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Advanced Vehicle Dynamics
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Vehicle Testing and Analysis

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1 Introduction

The objective of this technical report is to document the designing, running and results of a simulated test. The car being investigated is the Aston Martin DB9 Race Car model, through testing the aerodynamic and suspension performance will be characterised. These results are then analysed and discussed.

The data was collected over two one hour sessions in the simulator as part of a five-person group. These tests were planned in Microsoft Excel, see Appendix A. This report and the data analysis was carried out individually. The data was collected in the simulator as MoTeC files and then further analysed in MoteC.

1.1 Objective

The objective of the test is to accurately characterise the aerodynamics and handling behaviour of the Aston Martin DB9 Race Car by investigating a variety of setups.

1.2 Aims

- a. To plan and carry out simulator testing
- b. To collect and create maths channels in MoTeC
- c. To Analyse and characterise the vehicle performance

2 Methodology

At the beginning of this project work was carried out as a group to identify a test plan and schedule for the two, single hour simulation sessions. The test plan that was created, see appendix A.

The plan for the first session was to carry out the straight-line testing and one complete lap around Silverstone South track for each aerodynamic and suspension setup, not including damper setups. Nearly all but two were completed in this first session. After the first session, the data was checked to confirm all the runs were of good quality and if any bad runs were found they could be re-run in the following session. All the runs were good so no repeats were needed for session two.

Session two went more smoothly than the first with better communication between group members. This meant setup changes were quicker so the runs all ran through efficiently. This left time for a re-run of the standard setup to evaluate the consistency of the driving against the previous sessions standard setup.

The next part of the project was to produce maths channels in MoteC and analyse the data both through data traces and graphs. The maths channels created can be seen in figure 1. To see all the formulas for these maths channels, see Appendix D.

Corrected Speed (m/s)	Corner Radius (m)	Theoretical Wheel Steer Angle (deg)	Theoretical Steer Percentage (%)
Understeer	Actual Front Weight Transfer (N)	Actual Rear Weight Transfer (N)	Actual Total Weight Transfer (N)
Lateral Acceleration (m/s/s)	Overturning Moment (Nm)	Front Aerodynamic Loads (N)	Rear Aerodynamic Loads (N)
Total Aerodynamic Loads (N)	Centre of Pressure (%)	Predicted Roll Angle (rad)	Predicted Elastic Weight Transfer Front (N)
Predicted Elastic Weight Transfer Rear (N)	Predicted Sprung Weight Transfer Front (N)	Predicted Sprung Weight Transfer Rear (N)	Predicted Unsprung Weight Transfer Front (N)
Predicted Unsprung Weight Transfer Rear (N)	Predicted Weight Transfer Front (N)	Predicted Weight Transfer Rear (N)	Predicted Weight Transfer Total (N)
Basic Predicted Weight Transfer (N)	Actual Magic Number	Predicted Magic Number	Tyre Slip (Average Front / Total)
Roll Stiffness Distribution	Longitudinal Weight Transfer (N)	Damper Coefficients FL, FR, RL & RR	Damper Force (N) FL, FR, RL & RR
Damper Weight Transfer Front (N)	Damper Weight Transfer Rear (N)	Predicted Weight Transfer Front with Dampers (N)	Predicted Weight Transfer Rear with Dampers (N)
Predicted Weight Transfer Total with Dampers (N)	Predicted Magic Number with Dampers (N)	Aerodynamic Drag Force (N)	Aerodynamic Efficiency

Figure 1 – List of Math Channels

3 Aerodynamic Results

The Aerodynamic results were analysed over an entire lap of the circuit, the lap can be seen in Figure 2.



Figure 2 -
Silverstone South Circuit

All the graphs in section 3 use the following key.

Setup 1 = Red, Setup 2 = Black.

Setup one was the standard setup with splitter on option 2 and wing on option 8.

Setup two was the maximum setup with splitter on option 3 and wing on option 12.

3.1 Coefficients of Lift and of Drag

To gain these results, a straight-line test was carried out. The following equations were used to calculate the coefficients of lift and of drag respectively, from the data collected in the simulator.

$$Cd = \frac{\text{Drag Force}}{0.5 \times \rho \times A \times v^2}$$

$$Cl = \frac{\text{Total Aero Load}}{0.5 \times \rho \times A \times v^2}$$

(Hall, 2015)

The Coefficient of drag was calculated from a coast down test, where the car rolled from a high speed to a stop with no interference. This was done by calculating two points of acceleration; one where drag force and rolling resistance were present and one where just rolling resistance were present. Assuming rolling resistance was constant at all velocities, the drag force could be calculated and since the air density, the frontal area where constants and the average velocity could be recorded Cd was solved.

Coefficient of lift was calculated when the car was travelling at a constant speed on the limiter and the tyre loads where recorded, the static loads were taken away from this to give the total aero load so then CI could be solved.

	Cl	Cd
Standard Setup (2,8)	-1.755	1.056
Drivers Preferred Setup (3,12)	-2.015	1.190

Figure 3 – Coefficient of Lift and Drag values

These values calculated are also roughly what would be expected as race cars have an approximate coefficient of lift of -3 and coefficient of drag of 0.75 (Katz, 2016) which is similar values to the Astons where its coefficient of lift is slightly closer to zero and the coefficient of drag is a bit larger too.

From these resulting values, other maths channels could now be calculated. These included the aerodynamic drag force and the aerodynamic efficiency, to name a few.

3.2 Recorded Total Negative Aerodynamic Lift

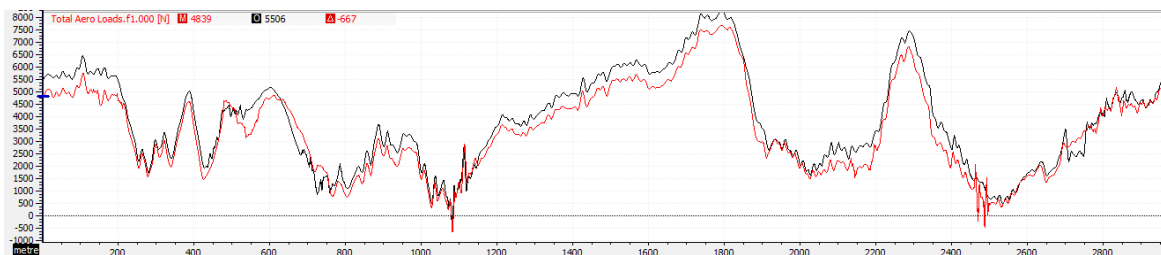
The following equations were used to calculate the negative aerodynamic lift force maths channel.

