Comparing Tire Data

Comparing the force and moment characteristics of two sets of tire data is an important task. It is important for tire manufacturers and also for vehicle dynamicists. Differences between the sets of data could include:

- Constructions
- Compounds
- Rim widths
- Inflation pressure
- Tires made in different batches
- Any other change that might make a difference

Simple comparisons usually focus on directly comparing the force and moment response of the tire. Comparisons like "which tire can generate more lateral force" fall into this category. This type of comparison is useful, but does not give you the whole picture. Comparing more complex quantities which cannot be directly measured, but are rather calculated, can give you a better understanding of the differences.

In this tech tip, we're going to compare two tires – we'll simply call them Tire A and Tire B. The data we'll use was collected at Calspan by the FSAE TTC (Tire Testing Consortium). We will start by doing the simple comparisons, then move on to more complex comparisons.

We can start the comparison process by creating a new project in OptimumT. We will create two *Tire Items*. These are the way that you organize a project in OptimumT. The *Tire Item* allows you to store information about the tire size, construction, manufacturing batch, test conditions and many other pieces of information. Any number of data files and tire models can be associated with each *Tire Item*. Since we're comparing two tires, we're going to create two *Tire Items*. We're going to import cornering data collected for each tire using the Import Wizard. This wizard allows us easily specify the format of the file (see Figure 1).

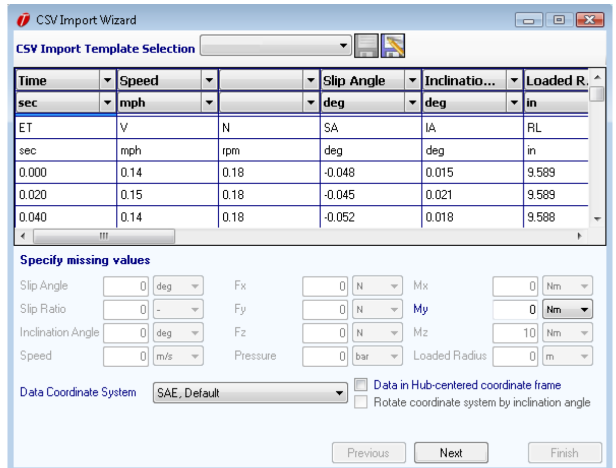

Figure 1: *Import Wizard*

Once we have imported the raw data, we can easily view it. A lateral force versus slip angle graph for Tire A is shown in Figure 2.

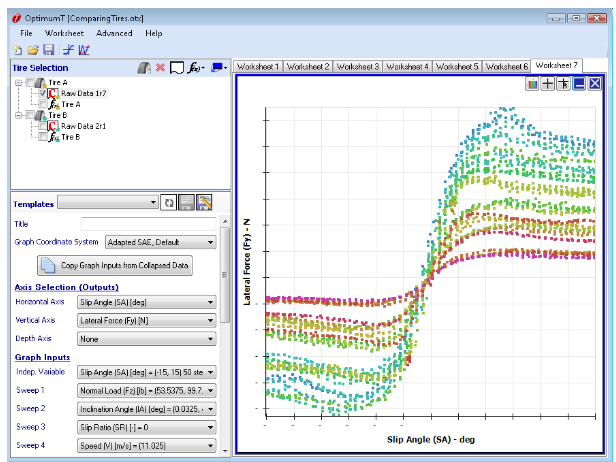

Figure 2: *Raw tire data (Tire A)*

It is often useful to fit a tire model to the data – even if we won't do any simulation work. Comparing two tire models instead of directly comparing the raw data allows us to more easily see differences – the model removes the experimental noise and test hysteresis inherent in the raw data. Fitting a tire model is a relatively simple task using OptimumT's Model Fitting Tool. For this example, we will fit Pacejka Magic Formula '96 models for both tires. For more information about this, please see the OptimumT documentation.

