Physics Lecture 10 - Using the Virtual Race to Make Design Decisions

Summary/Conclusions

The virtual race program is a sophisticated model that simulates a gravity driven vehicle of any size or type in a Windows environment. With only modest help, some Cub Scouts are designing and testing a virtual car in just a few hours. Previous lectures have covered the most important car and track parameters so we should be now be able to understand and use the VR effectively for design. What we shall do as an application example is look at the MAXI-L car body available in the Hodges Hobby shop. The question is will streamlining this body, which will require moving the *CM* forward slightly, still pay off in improved speed? Before we answer this question, we will review the 12 car parameters required as VR input.

Car Parameters

Below we will list the 12 parameters and their values for a typical PWD car which is based on the SBF body shown in Lecture 3. Units are cgs.

NK = Number of wheels touching = 3
IC = Moment of Inertia of car body around its CM = 2000 (only used if ramp inclined plane makes abrupt angle with horizontal run - very rare track)
I = Moment of Inertia of a wheel = 5.123 (Lecture 5)
AW = Proj area of a wheel = 2.96
AB = Proj area of body = **7.43**
CW = Drag coeff area of a wheel = 0.50
CB = Drag coeff of body = **0.42**
M = Weight of Body + Wheels = **141.75**
RW = Radius of a wheel = 1.515
RA = Radius of an axle = 0.113
MU = Coefficient of wheel/axle friction = 0.10
CM = Center of mass re body center = **4.24**

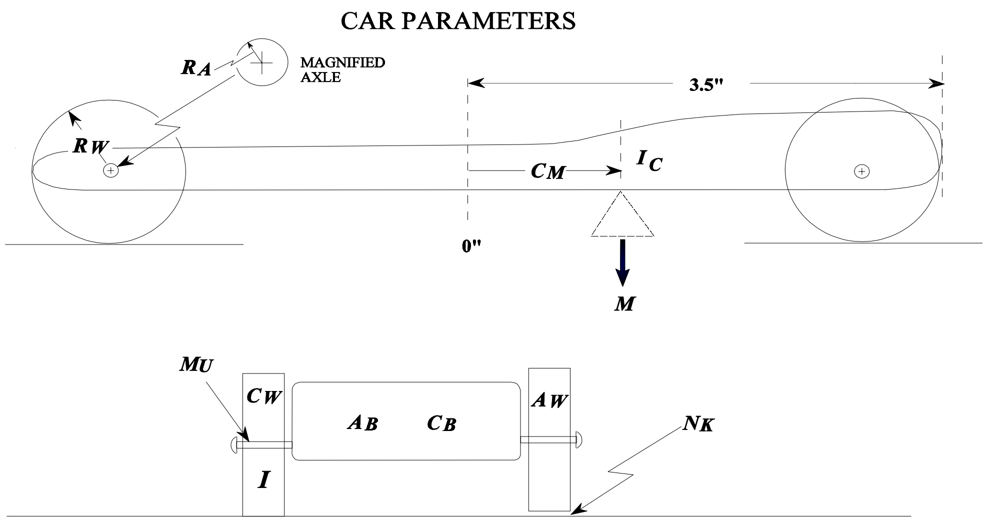

Figure 1 - *Showing 12 measurable car parameters that affect its overall performance.*

Making the Design Change

Figure 2 at the bottom shows a Hodges MAXI-L body with the lead holes placed all the way back. Its nose has been rounded. Another Hodges style body has the weight holes farther removed from the rear allowing room for the rear to be tapered in an airfoil shape. Making a body like this, and also sanding the height down some, we get the Test body at the top of **Figure 2**. It has a height of 0.508" while the MAXI-L's is 0.769"

Multiplying by the 1.75" width and converting to cm^2, the projected areas *AB* for the Test body and MAXI-L are 5.730 and 8.637 respectively. Installing Standard 1999 kit wheels and axles the lead is trimmed for M = 140.0 grams (4.94 oz) weight each, allowing for body putty and paint.