$$\text{Longitudinal Weight Transfer} = \frac{\text{Mass} \times \text{lateral acceleration} \times \text{Height of Centre of Gravity}}{\text{Wheelbase}}$$

$$\text{Front Aero Load} = (\text{Tyre Load FL} + \text{Tyre Load FR}) - (\text{Static Load FL} + \text{Static Load FR}) + \text{Longitudinal Weight Transfer}$$

$$\text{Rear Aero Load} = (\text{Tyre Load RL} + \text{Tyre Load RR}) - (\text{Static Load RL} + \text{Static Load RR}) - \text{Longitudinal Weight Transfer}$$

$$\text{Total Aero Load} = \text{Front Aero Load} + \text{Rear Aero Load}$$



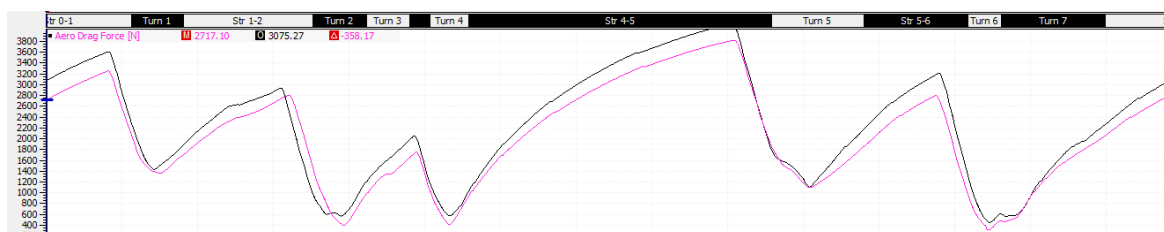
Graph 1 - Actual Total Negative Lift Force - Setup 1 and 2

Graph one shows that setup two has a higher negative lift over an entire lap at nearly every point. This is especially obvious when the car is at high speeds. This is caused due to setup two having a larger negative lift coefficient. At lower speeds however, the setups have similar aerodynamic loads. This means that changing the splitter and the wing set up will only drastically affect the downforce when at high speed. There is one point at about 600m to 700m where setup two is less, this could be due to the driver braking earlier in setup two causing the car to be going slower than in setup one so the downforce would reduce. Having a higher downforce allows the car to travel at higher velocities around corners (Yager, 2001) without running wide due to the increased grip.

3.3 Predicated Aerodynamic Drag

This maths channel used the previously calculated coefficient of drag in the equation below.

$$\text{Predicted Drag Force} = 0.5 \times \rho \times C_d \times A \times v^2$$



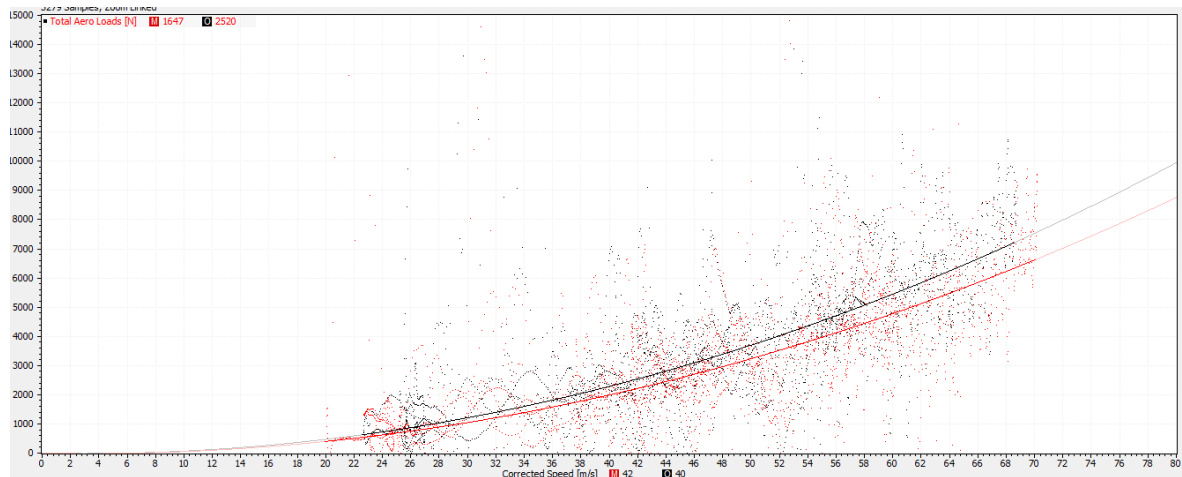
Graph 2 - Predicted Drag - Setup 1 and 2

Setup one can be seen to have less aerodynamic drag than setup two, in graph 2. This is because setup one has a lower coefficient of drag. Under braking, they have similar aerodynamic drag and this is due to the drag force helping the car brake. This means with setup two the driver can brake later into the corner, however setup one will be able to reach higher speeds quicker on the straights. This means to set up two will feel a better handling car, compared to setup one, but will feel slightly sluggish and slow at higher speeds when accelerating (Yager, 2001). Also as seen in the negative lift graph at the same point under

braking there is a slight anomaly for the drag were setup two is less than setup one. This confirms that there is a relationship between lift and drag and that the anomaly is highly likely due to driver input rather than a mathematical anomaly.

3.4 Aerodynamic Negative Lift vs. Longitudinal Speed

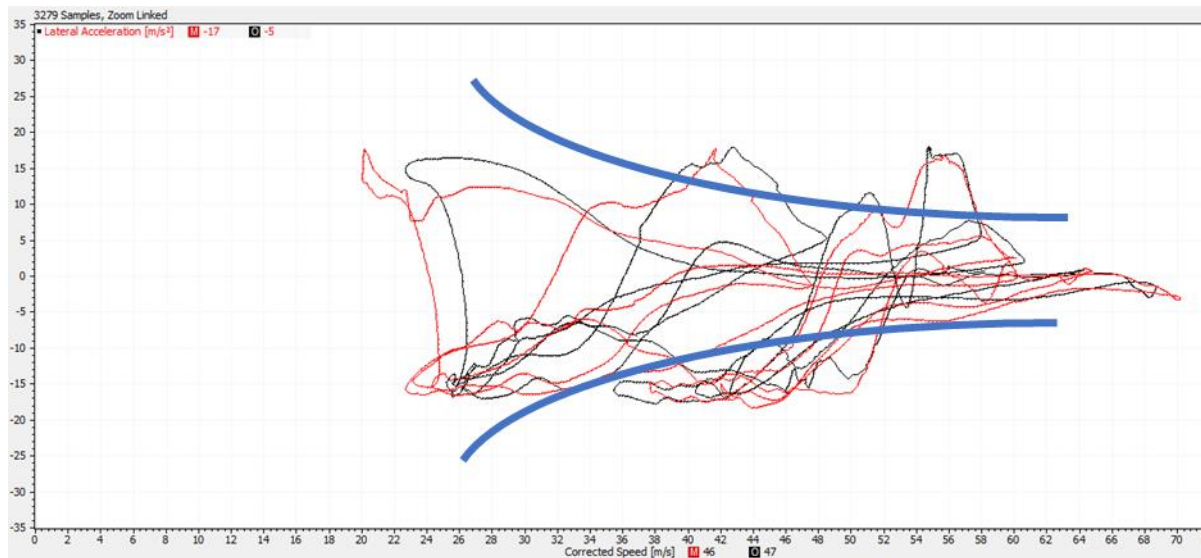
The maths channel used was the aerodynamic load which was used in section 3.2. This plotted against velocity has produce graph 3.