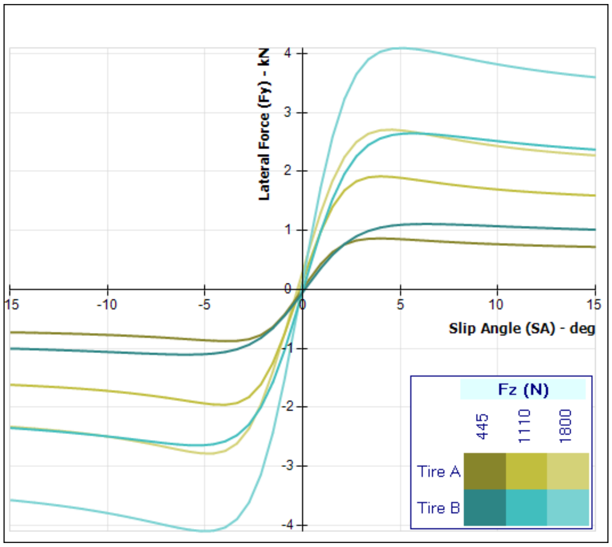

Figure 3: *Lateral Force vs. Slip Angle for two tires at three vertical loads. The curves are colored according to both the tire used and also the vertical load.*

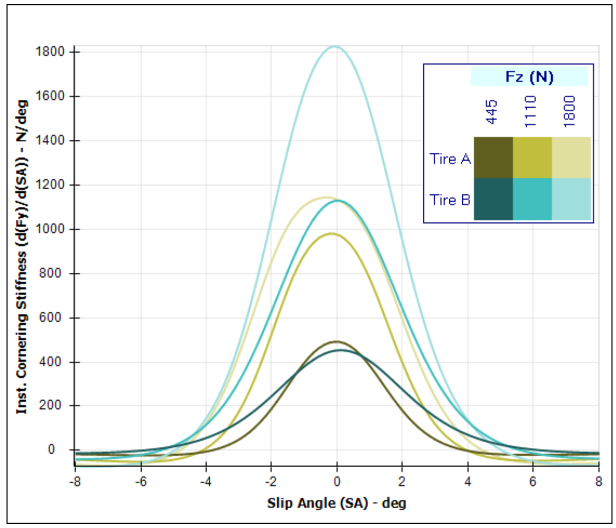

Figure 4: *Instantaneous cornering stiffness versus slip angle for two tires at three loads.*

Simple Comparisons

When looking at the lateral tire characteristics, the simplest comparison that we can do is overlaying the lateral force versus slip angle plots for the two tires (Figure 3). To aid in understanding a graph, OptimumT has powerful coloring functionality. In this case, we have colored the two models differently. The different vertical loads displayed are also colored differently to allow easy identification.

From this graph, we see right away that Tire B (blue) has much more grip than Tire A (yellow). It also appears that at low loads, Tire A has a higher initial cornering stiffness than Tire B, and this trend is reversed at high loads. We will quantify this later when we plot the instantaneous cornering stiffness. Furthermore, it appears that Tire A reaches its maximum lateral force at a lower slip angle. We will quantify this later as well.

More Advanced Comparisons

While looking at the simple force and moment characteristics of two tires is useful, the best use of OptimumT is to look at more complex quantities.

Earlier, we noticed apparent differences in the cornering stiffness of the two tires. We can use OptimumT to plot the Instantaneous Cornering Stiffness versus slip angle (Figure 4). This is the instantaneous slope of the lateral force versus slip angle curve ($\partial F_y/\partial\alpha$). By looking at this graph, we see that our initial observation was correct. At the lightest load displayed, Tire A has a cornering stiffness ($\partial F_y/\partial\alpha$ when $\alpha = 0$) of $492N/^o$ while Tire B has cornering stiffness of $451N/^o$. At the highest load, this trend is reversed. At the highest load, Tire B has a cornering stiffness that is over 50% greater than that of Tire A.

