Michigan Tech
MEEM/EE 4295: Introduction to Propulsion Systems for Hybrid Electric Drive Vehicles

HW_7
Topics: IC Engine Sizing, IC Engine Fuel Usage.
Due November 27th, 20102

There two types of questions for HW-7. HW-7 and HW-8 have “stand-alone” Matlab and Simulink portions. The “stand-alone” portions should allow you to debug the models without introducing errors from other Subsystems.

Question 1 will introduce you to the basic IC engine parameters, selecting an engine size for a given torque or power requirement and approximations of the fuel usage at the given requirements.

Question 2 will introduce you to the fuel maps of an actual IC engine. You will be given the data of fuel flow (grams/second) versus engine torque and engine speed. The data is given in the Matlab script. With the engine data, you will be able to determine the fuel usage for an actual drive cycle. Also provided is a Simulink model you will utilize to start Question 2. Since the goal of Question 2 is to gain an understanding of the impact of the **drive cycle** and **drivetrain parameters** on the fuel usage, a “suggested” Simulink model is provided with a Subsystem to determine the tractive force with the given parameters without consideration of braking, traction limits or regeneration constraints. They are NOT needed for this portion of HW-7. They will be utilized in HW-9 & 10.

Question 1: Questions 1a or 1b may be solved with “hand calculations,” Matlab, Simulink, Mathematica or Maple. It is your choice. Show the work and list assumptions.

1a) Design a four cylinder spark ignition engine with the following conditions

Your last name starts with	BMEP at max torque (kPa)	Torque Required (N-M)	Omega at T_{max} (rpm)
A-G	900	400	4,100
H-P	950	425	3,750
Q-Z	1,000	450	3,900

Use a B/L ratio of $0.9 \leq B/L \leq 1.1$ and an increment of 0.1 or less.

The maximum piston speed range is 8≤ $\bar{S}_P \leq 15$ m/sec

You should determine the following parameters

Results		Units
Bore		mm
Stroke		mm
Maximum Brake Power		kW and hp
Speed at Maximum Brake Power		rpm
Engine Displacement		Liters and cubic inches
$\bar{S}_P$		m/s

1b) Design a compression ignition engine with the following conditions

Your last name starts with	BMEP at max torque (kPa)	Power Required kW
A-G	700	250
H-P	725	300
Q-Z	740	350

The maximum piston speed range is 8≤ $\bar{S}_P \leq 10$ m/sec

Use a B/L ratio of 0.9≤B/L≤1.1

You should determine the following parameters

Results		Units
Bore		mm
Stroke		mm
Number of cylinders		
Speed at Maximum Brake Power		rpm
Engine Displacement		Liters and cubic inches
$\bar{S}_P$		m/s
Brake Torque at max speed		N-m
Fuel flow rate, $\dot{m}_f$		kg/h and gallons/h

<u>Question 2:</u> In Question 2, you will utilize the subsystem, FT_Model_HW_7 to determine the tractive force for a given drive cycle and then the fuel flow for the particular drive cycle. Notice that it **IS NOT** utilizing the LVD we developed in class nor should it use the LVD and our previously developed Driver Controller, E-Drive, Brake or Battery Subsystem from previous homework assignments. Those will be utilized in HW-9 &10 once we develop the IC Engine Subsystem. The Simulink model is shown below.

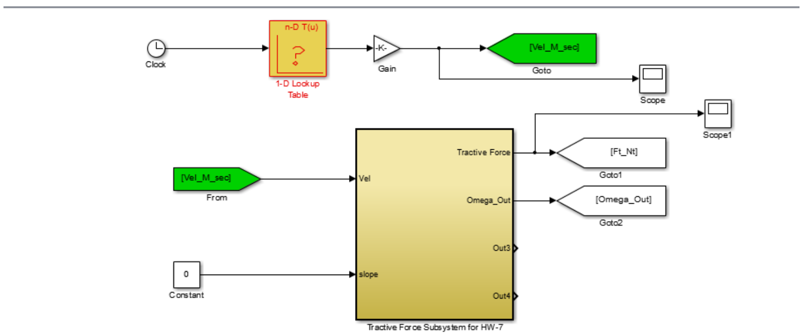

Figure 1: The Tractive Force Model for HW-7

Inside the Subsystem, the drive cycle velocity is used to determine the acceleration and the tractive force needed plus the angular velocity of the wheel. The subsystem is shown below.