Graph 3 – Negative Lift vs Speed – Setup 1 and 2

The Graph shows that for the same velocity, setup 2 has a higher downforce. However the larger the velocity the larger the difference between the two setups forces. This is due to aerodynamic downforce being proportional to velocity squared (The Building Speed Blog, 2012). This is why downforce is more important at circuits where higher velocities are reached whereas as low-speed circuits the change will have a negligible effect on the downforce performance but the drag force may still affect it

3.5 Lateral Acceleration vs. Longitudinal Speed

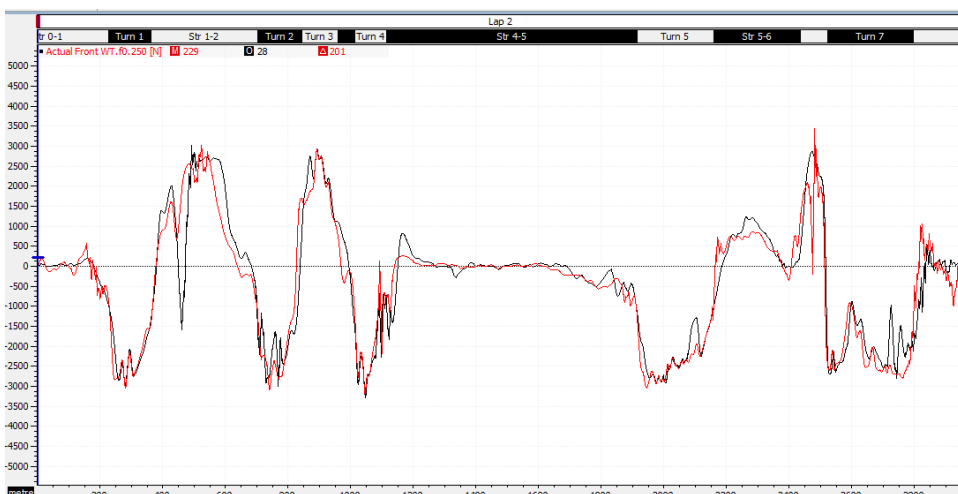


Graph 4 - Lateral Acceleration vs. Speed – with trend lines – Setup 1 and 2

This graph appears complicated and unorganised, but if you look closely you can see that at low velocities there is a high positive and negative lateral acceleration and as velocity increase, the lateral acceleration tends towards zero, as shown by the blue lines. There is little or no lateral acceleration at high speeds because high speeds only occur on the straights, however high lateral acceleration will occur in corners where the car will be travelling at lower speeds due to the limit in the grip. Setup two has higher positive and negative lateral acceleration at lower velocities as the increased downforce allows the car to travel at a higher velocity through corners, therefore, causing more lateral acceleration.

3.6 Aerodynamic Downforce on the Front and Rear Axels

The math channels used were the ones explained in section 3.2. Graph 5 shows how the aerodynamic setup affects the load on the front axle.

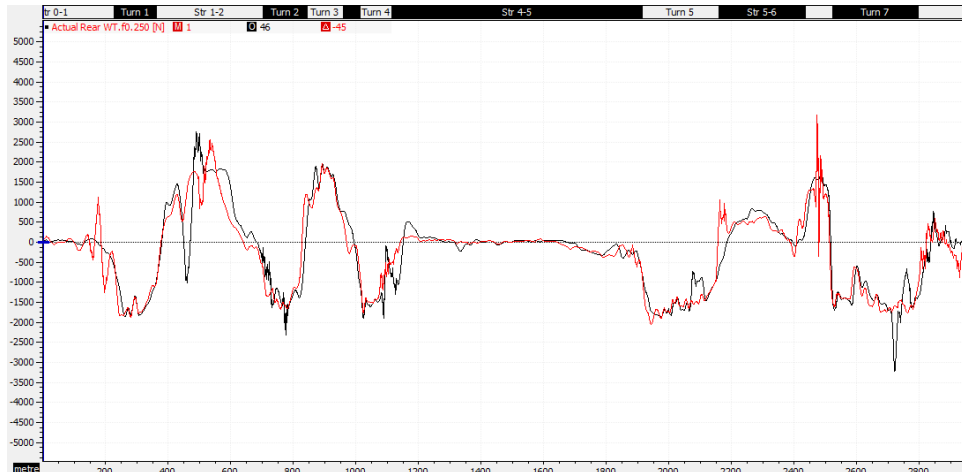


Graph 5 – Negative Lift on Front Axle – Setup 1 and 2

The front axle loads were very similar for both setups with setup two being marginally higher at some points. The reason there isn't much difference is that the splitter is what affects the

front axle loads and the difference in splitter types has a very small difference in the overall lift of the car. The splitters also have to be designed so they help reduce drag (Formula1 Dictionary, 2019) so if the splitters focused on reducing drag then the negative lift improvement wouldn't be very noticeable.

Graph 6 is showing the same equation but applied to the rear axle. This Graph appears very similar to graph 5.



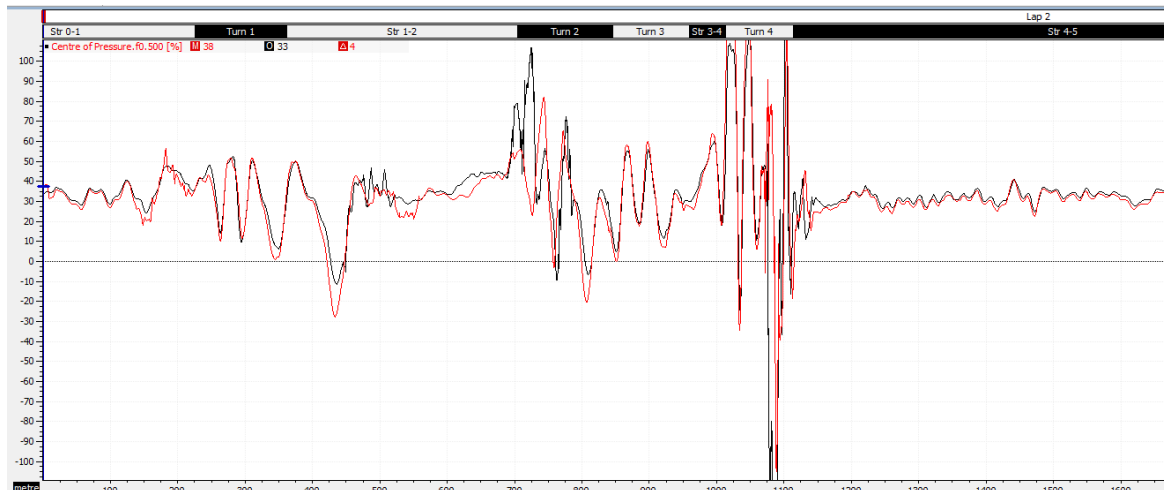
Graph 6 – Negative Lift on Rear Axle – Setup 1 and 2

The rear axle looks very similar to the front axle, however, the data doesn't look as clean. The loads on the rear axle are of similar values to the front which means that the aerodynamic forces are acting nearly equally at the front as they do at the rear. Even though on both graph 5 and 6 the difference in setups looks very small when adding the axles together, it does have an overall effect on the car as seen in section 3.2.

