The ChassisSim approach to lap time simulation – What makes us unique.

One of the most often asked questions we at ChassisSim get, is what makes us unique. After all, isn't ChassisSim just another lap time simulation and motorsport simulation package?

What makes ChassisSim unique is that we use a fully transient multi body vehicle dynamic engine for everything, including lap time simulation. This is what separates ChassisSim from its contemporaries and as we are about to see it is a critical distinction.

To put this into perspective let's review the industry standard for lap time simulation, pseudo or quasi static simulation. This approach to simulation has it's origins in the d'Alembert equilibrium assumption. This approach is illustrated below,

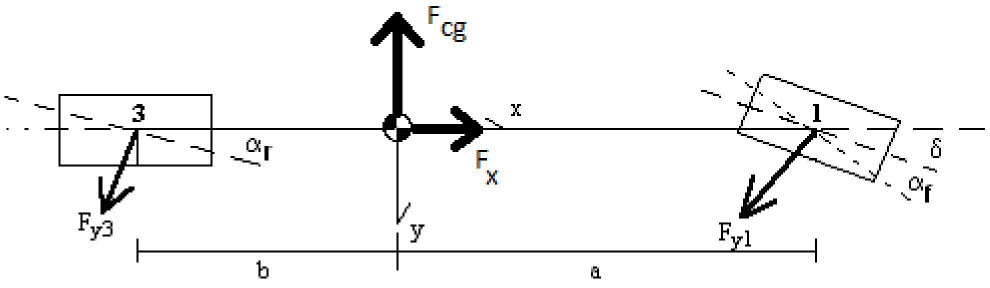

Fig-1 – An Illustration of d'Alembert equilibrium

As you can see with our bicycle model what we want is for all the forces to balance out. This way all the forces and moments add up to zero which reduces it to a static case so that we can deal with it easily. Consequently at the centre of gravity we place a force equal and opposite to the way we are going. This is given by,

$$F_{c.g} = \frac{m_t \cdot V_x^{2}}{R} \qquad (1)$$

Where,

$F_{c.g}$ = Force applied at the centre of gravity (N).
m_t = Total car mass (kg)
R = Radius of the corner (m)

The d'Alembert is an excellent first step in starting to understand transient and dynamic behaviour. The advantages of this approach are,

- It's an excellent tool for structural analysis.

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- It gives the engineer an excellent method for doing hand calculations to approximate tyre forces and other vehicle dynamics behaviour.

What pseudo static lap time simulation does is to extend this method by taking a number of different snapshots of the car around the lap and using this to figure out how fast we are going to go. Think of it applying what we just saw illustrated in Fig-1 but extended for many different points along the lap. We then piece the whole lap together. This results in a simulated lap that will look something like this,

