

Vehicle Testing and Analysis

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Introduction

The aim of this investigation is to evaluate the effect of aerodynamic and suspension setup changes on a vehicle's performance. Using the BPS Simulator to collect data, the user will see how an Aston Martin DB9 Race Car performs on the Pembrey circuit, comparing setup changes. The results of this investigation will also be compared to the results gained from steady state testing to see how dynamic movement can affect the results.

Test

Test Plan

Run	File Name	Description	Aero		Springs		ARB		Ride h	
			Front	Rear	Front	Rear	Front	Rear	Front	Rear
1	Default Setup	Pembrey	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
	Set up change									
2	Splitter Min	Pembrey	Min	Mid	Standard	Standard	Standard	Standard	Standard	Standard
	Set up change									
3	Splitter Max	Pembrey	Max	Mid	Standard	Standard	Standard	Standard	Standard	Standard
	Set up change									
4	Wing Min	Pembrey	Mid	Min	Standard	Standard	Standard	Standard	Standard	Standard
	Set up change									
5	Wing Max	Pembrey	Mid	Max	Standard	Standard	Standard	Standard	Standard	Standard
	Set up change									
6	Springs Fmin Rmax	Pembrey	Standard	Standard	202	307	Standard	Standard	Standard	Standard
	Set up change									
7	Springs Fmid Rmid	Pembrey	Standard	Standard	254	254	Standard	Standard	Standard	Standard
	Set up change									
8	Springs Fmax Rmin	Pembrey	Standard	Standard	307	202	Standard	Standard	Standard	Standard
	Set up change									
9	ARB Fmin Rmax	Pembrey	Standard	Standard	Standard	Standard	160	72	Standard	Standard
	Set up change									
10	ARB Fmid Rmid	Pembrey	Standard	Standard	Standard	Standard	280	48	Standard	Standard
	Set up change									
11	ARB Fmax Rmin	Pembrey	Standard	Standard	Standard	Standard	400	12	Standard	Standard
	Set up change									
12	RH Fmid Rmin	Pembrey	Standard	Standard	Standard	Standard	Standard	Standard	5.8	5.6
	Set up change									
13	RH Fmid Rmax	Pembrey	Standard	Standard	Standard	Standard	Standard	Standard	5.8	8
	Set up change									
14	RH Fmin Rmid	Pembrey	Standard	Standard	Standard	Standard	Standard	Standard	4.6	6.8
	Set up change									
15	RH Fmax Rmid	Pembrey	Standard	Standard	Standard	Standard	Standard	Standard	7	6.8
	Set up change									
16	RH Fmax Rmin	Pembrey	Standard	Standard	Standard	Standard	Standard	Standard	7	5.6
	Set up change									
17	RH Fmin Rmax	Pembrey	Standard	Standard	Standard	Standard	Standard	Standard	4.6	8
	Set up change									
18	Low Speed Corner	Skidpad	Standard	Standard	Standard	Standard	Standard	Standard	4.6	8

Table 1: Simulator session 1 - Test Plan: Aero, Springs, ARB and Ride Height

File name	front	rear
Baseline 1		
low speed bump 0 clicks	6000	6000
low speed bump 2 clicks	6600	6600
low speed bump 4 clicks	7200	7200
low speed bump 6 clicks	7800	7800
low speed bump 8 clicks	8400	8400
baseline 2		
low speed rebound 0 clicks	10000	10000
low speed rebound 2 clicks	11200	11200
low speed rebound 4 clicks	12400	12400
low speed rebound 6 clicks	13600	13600
low speed rebound 8 clicks	14800	14800
baseline 3		
high speed bump 0 clicks	2800	2800
high speed bump 2 clicks	3100	3100
high speed bump 4 clicks	3400	3400
high speed bump 6 clicks	3700	3700
high speed bump 8 clicks	4000	4000
baseline 4		
high speed rebound 0 clicks	4600	4600
high speed rebound 2 clicks	5200	5200
high speed rebound 4 clicks	5800	5800
high speed rebound 6 clicks	6400	6400
high speed rebound 8 clicks	7000	7000
Baseline 5		

Table 2: Simulator session 2 – Test Plan: Dampers

As the tables above show, a wide range of tests were carried out on the vehicle, each designed to investigate a different area of the vehicle and the effect the given component has on the vehicle's behaviour around a track.

Over the course of two test sessions, the effect of aerodynamics, spring rates, anti-roll bar stiffness, ride height and damping rates were investigated. During the course of each run, one area was tested in isolation of the other settings, with the areas not under investigation being maintained at their standard value.