3.7 Centre of Pressure

The Centre of Pressure is the point at which the resultant aerodynamic forces act on the car (Collins Dictionary, 2019). This is taken as a percentage from the front axle, where 100% is all on the front axle and 0% is all on the rear axle. This investigation uses the calculated values for the front aerodynamic load and the total aerodynamic load using the following equation.

$$\text{Centre of Pressure} = \frac{\text{Front Aero Load}}{\text{Total Aero Load}} \times 100$$



Graph 7 – Centre of Pressure – Setup 1 and 2

Graph 7 shows that setup two has a centre of pressure slightly further forward than setup one. This means when turning in to a corner, set up two is slightly more unstable as there is limited grip at the rear which could cause more chance of turn in oversteer (Formula1 Dictionary , 2019). However, at higher speeds, the car has a more even front to rear load distribution with set up two.

The anomalies of the negative centre of pressure are due to points at which the apex of the corner was hit which caused there to be no load on the front inside tyre causing a negative front aerodynamic load to occur.

4 Suspension Results

Two corners were used for the investigation. Figure 4 shows the corner used for the high speed corner and Figure 5 shows the low speed corner used.



Figure 4 – high speed corner

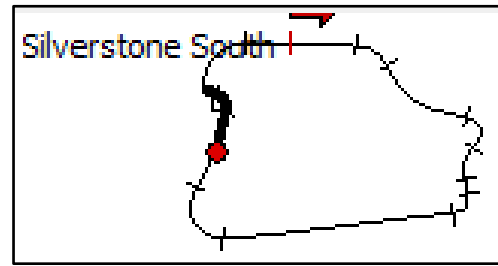
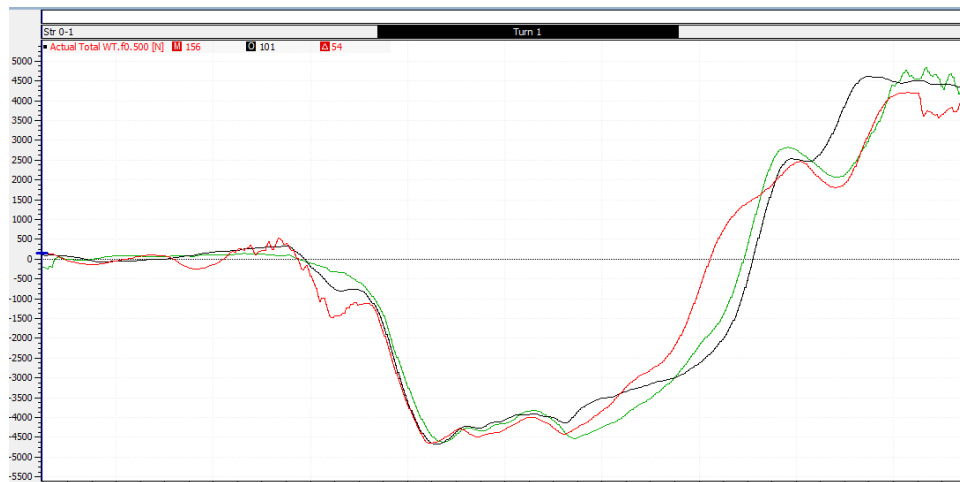


Figure 5 – low speed corner

4.1 Anti-Roll Bar

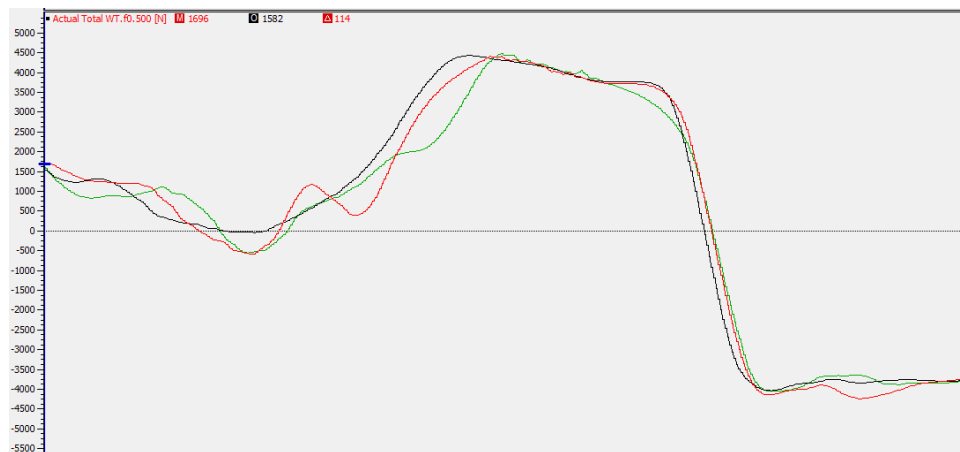
4.1.1 High Speed Corner



Graph 8 – Anti Roll Bar rate – three setups – high speed corner

Graph 8 shows three setups, standard in red, maximum stiffness in green and minimum stiffness in black. At the entry to the corner, the weight transfer for all three setups is very similar. This means that the anti-roll bar rate has little effect on high speed corner entry this is also true for the apex of the corner as they all have a very similar weight transfer. However, at the exit of the corner, the standard setup experiences the least weight transfer, which isn't expected but the stiffest anti-roll bar rate has a large weight transfer which would be expected. As the stiffer, the anti-roll bar the more lateral load is transferred (Suspension Secrets, 2017).