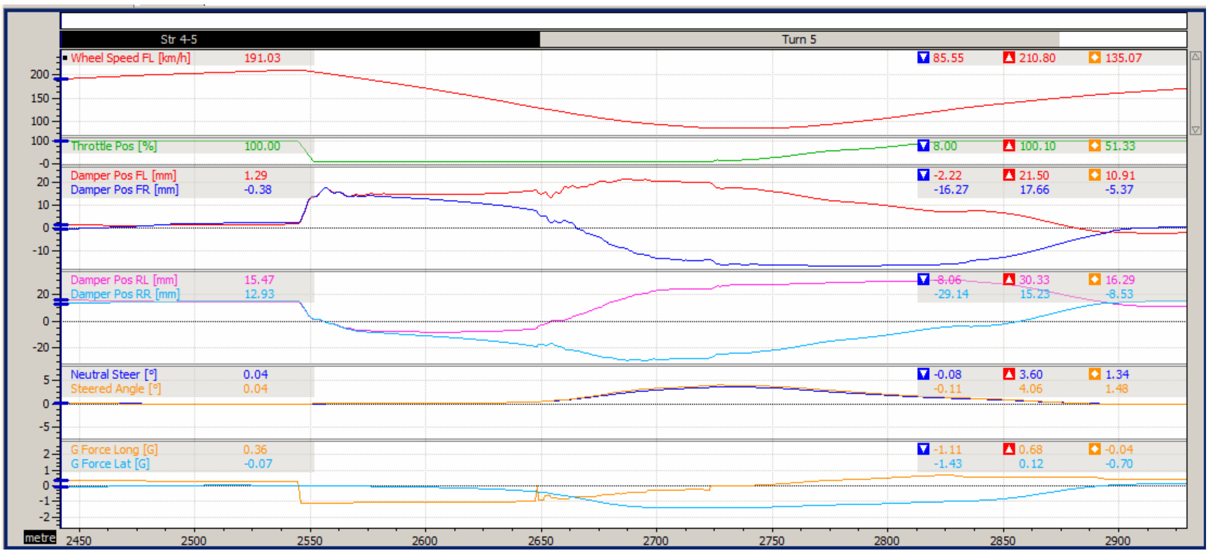

Fig-2 – An example of what to expect from pseudo static lap time simulation

As we can see the damper traces are all changing slowly from point to point so it gives us a good approximation of what to expect from our race car. This method does the following very well,

- Since it is static it executes quickly.
- Does a good job of looking at Wings.
- Good for looking at gear ratios.

To consider the interactions of different setup variables, pseudo-static lap time simulation is a good start point. But is it the complete story?

Let's have a look at some actual data of a car going through a corner. This is illustrated below,

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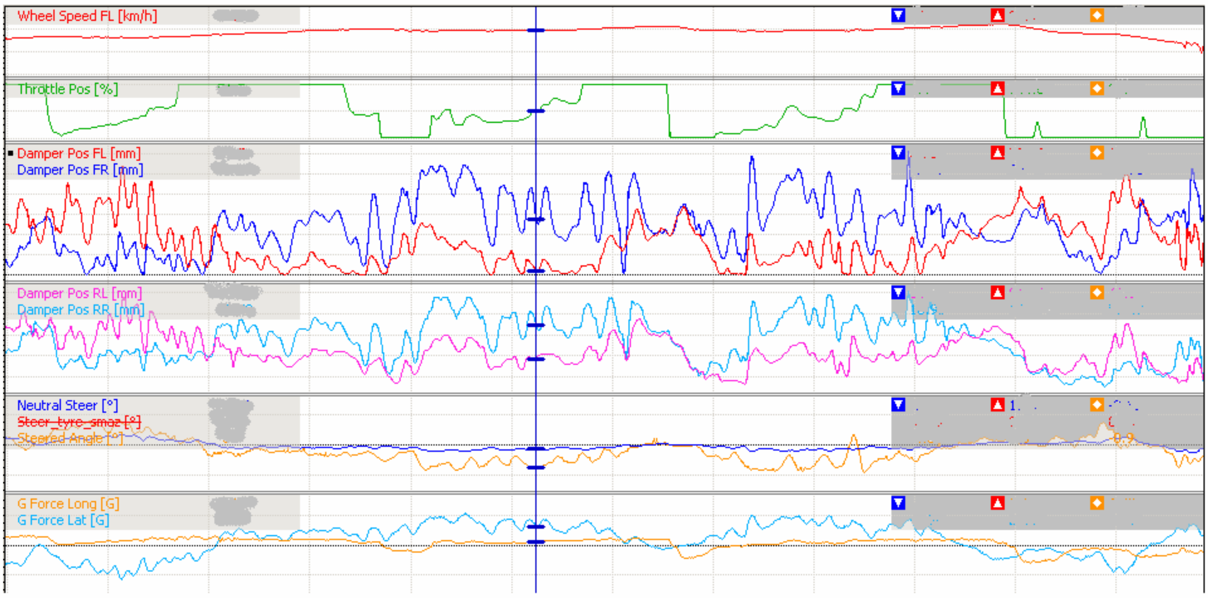

Fig-3 – Racecar going through a corner.