Track Choice

When choosing the track, two major deciding factors came into consideration when this choice was made. The first factor was the driver. In order to gain consistent results, the driver had to be familiar and comfortable with whatever track was chosen. This restricted our choices to a range of tracks around the UK. Another factor had to be the track itself. In order to make calculations as straightforward as possible, allowing comparable results from run to run, the ideal track would have no change in elevation and would be as smooth as possible. Furthermore, the track needed to have a range of corners, including left and right handers, tight and sweeping corners and it needed to have some straights. The final consideration was the tracks available to us through the BPS simulator. As a result, Pembrey circuit was chosen to best fulfil the requirements.

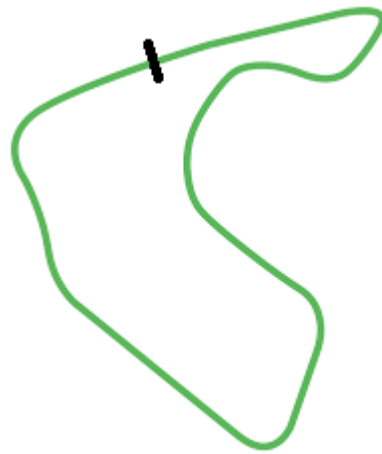


Figure 1: Pembrey Track Map (LTD, 2019)

Consistency

In order to gain the most accurate results, consistency is key. Ideally, the inconsistency introduced by a real-world driver would be eliminated by using a Driver-Out-The-Loop Simulation. However, due to the unavailability of an accurate simulation model capable of this type of testing, the author used the most consistent driver available to collect data. Since even the most consistent driver is known to make mistakes (BOSCH GMBH, 2018), part of the test procedure was also to make sure that for each setup, at least 3 runs were carried out, consisting of one out lap and two flying laps. This meant that an average result could be taken where relevant. Furthermore, rather than the driver pushing himself and the car to the limit, they were asked to maintain 80% capacity. Although this means that there is more to gain from each setup, it also means that the level of repeatability is increased, meaning results are more consistent. Since the aim of this investigation is to compare the effect the setup has on performance over an entire lap, consistency is more important than gaining the fastest possible lap times.

Steady State

Through a previous piece of work, the author investigated the effect changing the aerodynamic setup of the car would have on the lift and drag coefficients of the Aston Martin. The results from this investigation can be seen in Table 3.

Setup	Cda	Cl _a	CoPf	Cl/Cd	FrontAngle	RearAngle
1	1.312298196	1.60110234	33.58116481	1.220075	1	1
2	1.358729597	1.847940505	45.82312925	1.36005	1	6
3	1.255546998	2.117583678	32.20991815	1.686583	1	12
4	1.140088943	1.834107424	59.27352779	1.608741	2	1
5	1.283387148	1.976849814	49.11779969	1.540338	2	6
6	1.417569082	2.136887901	45.02654169	1.507431	2	8
7	1.551751016	2.296925988	40.93528369	1.480216	2	12
8	1.20887382	1.949059693	50.30549898	1.612294	3	1
9	1.280196342	2.151748495	42.27924179	1.680796	3	1
10	1.39394968	2.386613243	33.57038277	1.712123	3	12
11	1.42682637	2.415229772	33.5956918	1.692729	3	12
12	1.268694427	2.022378486	31.57635468	1.594063	1	1
13	1.457237811	2.087414261	32.84044837	1.432446	1	1
14	1.495011529	1.987509891	30.67669173	1.329428	1	1
15	1.457237811	2.087414261	32.84044837	1.432446	1	1

Table 3: Steady-State Aero (May, 2019)

This was done through a coast down test, allowing the calculations of these values in a steady state. Although steady state gives a good indication of the vehicle's performance on track, dynamically a vehicle can often behave very differently. Each of the values calculated above, would vary over the course of a track lap, even if the aerodynamic setup did not change. Part of the purpose of this investigation is to compare the steady state results to their dynamic equivalent.

In order to gain this aerodynamic data, the coast down test (ISO 10521-1:2006) was used. Figure 32 shows the Speed vs. Distance graph used to calculate the values above. The aerodynamic lift can be measured at point 1. At this point the vehicle is in a steady state (no lateral or longitudinal acceleration). Measuring the tire load at this point, at taking them away from the tire load when the vehicle is static, results in the load created due to the aerodynamic features of the car. Measuring the acceleration around points 2 and 3 allows the calculation of aerodynamic drag. At point 2, the aerodynamic drag can be thought to be the sum of the aerodynamic drag and the rolling resistance of the vehicle. At point 3, where the velocity of the car is almost, but not quite, zero, the aerodynamic drag is negligible resulting in the deceleration at this point being caused solely by the rolling resistance. Taking on value from the other results in aerodynamic drag.

