$. You can assume the flow in the intake is fully turbulent, which allows you to compute the friction factor *f* from a formula instead of looking it up on a graph. The Haaland formula is usually a good one and a function is provided. You can assume the correlation 6.43 for the exhaust system (with the pressure drop of 40 kPa at WOT).

iii. Calculate the pressure drop through the intake manifold, and intake and exhaust valves (see Ferguson and KirkPatrick)

iv. Calculate the pmep

Include in report: What are your calculated values of valve diameters, what is the total pmep at the single condition $N = 4000\,\mathrm{RPM}$?

Task 4: Implement friction losses

Instead of assuming a constant mechanical efficiency, calculate friction losses as a function of the engine geometry and RPM. Calculate those losses as MEP losses for the piston skirt, the piston rings and the piston gas loading (described in Ferguson and Kirkpatrick section 6.6 and following).

Include in report: What are your calculated values of fmep at the single condition N=4000 RPM?

Task 5: Calculate the brake parameters

The skeleton code calculates the basic indicated and brake properties: work, torque, power and some components of MEP. Augment the code (you will have to find where, it is not indicated in the skeleton) to calculate:

- isfc and bsfc
- mechanical efficiency

Include in report: Report your isfc, bsfc and mechanical efficiency at N = 4000 RPM.

Task 6: Vary the crank speed *N* to obtain the torque and power curve

Now that you have implemented all the models required in this project, you can calculate the properties at different values of *N*. You could do this by hand, i.e. run your script several times and write the answers on a piece of paper, but it's actually a better idea to make matlab do that. Your skeleton code is already set up to vary the RPM in the driver. You can select the start, stop and number of points of RPM to calculate.

Include in report:

(a) plot the torque and power curve in the range $N = 500 \rightarrow 5000\ \text{RPM}$. Do these curves make sense physically?

(b) extend the range of RPM to cover $N = 500 \rightarrow 6000$. What do you observe? Can you explain the behaviour? What in the model do you think is wrong?

Task 7: Discuss the behaviour of engines

You now have a partial model that, while not complete, can reproduce basic behaviours of a 4 stroke ICE. **Consider the following questions and answer in your report:**

(a) What is the effect of changing the spark timing, θ_s ,on the engine performance? For this model, is there a single, best value of spark timing? [Hint: explore small changes of spark timing first, say in the range $\theta_s \in (-30, -10)$. Extend the range so combustion starts very early before TDC and after TDC. How do the P-V curves look? How sensitive is the engine behaviour to spark timing?

(b) What is the effect of changing the combustion duration, θ_d, on the engine parameters? Do you think it is possible to consider the combustion duration as a parameter you can control?

(c) What is the effect of the valve sizing on the behaviour of your model? What happens if you make the intake/exhaust valves bigger or smaller? [Hint: again, explore small changes at first, maybe 10% changes in the sizes.)

(d) Is there one other interesting parameter in your model you can discuss? What is its effect on the engine performance?