The particular car in question is a V8 Supercar with the following parameters,

Table – 1 – V8 Supercar setup variables

Setup Variable	Value
Front Spring Wheel Rate	70 N/mm
Front Tyre Spring Rate	320 N/mm
Downforce (C_LA)	1.0

As we can see there is some significant variation in the dampers as the car is going through the corner. Given that the road spring rates are significantly less than the tyre spring rates, this is also a pretty good indication of tyre load. Let's see how our pseudo static assumptions add up. Compare the roll for the pseudo static case vs. the actual case. Unfortunately due to confidentiality I can't give you the actual numbers but I will compare magnitudes. So comparing the pseudo static roll to the actual data we have,

Table- 2 – Relative comparison of suspension roll for Pseudo static roll calculation vs actual data

	Pseudo static	Actual Data
Front	1	1.11
Rear	1	1.13

This isn't bad to get us into the ball park and give us an indication of what to expect. However while our pseudo static assumption have got us close what we are missing is the transients.

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Let's illustrate this by considering the relative force between the compression of a damper and the associated damping velocity. For the sake of argument let's say we have the following as illustrated in Table 3.

Table – 3 – Illustration of spring and damper forces

	Spring/damper velocity	Spring rate/ Damping force	Force (N)
Damper Movement	30 mm	80 N/mm	2400
Damper Velocity	50 mm/s	400 N	400

What Table 3 illustrates is the fact the spring is the bulk of the force. However you would be foolish to ignore the damper contribution which is in the order of 20% of the spring rates. Table 3 indicates that transients play as much of a role in what a race car is going go to as the springs, bars, dampers as wings.

Where pseudo static lap time simulation runs out of steam is it doesn't take into account transients as illustrated in Tables 2 and 3. Yes it will give you a fair picture of what to expect with your race car. However it can't fill you in on what to expect as you transition from one state to another as you progress through the corner, and the vehicle changes state from braking through turn in to mid corner and eventually to exit. Unfortunately, these transient influences make all the difference in setting up your car. Also by definition pseudo static laptime simulation can't deal with bumps. This has a massive impact on the setup

For those of you that think that bumps and transients are irrelevant on a high downforce car think again. Look at Fig-3. This may be a low downforce car, but translate all that damper movement to a ride height sensitive aeromap. If you can't control the variation of your ride height, your driver is going to have a wild ride through the corner. Think of it another way, F1 teams didn't spend fortunes on active suspension for no good reason.

Also remember that tyre load variation counts almost as much as the average tyre load through a corner. This is illustrated overleaf in Fig-4. As we can see the tyre load variation through this corner is quite significant. We all know tyre load is a direct indicator of how much force we have available from the tyre. While this is a bumpy corner, it nonetheless has massive implications for how you drive the corner. You would have to be pretty brave to say you could approximate this using a static assumption.

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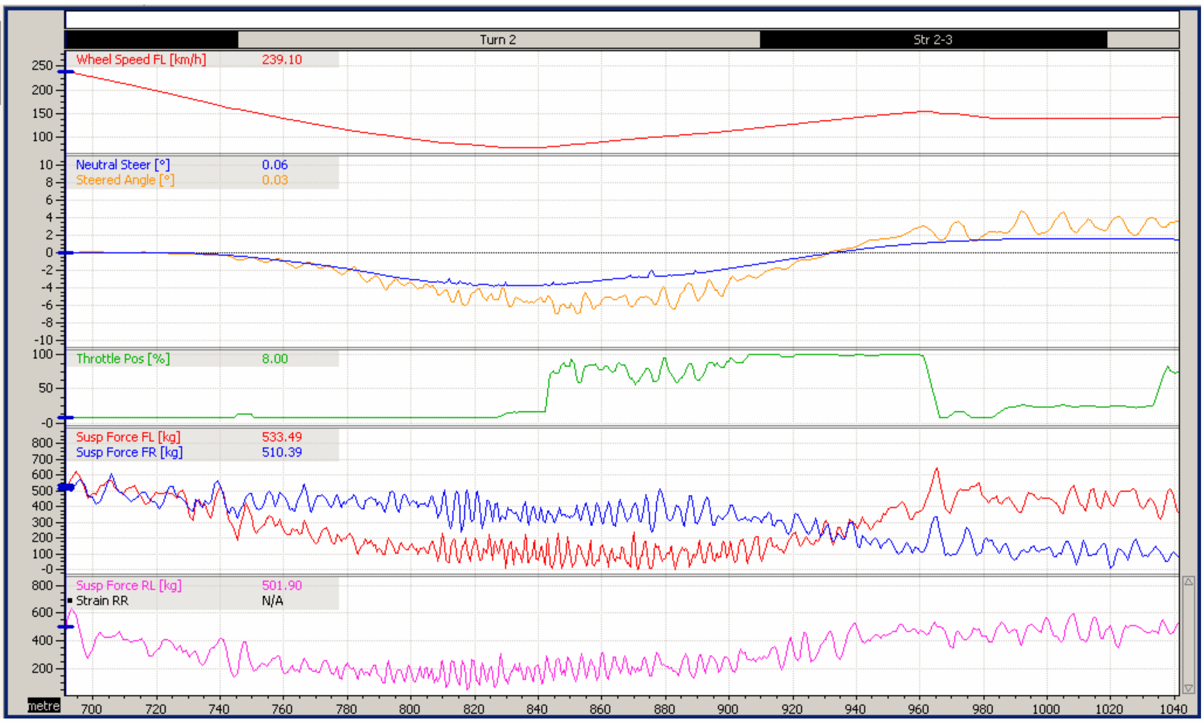