4.1.2 Low Speed Corner

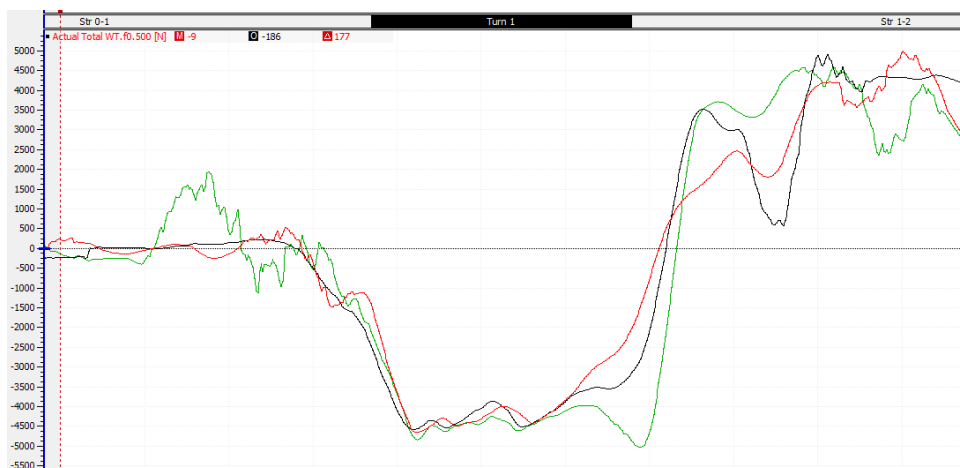


Graph 9 – Anti Roll Bar rate – three setups – low speed corner

In the low speed corner on the entry, the stiffest setting has the smoothest weight transfer whereas the two softer settings display a slight oscillation in weight transfer. At the apex of the corner, the maximum weight transfer is seen from the softest anti-roll bar rate and the minimum weight transfer happens on the stiffest setting. The exit of the slow speed corner has a very similar weight transfer for all three setups which suggests under low speed acceleration the anti-roll bar rate has minimal effect in the cars characteristics, which would be expected as the anti-roll bar rate affects the lateral load (Santos, 2015) which would be minimal at low velocity.

4.2 Springs

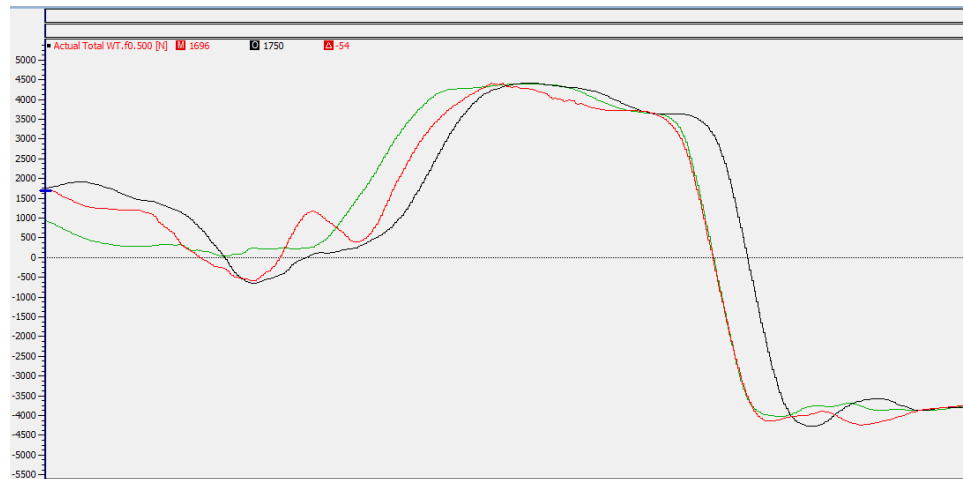
4.2.1 High Speed Corner



Graph 10 – Spring rate – three setups – high speed corner

Graph 10 shows three setups, standard in red, maximum stiffness green and minimum stiffness black. At the turn into the high speed corner, the softest spring rate has a smooth weight transfer which would give predictable handling whereas the stiffest spring rate has quite an erratic weight transfer. At the apex of the corner, all the setups have a similar peak weight transfer but at the exit, the stiffest setup has a higher weight transfer. However, in a high speed turn aerodynamics plays a larger roll in weight transfer than the spring rates (Alexander, 2014), which only affect the roll distribution, so whether it understeers or oversteers.

4.2.2 Low Speed Corner

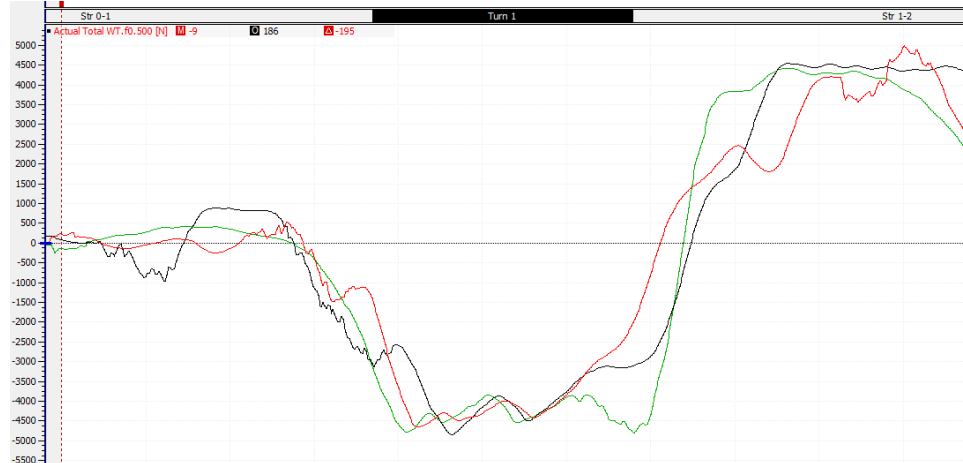


Graph 11 – Spring rate – three setups – low speed corner

On entry into the low speed corner, the softest setup has the least weight transfer but they all have a similar peak weight transfer at the apex however at the exit of the corner the softest setup has the most weight transfer. This is because the car can accelerate quicker out of the corner as it has more grip. At low speed where aerodynamic force is minimal the softest spring setups have more grip than the stiffer setups (Fenske, 2017) however when at higher speeds, stiffer springs are needed due to the aerodynamic force exerted by the car.