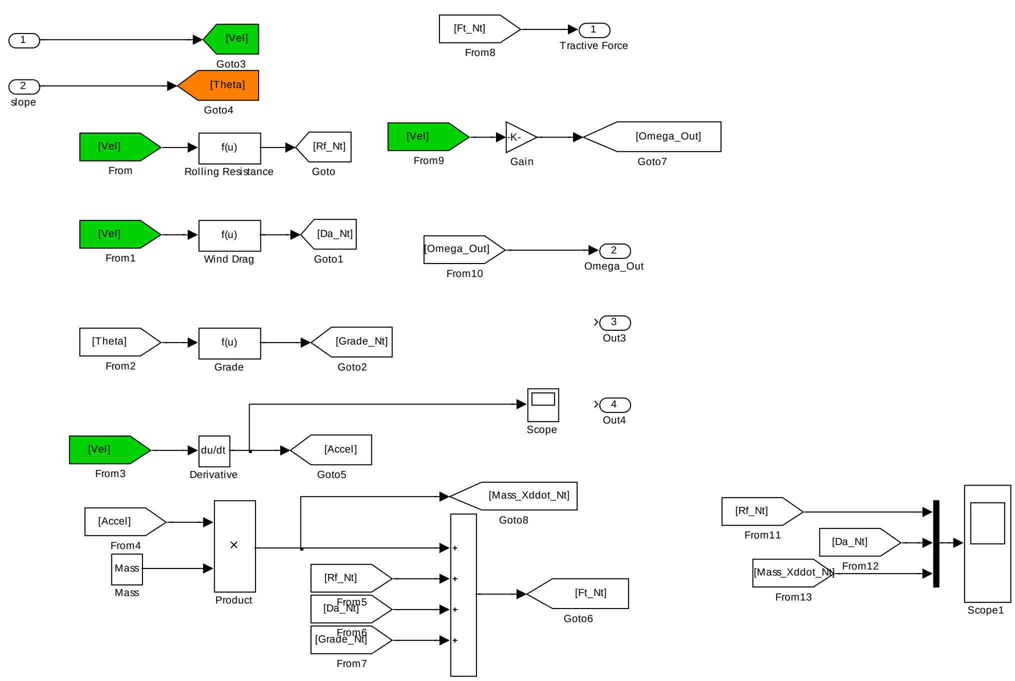

Figure 2: The subsystem to determine the tractive force neglecting weight distribution, etc. .

With the given subsystems, do the following for Question 2.
1) Design the IC Engine Subsystem **similar** to the one shown below. You will not need the engine stop or battery SOC for inputs to the Subsystem. The engine diagnostics output is optional. The "raw data" is supplied in a Matlab file and will be used to develop your "new" IC Engine Subsystem.

2) All that is provided to the class is the method to determine the tractive force and the angular velocity of the wheel for a given drive cycle. You need to add a method to determine the engine speed and the engine torque required for EACH possible gear ratio. With that information, it is possible to determine the fuel flow for each possible gear ratio.

3) Determine the instantaneous fuel flow rate and the total fuel used for each gear ratio over the given drive cycle.

Here are several items to consider.

a) For negative values of Ft, the engine is not providing power, but is still operating and using fuel, use the minimum value for the flow.

b) For speeds of the engine below the IC engine minimum, we DO NOT have a clutch or torque convertor, therefore assume we have some other method to provide the tractive force so DO NOT use the fuel flow in this range.

c) Design the IC Engine Subsystem so you may utilize it in the remaining HW. For HW-7 , we are just determining "fuel economy" without all the other control issues that can easily plague the students. You will probably need to spend considerable time getting the data given into the proper 2-D table format.

d) The input values (Weight, wheel radius, etc) in the Matlab code should be changed to the appropriate values.

e) There is ONLY one engine provided for the problem.

f) Use the first 1000 seconds of the drive cycle.

g) **THE MOST IMPORTANT POINT. Check the Simulink model and drive cycle to insure they initially work and do this ASAP!!!!!**