Fig-4 – Tyre load variation through a corner.

In complete contrast ChassisSim uses a full multi body vehicle dynamics model for the lap time algorithm. To illustrate this consider this comparison of actual vs. simulated data on an oval.

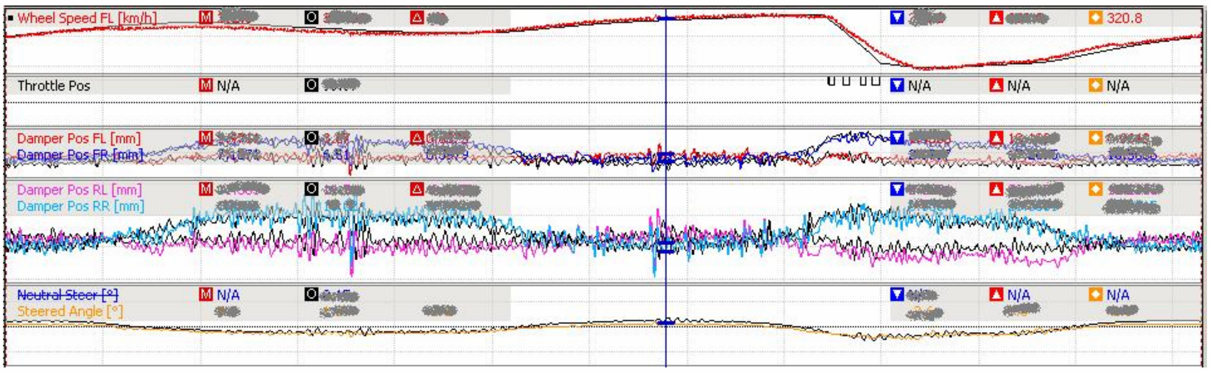

Fig-5 – Actual Data vs. simulated data on a high speed oval

The actual data is coloured, the simulated is black. As with the V8 Supercar case I've blocked out the scaling due to the fact that this is actual data. But you can see clearly that there are some very noticeable bumps on this circuit. This illustrates that while pseudo static calculations might get you into the ball park, those bumps are going to have nearly as much say on your mid corner grip as your wing settings.

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What you see in Fig-5 illustrates the power of transient simulations because it opens up a much wider world of setup variables to investigate and vehicle properties you can reverse engineer. Using ChassisSim you can investigate how damper adjustments are going to impact on lap time. You can see transiently what the car is doing so you can zero in on what to adjust. Also just remember every lap time simulation you do in ChassisSim is the equivalent of running the car on a 7 post rig simulator. This is the power of what you have at your finger tips.

Another consequence of using ChassisSim is the fact it is not ultra reliant on grip factors. We have had several instances of customers developing a tyre model for one circuit and then applying that tyre at multiple circuits. Indeed grip factors in ChassisSim are more of a fine tuning tool as opposed to a necessity. This is the power of transient simulation.

Let us conclude on an historical note. When ChassisSim was first coming together 15 years ago we actually looked into the pseudo static approach. However this got rejected within 15 minutes for all the reasons we have discussed above. Just remember pseudo static lap time simulation will get you into the ball park. The ChassisSim transient simulation will take you all the way.

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