4.3 Damper Bump

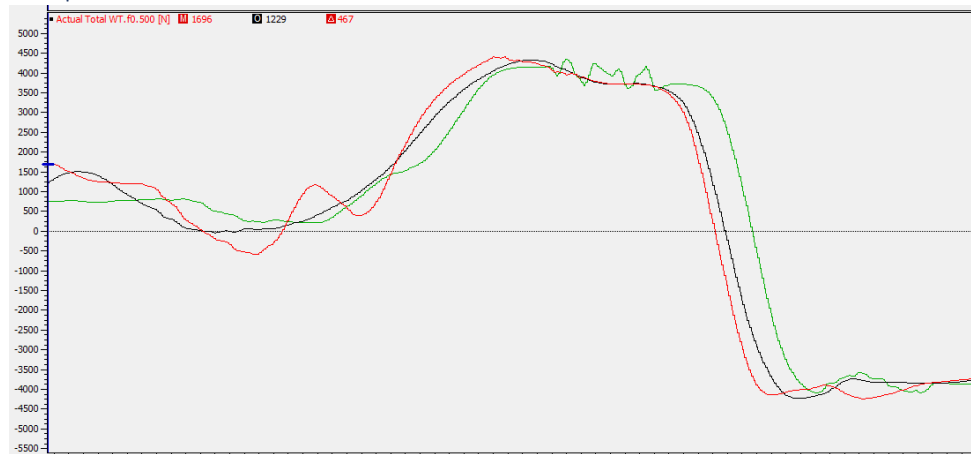
4.3.1 High Speed Corner



Graph 12 – Damper Bump – three setups – high speed corner

Graph 12 shows three setups, standard in red, maximum slow and fast bump in green and minimum slow and fast bump in black. At the entry to the high speed turn the most weight transfer occurs from the minimum setup however the maximum bump setup has smoother weight transfer which happens because the higher bump force prevents suspension oscillation therefore prevents weight transfer oscillation (Suspension Secrets, 2017). At the apex of the corner, the damper set up has no effect as the damper doesn't have a velocity unless the kerb is hit (Suspension Secrets, 2017). The stiffer damper experiences more weight transfer leaving the corner as there is less body roll.

4.3.2 Low Speed Corner

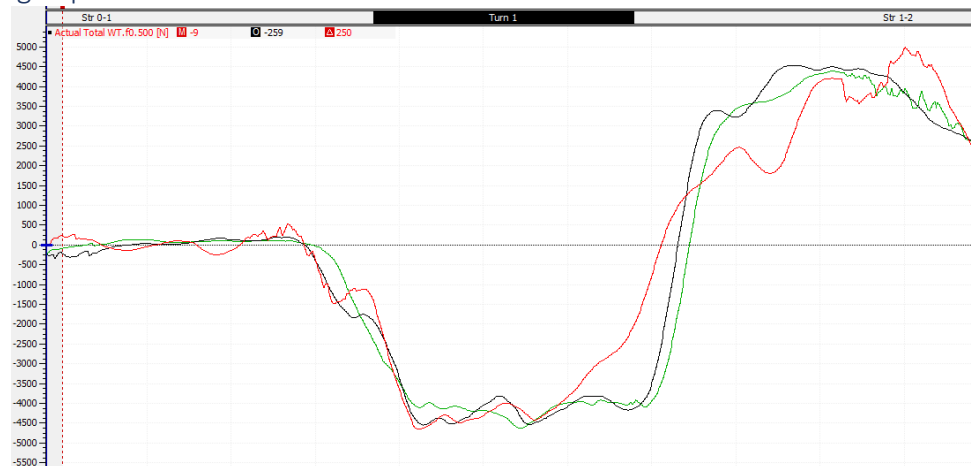


Graph 13 – Damper Bump – three setups – low speed corner

At the low speed corner, the apex of the corner, like the high speed, shouldn't be affected by the damper setup. However, the maximum setup does display different behaviour at the apex which means the car made contact with the kerb and because of how hard the bump was, the weight transfer was small spikes whereas if it was softer there would have been less more smoothed out peaks of weight transfer. The softest setup has the smoothest weight transfer on turn into the corner and this is because more grip is available so the car could turn in at higher speed. Exiting the corner, all three setups display the same smooth trend. This is because bump doesn't affect the contracting of the damper (Suspension Secrets, 2017).

4.4 Damper Rebound

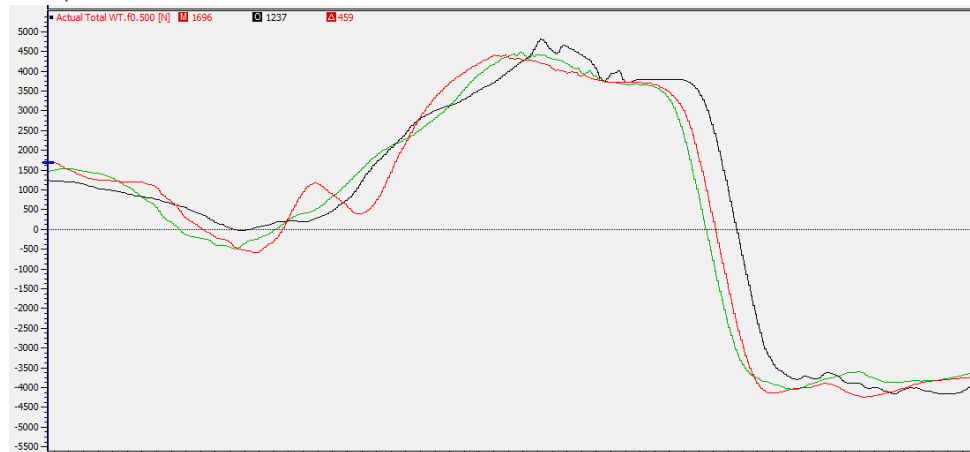
4.4.1 High Speed Corner



Graph 14 – Damper Rebound – three setups – high speed corner

Graph 14 shows three setups, standard in red, maximum slow and fast rebound in green and minimum slow and fast rebound in black. The rebound has no effect at the apex of the corner as the damper has no velocity, also upon entry to the corner the rebound doesn't affect the handling, as can be seen in graph 14, due to the damper only compressing. However, at the exit of the corner, the damper rebound does affect the handling characteristics (Suspension Secrets, 2017). The increased rebound setting has more weight transfer which is what would be expected (De Groote, 2002). If the damper rebound is set to high then on exit of the corner the spring will extend to quick which could unsettle the car and reduce grip (Suspension Secrets, 2017), so getting an optimal rebound, such as the standard red setup in graph 14, will give the car a better exit to the corner.

4.4.2 Low Speed Corner



Graph 15 – Damper Rebound – three setups – low speed corner

As discussed in the high speed corner rebound has no or minimal effect on entry and the apex of the corner but does affect how well it exits the corner. In graph 15, the lowest rebound setting has more weight transfer and this happens because the slowness of the rebound allows the car to have a settled acceleration so a higher velocity can be achieved without the risk of losing grip (Suspension Secrets, 2017).

4.5 Weight Transfer Analysis

The equations used in the weight transfer prediction can be seen in appendix D. The difference between the predicted weight transfer and predicted weight transfer with dampers is just the addition of the front and rear damper weight transfer.