The center of mass (*CM*) is found by balancing as in **Figure 1** and we get 1.450" = 3.683 cm back from the body center for the MAXI-L and 1.235" = 3.137 cm for the Test body. Referring to **Figure 1** in Lecture 8 we see that the streamlined airfoil type design of the Test body eliminates the rear vacuum drag giving *CB* = 0.24. This drag is still present in the MAXI-L for a *CB* = 0.42.

Figure 2 - *The Hodges MAXI_L body at the bottom and a streamlined Test body at the top.*

Building the Virtual Cars

This is pretty easy. Open an existing editable car file like the SBF car whose parameters are the values in red print given earlier. The SBF car has Standard wheel/axle parameters so we only need to update the 4 bold and underlined red data. When this is done, rename the car as in **Figure 2** top entries and click save to create the car.

Finally, lets spend 30 seconds and build 2 more virtual cars, one by sanding down MAXI-L to the same height as TEST body and saving it as MAXI-L(5.730) and the other by moving the CM of MAXI-L(5.730) forward to match TEST body's CM position and calling this 4th car MAXI-L(5.730)(3.137).

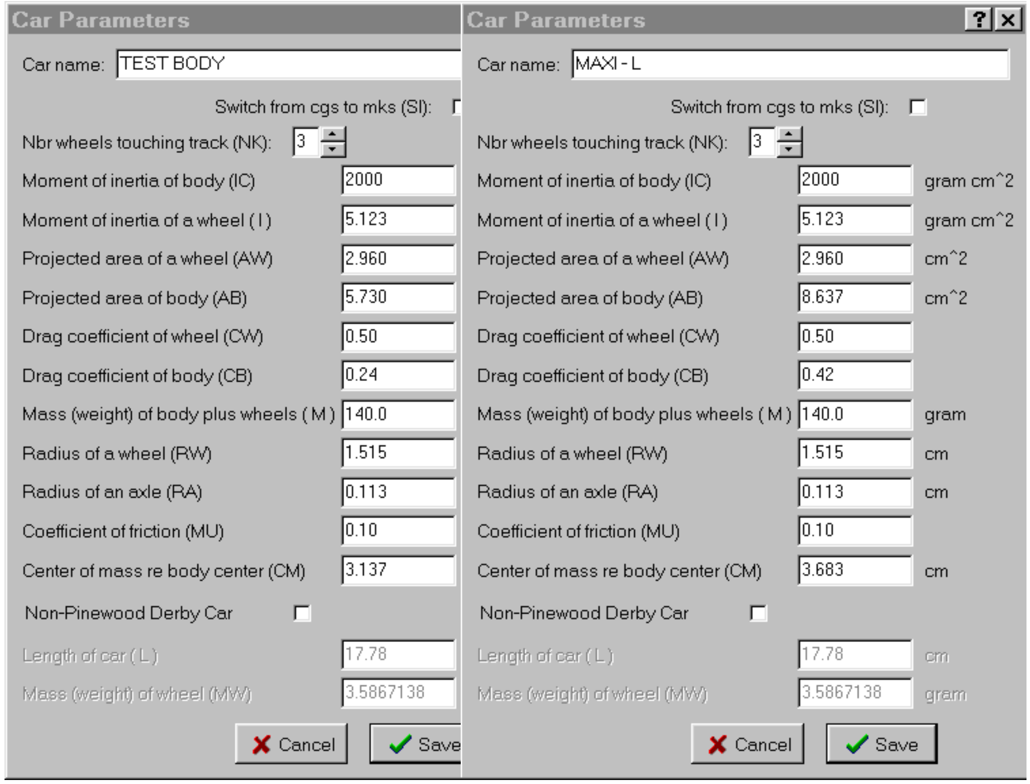

Figure 2 - *Showing the VR car create/edit screens.*

Running the Virtual Race

Choose a track from the 6 Standard tracks listed. A good one to start with is the StdTrk_HOUSTON_C-BT. The HOUSTON means is uses the local Houston *g* force and air density. This track has a circular are ramp (16' - 7") and a horizontal run (16' - 3'). The net drop height = 47". The BT means the timer is set to trip on the front bumper and not the car CM. Select [Race Group of Cars] tab and you will see on the left all the cars in your main car file. Put a check next to the 4 cars we just built for the ones selected to race. Now we race by clicking on [Go] to get the results in **Figure 3**. Then select the inclined plane ramp StdTrk_HOUSTON_I_BT which has identical track dimensions to the circular arc ramp (except length down the inclined plane ramp is about 2" less). Click [Go] to get the results shown in **Figure 4.