What we can gain from this graph goes far beyond the initial cornering stiffness, though. We see that at low loads, the instantaneous cornering stiffness of Tire A falls off a lot more sharply. This means that at low loads, Tire A will be more controllable but less responsive. The shape of the instantaneous cornering stiffness curves is similar for the two tires at the two highest loads.

We can also look at the cornering stiffness coefficient. This is defined as the cornering stiffness (at zero slip angle) divided by the vertical load. We plot this against normal load for three different camber angles in Figure 5. We can see from this graph that Tire B's cornering stiffness is roughly proportional to the vertical load. Tire A's cornering stiffness varies

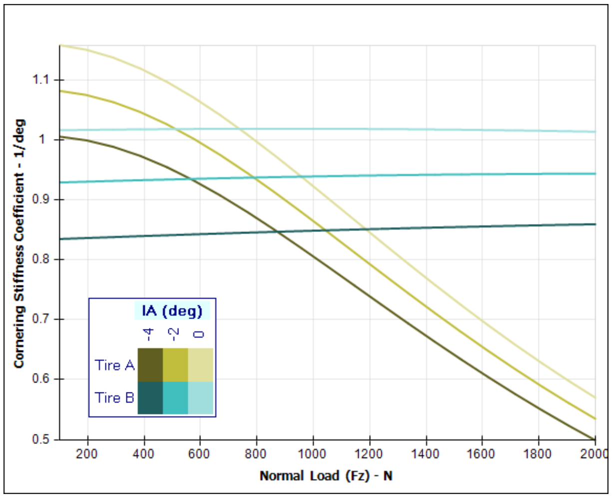

Figure 5: *Cornering stiffness coefficient*

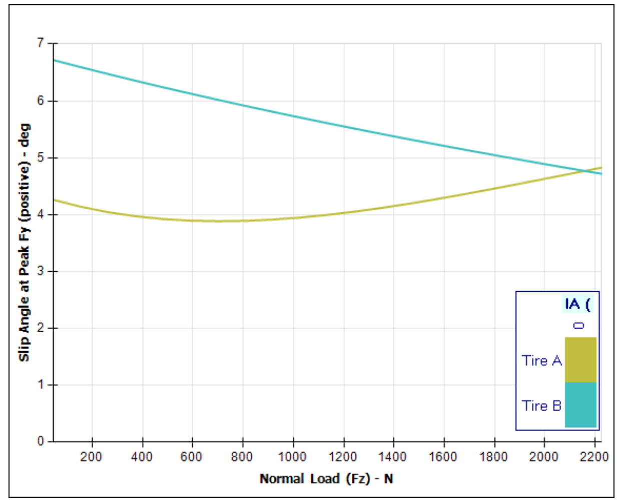

Figure 6: *Slip angle at peak lateral force for two tires*

less than linearly with load. In simple terms, if the load is doubled, the cornering stiffness of Tire B will roughly doubled, while Tire A's cornering stiffness will not increase nearly as much. This can give us insight about how the tire will affect the handing of a car.

Another difference that we saw when looking at the Figure 3 was that Tire A appeared to reach its peak lateral force at a lower slip angle. We can use OptimumT to quantify this. We can plot Slip Angle at Peak Fy versus vertical load. See figure 6. From this graph, we see that at very low loads, Tire A reaches its peak lateral force at nearly 2.5^o less slip angle than Tire B. At nearly $2200N$ vertical load, the slip angle at peak lateral force is equal. The difference in the slip angle at the peak lateral force has an effect on the wear of the tire, the power consumption when cornering and also the rate at which the tire builds temperature.

Let's take a look at the camber response of the two tires since this is an important factor in how the tire behaves on a car. We're going to plot the Instantaneous Camber Stiffness ($\partial F_y/\partial\gamma$) against slip angle for three loads for the two tires. This is shown in Figure 7. In this graph, the instantaneous camber stiffness is evaluated at 0^o inclination angle. This graph tells us how much of a change in the lateral force will result when the camber is changed. As an example, if $\partial F_y/\partial\gamma = 0$, then changing camber would have no effect on the lateral force; if $\partial F_y/\partial\gamma = 100N/^o$, then changing the camber by 1^o would increase the lateral force by approximately $100N$.