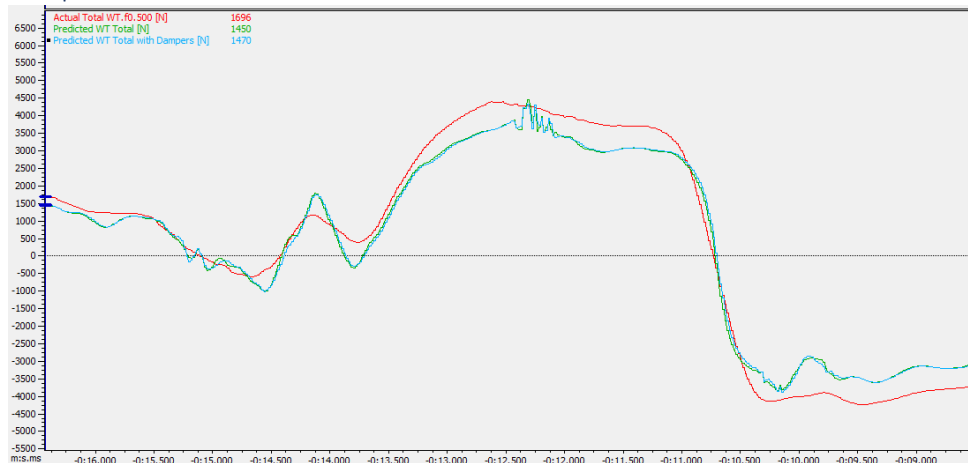
The new predicted weight transfer equation which includes damper weight transfer gives a closer estimate to the actual weight transfer. However, the improvement is negligible compared to how far away the predicted weight transfer is from the actual. This suggests that the prediction equation has other problems that would need addressing before the need to use the damper weight transfer to get a closer approximation. For the amount of time and effort to add the damper weight transfer to the prediction and such a small improvement it would not be worth doing in the future.

4.5.1 High Speed Corner



Graph 16 – Weight Transfer comparison equations – high speed corner

4.5.2 Low Speed Corner



Graph 17 - Weight Transfer comparison equations – low speed corner

At high speed cornering the prediction is quite far away from the actual weight transfer, however, at the low speed corner the prediction was quite accurate but there is still no real need to add the damper weight transfers to the equation.

5 Conclusion

To conclude the aerodynamics play a much larger roll in high speed cornering than suspension setup. Also depending on the track, the car wants the highest setting for wing and splitter to give it as much downforce as possible however there is the trade-off of increased drag force. So on tracks with high speed, the setting will have to be reduced but on low speed tracks the higher settings will be best.

The suspension has its most effect at low speed cornering. The springs and anti-roll bar rate don't dramatically affect the weight transfer but it's the difference between the front and the rear which do. So if it is stiffer at the front then more understeer will occur. Whereas when bump and rebound are increased this causes more weight transfer during entry and exit of the corner but they does not affect the apex unless the wheel hits the kerb.

6 References

- Alexander, D., 2014. *Weight Watching – Understanding Weight Transfer and Racecar Dynamics*. [Online] Available at: <https://nasaspeed.news/columns/driver-instruction/weight-watching-understanding-weight-transfer-and-racecar-dynamics/> [Accessed 28 12 2019].
- Brastow, D., 2004. *Car Suspension and Handling (Premiere Series Books)*. 4th ed. Warrendale: SAE International.
- Clover, C. & Bernard, J., 1993. *The Influence of Lateral Load Transfer Distribution on Directional Response*, Iowa State: SAE Technical Paper 930763.
- Collins Dictionary, 2019. *Centre of Pressure Dictionary*. [Online] Available at: <https://www.collinsdictionary.com/dictionary/english/centre-of-pressure> [Accessed 20 12 2019].
- De Groote, S., 2002. *The effects of adjusting a damper*. [Online] Available at: <https://www.f1technical.net/features/10696> [Accessed 28 12 2019].
- Fenske, J., 2017. *Why stiff suspensions have less grip*. [Online] Available at: <https://www.roadandtrack.com/car-culture/a10385629/why-stiff-suspensions-have-less-grip/> [Accessed 21 12 2019].
- Formula1 Dictionary , 2019. *Weight transfer: Formula1 Dictionary*. [Online] Available at: http://www.formula1-dictionary.net/weight_transfer.html?fbclid=IwAR0HsXsq-W4eqAOtoPfil1yxKg_-lEEDX4NyjWLtEA5uQjhBGVoN3BaTTVg [Accessed 20 03 2019].
- Formula1 Dictionary, 2019. *Dictionary: Downforce*. [Online] Available at: <http://www.formula1-dictionary.net/downforce.html> [Accessed 20 12 2019].
- Hall, N., 2015. *Glen Research Centre: The Drag Coefficient*. [Online] Available at: <https://www.grc.nasa.gov/www/k-12/airplane/dragco.html> [Accessed 28 12 2019].
- Heisler, H., 2002. *Advanced Vehicle Technology*. Oxford: Butterworth-Heinemann 2002.
- Katz, J., 2016. *Aerodynamics: AN INTRODUCTION TO AUTOMOBILE AERODYNAMICS*. [Online] Available at: <https://mechanixillustrated.technicacuriosa.com/2017/03/04/an-introduction-to-automobile-aerodynamics/> [Accessed 28 12 2019].
- Katz, J., 2016. Chapter 7: Examples. In: *Automotive Aerodynamics*. Honoken NJ: Wiley and Sons, pp. 262-283.
- Milliken, W. F. & Milliken, D. L., 1995. *Race Car Vehicle Dynamics*. Warrendale: Society of Automotive Engineers.
- Santos, R., 2015. *A DISCUSSION ON STEADY-STATE LATERAL WEIGHT TRANSFER AND HOW TO USE IT IN SETUP*. [Online] Available at: <https://racingcardynamics.com/weight-transfer/> [Accessed 28 12 2019].
- Suspension Secrets, 2017. *Spings, Dampers and Roll Bars: Anti-Roll Bars*. [Online] Available at: <https://suspensionsecrets.co.uk/anti-roll-bars/> [Accessed 21 12 2019].
- Suspension Secrets, 2017. *Spings, Dampers And Roll Bars: Dampers*. [Online] Available at: <https://suspensionsecrets.co.uk/damper/> [Accessed 28 12 2019].
- The Building Speed Blog, 2012. Aerodynamic downforce: a passing fad?. *The Building Speed Blog*, 21 05.
- Yager, B., 2001. *Nasa: Education: Physics: Racing Physics*. [Online] Available at: <https://www.nas.nasa.gov/About/Education/Racecar/physics.html> [Accessed 26 12 2019].