**

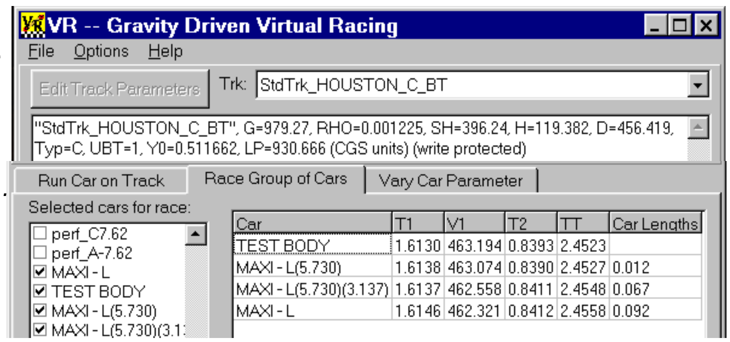

Figure 3 - *Race results for the standard circular arc ramped track.*

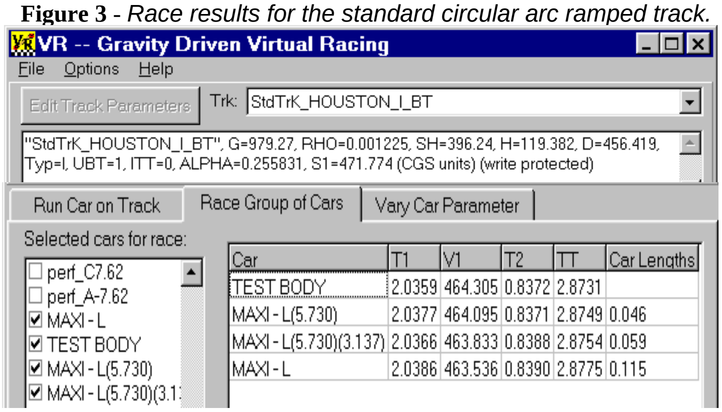

Figure 4 - *Race results for the standard inclined ramped track.*

Discussion of Results

The TEST body car won on both tracks and MAX-L(5.730) was within about an axle width (0.012 car lengths) on the C_BT track. Thus with *AB* the same, the lower drag coefficient of the TEST body was almost canceled out by the farther back CM of MAX-L(5.730). On the I_BT track, the CM was not as effective in improving speed (see lecture 7) and so the TEST body car did about 4 times better at 0.046 car lengths = 5/16". Move the CM of the MAXI-L forward as in MAXI-L(5.730)(3.137) and you see you come in 3rd place with the largest relative effect being on the C_BT track. Finally, the 4th car which is MAXI-L with also a larger *AB* than TEST car, comes in last place with finish differences as shown in **Figures 3 and 4.** So it could be concluded that the slight advantage of TEST body streamlining could be retained and perhaps added to other subtle design changes to make an overall significant effect. Now these are perfect races, with no time repeatability noise introduced by uncontrollable effects such as a variable center strip bumping. Nevertheless, good designs and lubrication strategy reduce such extraneous effects, and races close to perfect are occasionally observed. Also, over a long term repeated average, the theoretical perfect race time is the actual average time that is approached.