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

**HW_3**
**Topics: Performance Modeling, ODE Solutions, Introduction to Shift Criteria and Torque Modeling.**

<u>WOT performance and vehicle modeling, engine torque, power, and power flow through the transmissions to wheels.</u>

In the previous homeworks, a drive cycle was provided and various forces were determined independent of a vehicles' ability to meet the drive cycle. In this homework, a math model will be developed to predict the performance of a vehicle (position, velocity and acceleration) as a function of time and implemented in Matlab. Using a polynomial to approximate the IC engine torque, the 2$^{nd}$ order, non-linear ODE (with changing coefficients) defining the linear vehicle dynamics is numerically integrated to predict the performance from a given powertrain considering gear ratio, weight distribution, road friction, gear and transmission ratios.

Using the vehicle model (Basic FBD's) developed in class, develop the model to do the following.

1) Determine the position and velocity for a real vehicle operating under WOT conditions for the CVT and for a finite ratio transmission. Develop your own Euler[1] integration code, implement in Matlab.
2) Integrate the second order, non-linear differential equation that describes the acceleration of the vehicle based on rolling resistance, wind drag and road slope for these two cases.
    a. The CVT with 100% efficiency.
    b. The finite ratio transmission, $\eta_t$ =0.97 per gear sets. For this particular type of transmission it is 3 sets. It would be 3 sets even if it were a 6 speed.
3) Develop the shift logic for the above code, add to the model
4) Optimize your gear ratios for a three speed at the minimum, we will add a six speed at later date. Use a 3.08 $N_D$.

Plot the velocity and position of the vehicle similar to the lecture examples. Be sure to include the maximum tractive force on the plots (horizontal line).

Assumptions/Givens

1) Use a 2$^{nd}$ order polynomial for the torque curve. Fit a curve to the data shown in Figure 1. This engine is for an example to be used for fitting a torque curve, not to represent a

[1] This is one of the "least accurate" integration methods, however it will demonstrate the methods used later in Simulink and should produce a solution within 1% of the actual values.

modern engine. The engine shown is the Ford, Flathead V-8[2]. You may use another example of a modern engine if you choose. The GM, LNF is a “torquey” 4 cylinder engine capable of 400+hp with simple modifications. The EcoTec engine can be “rodded” to exceed 1,200 hp. For the Ford folks, try the Zetech engine family.

2) Use the gear ratios given and then compare them to your optimized ratios. You may optimize the ratios by “trial and error,” however Chapter 2 has details on how to select ratios.

1st=2.1
2nd=1.5
3rd=1.0

[2] The Ford Flathead V8 was introduced in 1932 and was the first modern V8 with a continuous cast block. The famous (or infamous) bank robbers “Bonnie and Clyde” preferred stealing this platform over all others. John Dillinger was known to steal Fords.