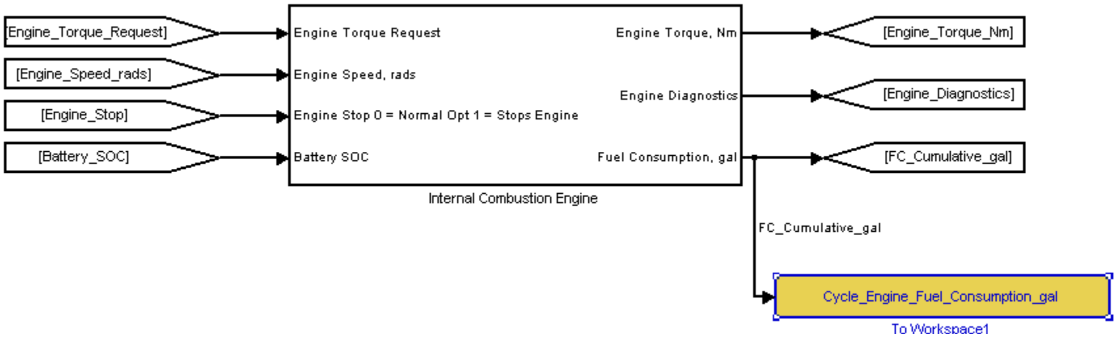

Figure 3: The Internal Combustion Engine Subsystem with the input/outputs.

Your last name starts with	1st	2nd	3rd	4th	Differential Ratio	Other information
A-G	2.2/1	1.64/1	1.28/1	1.0/1	3.73/1	Muncie “rock crusher” Transmission
H-L	2.56/1	1.91/1	1.48/1	1.0/1	3.55/1	Muncie Transmission
M-P	3.42/1	2.14/1	1.45/1	1.03/1	3.82/1	Compact car
Q-Z	2.78/1	1.93/1	1.36/1	1.0/1	3.25/1	Ford “top loader”

Table 1: Transmission and final drive (differential) ratios.

Your last name starts with	Weight, Newton	Area, meters^2	Tire Radius, meters	Cd	Wheelbase, Meters L=variable	Front/Rear Weight Ratio	L/H Ratio H=height to cg.
A-G	18,680	2.40	0.318	0.44	2.89	52.0	3.71
H-L	18,680	2.45	0.318	0.44	2.89	52.0	3.71
M-P	13,400	2.10	0.303	0.38	2.61	51.5	3.93
Q-Z	18,460	2.37	0.355	0.42	2.91	52.1	3.69

Table 2: Vehicle Parameters

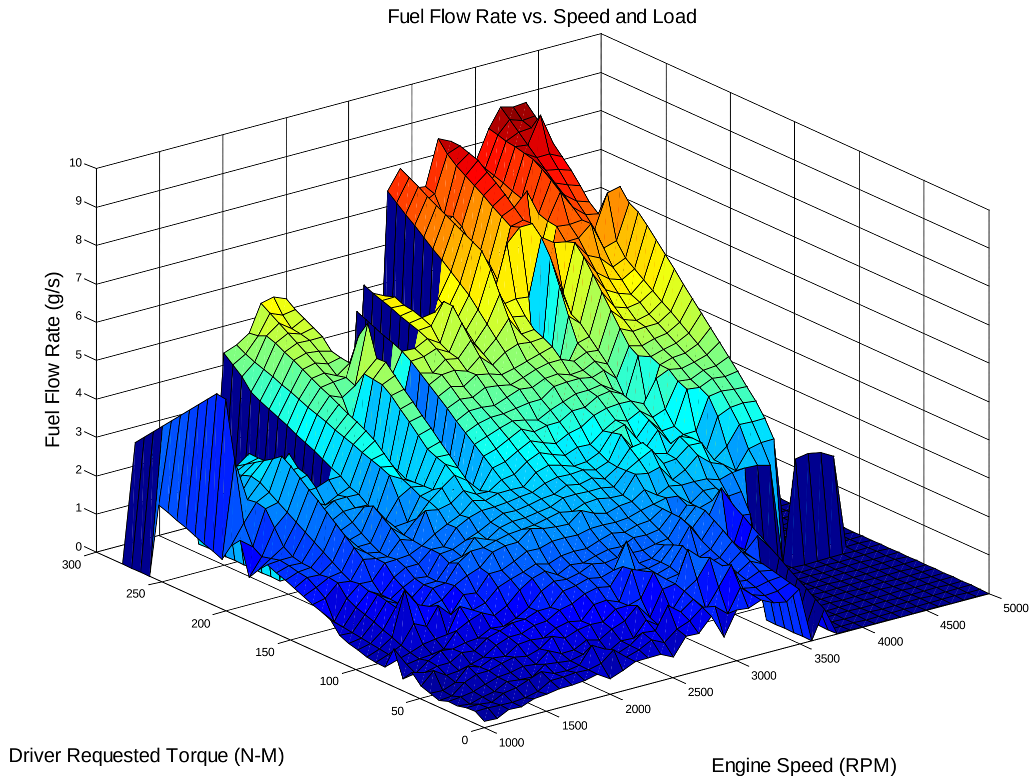

Figure 4: Fuel flow rate for a similar IC engine utilizing engine test data in format shown in .