Right away we notice one thing: Tire B has almost no response to camber when the slip angle is above about 4^o. As we saw before, the slip angle at the peak lateral force for this tire varies between about 6.5^o and 4.5^o, so the peak lateral force for Tire B does not depend strongly on camber. Tire A has a much stronger camber response at all slip angles. This is important information to have, especially when choosing camber curves for the car that this tire is fitted to and also when choosing the caster and KPI angles.

Finally, we're going to look at the coefficient of friction of the two tires. In OptimumT, the coefficient of friction is defined as the peak lateral force, neglecting the camber thrust, divided by the vertical load. We remove the camber thrust so that the coefficient of friction is independent of the sign of the slip angle. We can create a graph of the coefficient of friction versus the vertical load for the two tires. This is shown in Figure 8. This graph tells us about the load sensitivity of the tire. The more horizontal the curves are, the less load sensitivity the tire has. Here we see that Tire A has more load sensitivity (the line is steeper). This means that a change in the anti-roll stiffness of one axle will have a greater effect on a vehicle with Tire A than on one with Tire

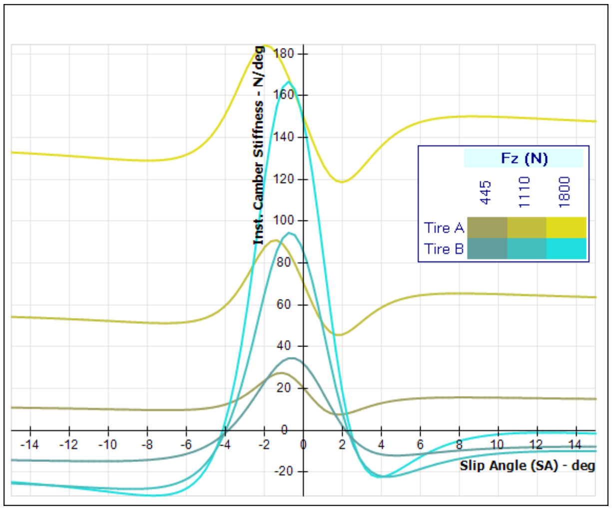

Figure 7: *Instantaneous camber stiffness of two tires at three loads (the inclination angle is zero degrees)*

B. This graph also gives an alternative representation of the observation that we made earlier: that Tire B has more grip than Tire A.

This tech tip only gives a brief example of what can be done when comparing the lateral characteristics of two tires. Similar analysis can be done to compare the longitudinal characteristics as well as the combined characteristics.

If you have any questions about OptimumT or any of OptimumG's other products and services, please email engineering@optimumg.com. Also, don't forget to visit `www.optimumg.com`

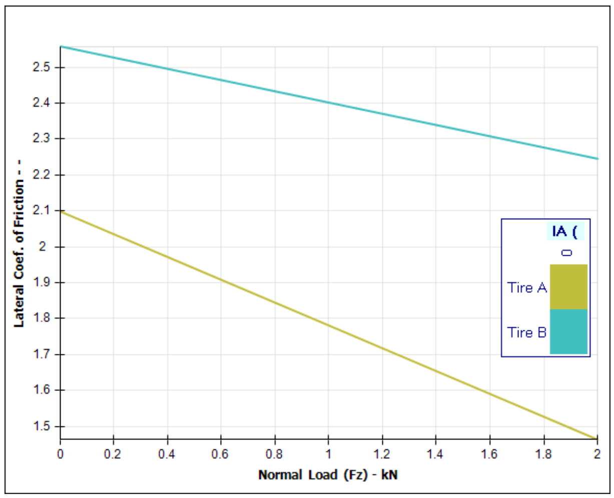

Figure 8: *Coefficient of friction for two tires.*