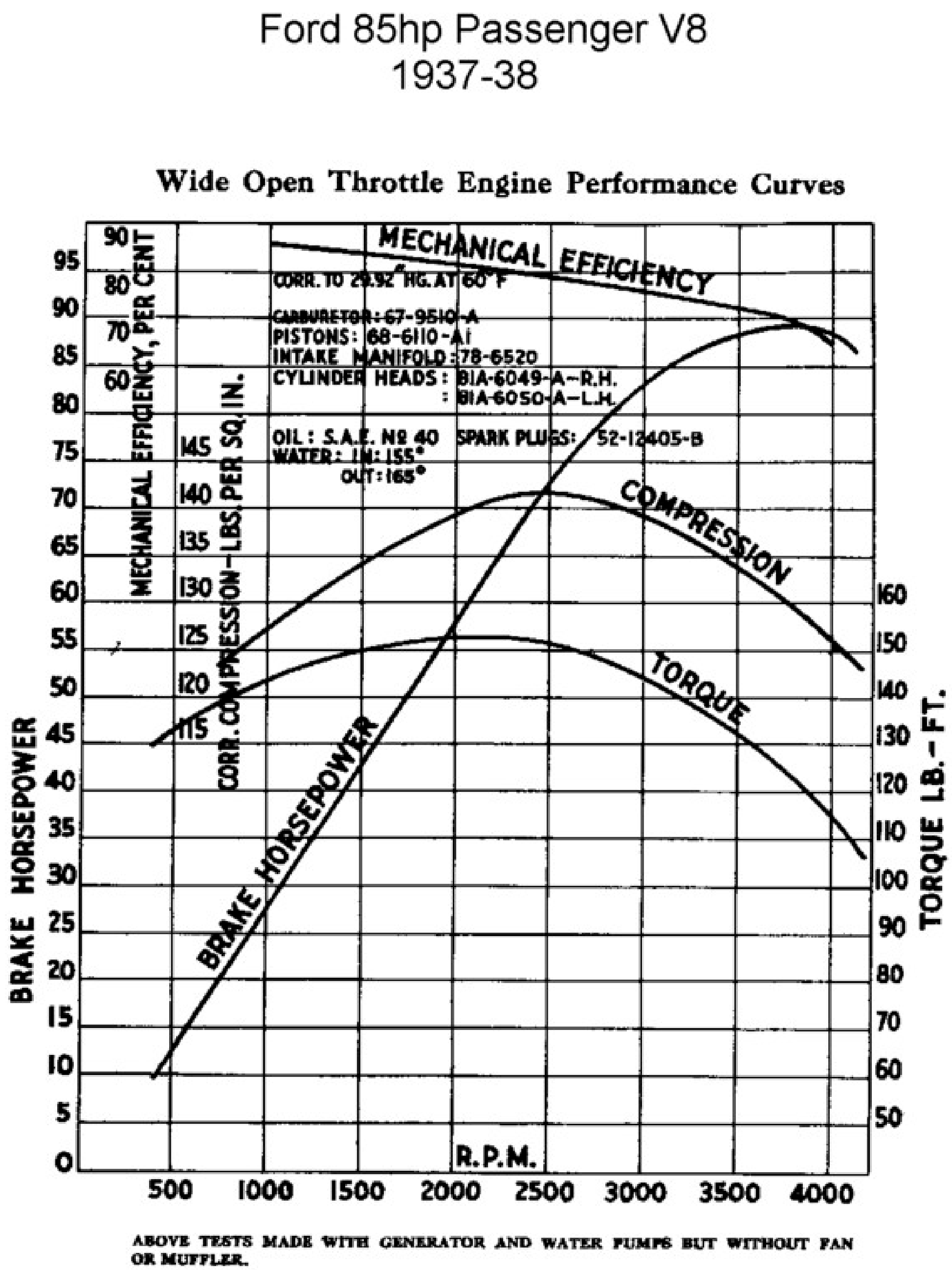


**Figure 1: Basic Flathead V-8, for simple model. Definitely not a modern engine.**

## Vehicle Data

Table 2:

| Item | Value | Units | Values, all SI units |
|---|---|---|---|
| Weight | 3,776 | Lbf | |

| | | | |
|---|---|---|---|
| ρ | 0.00236 | $Lbf\text{-}sec^2/Ft^4$ | |
| g | 32.17 | $Ft/sec^2$ | |
| $C_d$ | 0.4 | Unit less | |
| A | 2.7 | $meters^2$ | |
| θ | 0 | degrees | |
| Wheel radius | 0.56 | meters | |
| Wheel base | 2.86 | meters | |
| Weight distribution | 52/48 | Front/Rear | |
| h, height to cg from road | 0.5 | meters | |

## Shift Criteria for Finite Ratio Transmission

The primary criteria for your shifting "decision tree" simply put is "am I better off in the next gear than this gear?" In Figure 2, a poorly designed finite gear ratio transmission performance curve is shown in addition to the constant power curve for a CVT. The peak power is 83.2 hp at 4,801 rpm, 2nd order curve fit for the torque. The Flathead Ford V-8 is slightly better than the engine used to generate this plot.

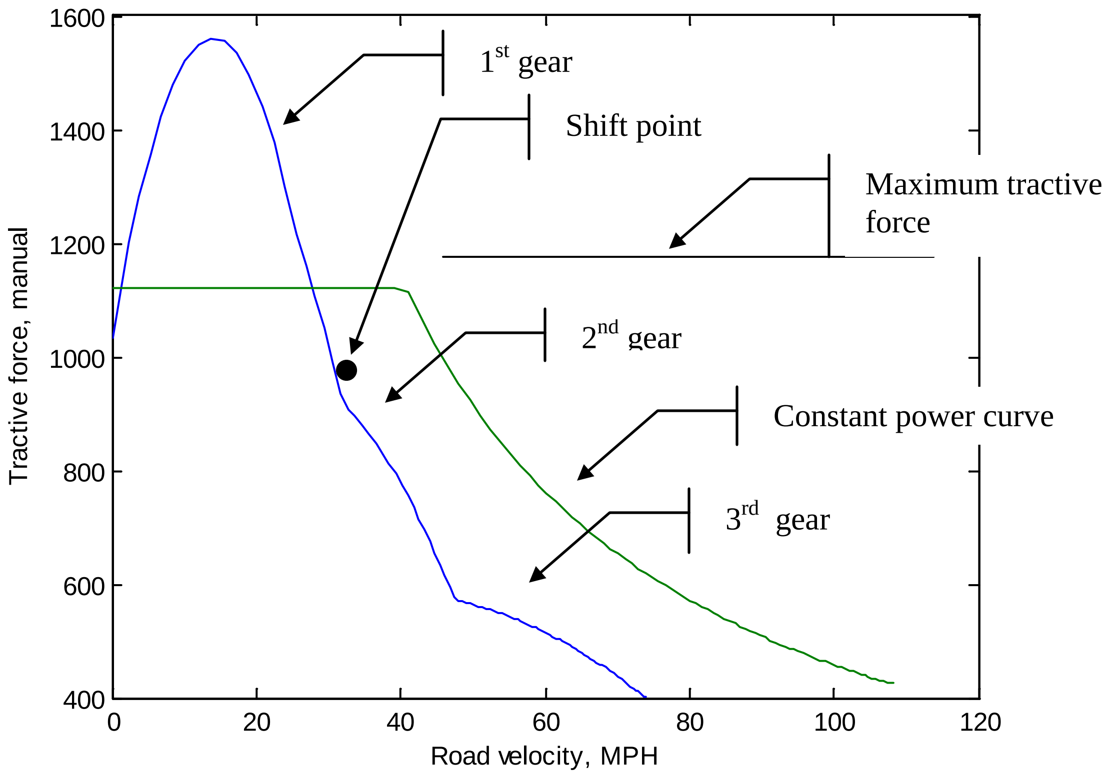


Figure 2: Velocity versus available tractive force, WOT.

Review of the Basic Assumptions for WOT Model

1) Write the speed of the vehicle as a function of $\omega_e$, tire radius, gear ratios and differential ratio.
2) Use the speed to determine the gear that provides the maximum tractive force.
3) Shift the gears.
    - ❑ Assume instantaneous change in engine speed @ shifts.
    - ❑ Assume tire radius stays constant.
    - ❑ Assume a one speed differential

- ❑ Let $N_t(i)$ define the speed ratio between the engine and transmission output.
- ❑ Let $N_D$ define the differential ratio, normally use numbers such 411, 273, 308
- ❑ Overall mechanical efficiency of $\eta_t$, constant, approx=0.97 per pair.