Appendix A –Test Plan/Schedule

R0	COAST DOWN 1 - std			Springs			
C D2	COAST DOWN 2 - R4			Front		Rear	
CD1	UNDERSTEER COEFF			Standard	Standard		
			R14	Min	Min		
			R15	Min	Max		
			R16	Max	Max		
			R17	Max	Min		
				Dampers			
				Front BUMP		Rear BUMP	
				SLOW	FAST	SLOW	FAST
				Standard	Standard	Standard	Standard
				Min	Min	Min	Min
				Min	Max	Min	Max
				Max	Max	Max	Max
				Max	Min	Max	Min
				Dampers			
				Front RBOUND		Rear RBOUND	
				SLOW	FAST	SLOW	FAST
				Standard	Standard	Standard	Standard
				Min	Min	Min	Min
				Min	Max	Min	Max
				Max	Max	Max	Max
				Max	Min	Max	Min
				Dampers			
				Front BUMP		Rear BUMP	
				SLOW	FAST	SLOW	FAST
				Min	Standard	Max	Standard
				Max	Standard	Min	Standard
				Standard	Min	Standard	Max
				Standard	Max	Standard	Min
				Dampers			
				Front RBOUND		Rear RBOUND	
				SLOW	FAST	SLOW	FAST
				Min	Standard	Max	Standard
				Max	Standard	Min	Standard
				Standard	Min	Standard	Max
				Standard	Max	Standard	Min

<u>SESSION 1 PLAN</u>	<u>JOB</u>
<u>Test Track</u> Pull forwards Stop so no interruption for corner masses Steady state - big radius constant low speed Costdown 1 - standard setup	<u>Ainsley</u> Driver <u>Max</u> Setup change
<u>Silverstone Intl.</u> Baseline Aero Ride height ARB Springs Bump Rebound	<u>Nick</u> Setup change <u>Sam</u> Data organisation
<u>Test Track</u> Costdown 2 - R4 setup (drives two units)	<u>Simon</u> Setup photos <u>Ewan</u> Data feed supervisor
<u>SESSION 2 PLAN</u>	
<u>Silverstone Intl.</u> Dampers slow and fast variation If time - dampers singular variation	

i. Vehicle General

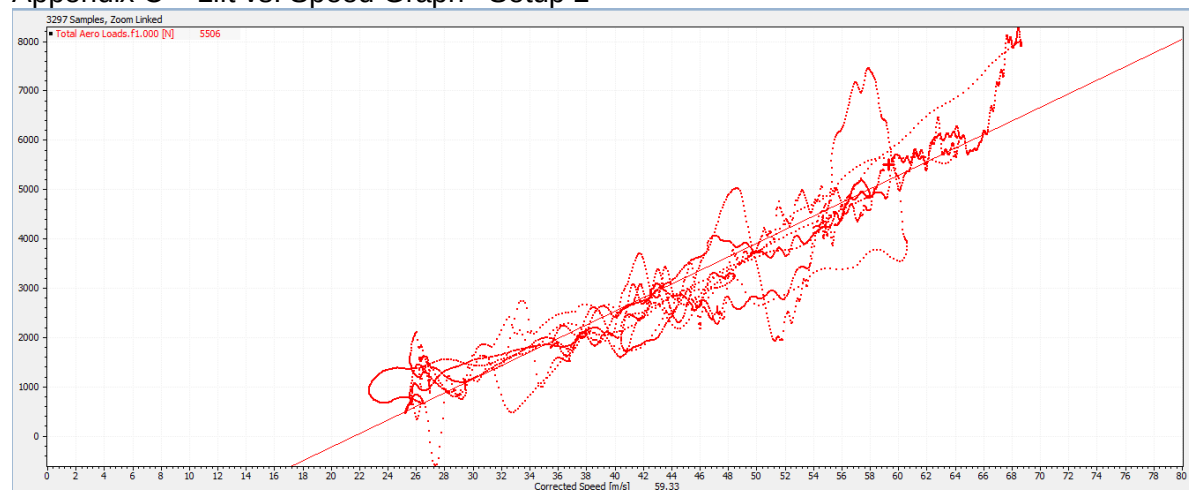
ii. Suspension

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iii. Aero

	A	B	C	AX	AY	AZ	BA	BB
	MoTeC							
				Aero	Wing Setup	Spline Setup	Oct	C
1								
2	Hide Values	Date	Time					
3	Set							
4	Set							
5	Difference			0	0	0	0	0
6		01-Jan-96	09:00:00	8	2	1.056	1.755	
7	CD1	28-Oct-19	15:02:20	8	2	1.056	1.755	
8	R0	28-Oct-19	15:04:00	8	2	1.056	1.755	
9	R1	28-Oct-19	15:06:40	8	2	1.056	1.755	
10	R2	28-Oct-19	15:12:00	1	1			
11	R3	28-Oct-19	15:15:45	12	1			
12	R4	28-Oct-19	15:20:50	12	3	1.19	2.015	
13	R5	28-Oct-19	15:23:30	1	3			
14	R6	28-Oct-19	15:30:20	8	2	1.056	1.755	
15	R7	28-Oct-19	15:33:00	8	2	1.056	1.755	
16	R8	28-Oct-19	15:35:45	8	2	1.056	1.755	
17	R9	28-Oct-19	15:38:45	8	2	1.056	1.755	
18	CD2_R4	28-Oct-19	15:43:15	12	3	1.19	2.015	
19	R10	28-Oct-19	15:46:00	8	2	1.056	1.755	
20	R11	28-Oct-19	15:48:30	8	2	1.056	1.755	
21	R12	28-Oct-19	15:51:00	8	2	1.056	1.755	
22	R13	28-Oct-19	15:53:35	8	2	1.056	1.755	
23	R14	28-Oct-19	15:56:20	8	2	1.056	1.755	
24	R15	28-Oct-19	15:58:45	8	2	1.056	1.755	
25	R16	15-Nov-19	16:02:00	8	2	1.056	1.755	
26	R17	15-Nov-19	16:04:35	8	2	1.056	1.755	
27	R18	15-Nov-19	16:08:35	8	2	1.056	1.755	
28	R19	15-Nov-19	16:12:30	8	2	1.056	1.755	
29	R20	15-Nov-19	16:19:50	8	2	1.056	1.755	
30	R21	15-Nov-19	16:22:30	8	2	1.056	1.755	
31	R22	15-Nov-19	16:25:45	8	2	1.056	1.755	
32	R23	15-Nov-19	16:28:15	8	2	1.056	1.755	
33	R24	15-Nov-19	16:31:15	8	2	1.056	1.755	
34	R25	15-Nov-19	16:34:00	8	2	1.056	1.755	
35	R26	15-Nov-19	16:37:00	8	2	1.056	1.755	
36	R27	15-Nov-19	16:39:40	8	2	1.056	1.755	
37	R28	15-Nov-19	16:42:20	8	2	1.056	1.755	
38	R29	15-Nov-19	16:45:00	8	2	1.056	1.755	
39	R32	15-Nov-19	16:52:45	8	2	1.056	1.755	
40	R33	15-Nov-19	16:55:20	8	2	1.056	1.755	
41	R18	15-Nov-19	16:57:50	8	2	1.056	1.755	
42	R30	19-Dec-19	16:07:30	8	2	1.056	1.755	
43	R31	10-Dec-19	16:14:40	8	2	1.056	1.755	
44								

Appendix C – Lift vs. Speed Graph– Setup 2



Appendix D – Math Channels