Dynamic

Complete Track

For the evaluation of the dynamic characteristics of the vehicle, several different setups were looked at. For the best evaluation, the various data sets are overlapped allowing easy comparison. The data in *red* shows the default setup, the data in *white* the default setup with a minimum rear wing angle and the *green* the default setup with a maximum rear wing angle.

Aero

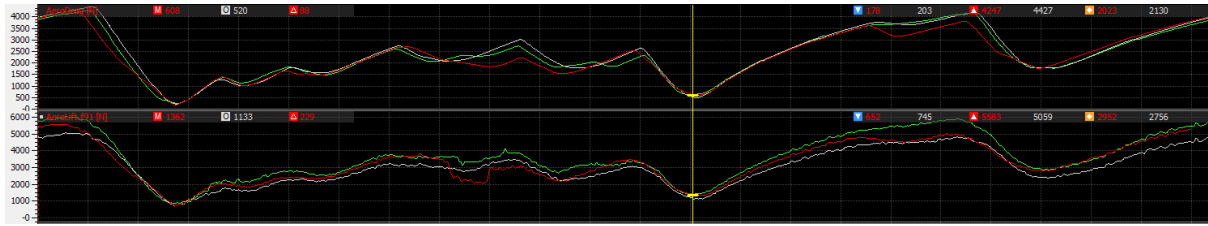


Figure 2: Aerodynamic Lift (N) and Aerodynamic Drag (N) vs. Distance (m) for default setup, max wing and min wing

The graphs above show the values for aerodynamic lift and drag forces and how they change across a lap at Pembrey. Looking at the steady state data, we can see that for the default setup we have one constant value of 1.41 for the coefficient of drag and 2.14 for coefficient of lift. Using Equation 1 the drag force can be calculated (Grc.nasa.gov, 2020) at each section of the track. This however has the down side that a constant air density needs to be measured throughout the run or assumed to be constant, and that the frontal surface area, as defined by Bauer, 1996, is assumed to be constant, which due to the pitching and yawing of the vehicle is not the case. A similar equation can be seen in Equation 2. This can be used to calculate the lift of the vehicle (Engineeringtoolbox.com, 2020), with the same drawbacks as the drag equation. An alternative method can be used, which measures the load through the tires. By comparing the static load through the tires, i.e. the weight of the car, to the load at any given velocity at any point on the track and by taking the weight transfer into account, a more accurate value for the lift force can be calculated (Equation 3).

$$Drag (N) = C_d \times \frac{1}{2} \rho v^2 A$$

Equation 1: Aerodynamic Drag Force (N)

- C_d = Coefficient of Drag
- ρ = Air Density (kg/m^3)
- v = Velocity of the vehicle (m/s)
- A = Frontal Surface Area (m^2)

$$Lift (N) = C_L \times \frac{1}{2} \rho v^2 A$$

Equation 2: Aerodynamic Lift Force (N)

- C_L = Coefficient of Lift

$$\begin{aligned} & \text{Single Axle Lift (N)} \\ &= (\text{Left Tire Load} + \text{Right Tire Load}) - \text{Axle Load} \\ &\mp \text{Longitudinal Weight Transfer} \end{aligned}$$

Equation 3: Aerodynamic Lift Force (N) - Single Axle

Comparing Figure 2 and Figure 28 shows that there is a strong positive correlation between the magnitude of the aerodynamic force and speed of the vehicle. Further analysis also shows that increasing the wing angle causes a proportional increase in the aerodynamic forces. Normally it might be expected to see a decrease in lift at the maximum wing angle, due to the flow becoming

separated however, the simulator is not capable of calculating this complex type of aerodynamic behaviour. This is further evident when investigating the aerodynamic efficiency in a steady state scenario in Table 3, where the aerodynamic efficiency, represented by Cl/Cd (Sciencedirect.com, 2020), increases as the splitter and wing angles increase. Since it is not possible to determine when separation begins to occur from the data from the simulator, it is possible that within the given range of wing angle, no separation occurred at all and that a steeper wing angle would be required for separation to become apparent in a real world scenario. Future work could include some real-world testing, perhaps using a wind tunnel, in order to determine at which wing angle separation begins to occur.

Total Lift Vs Speed

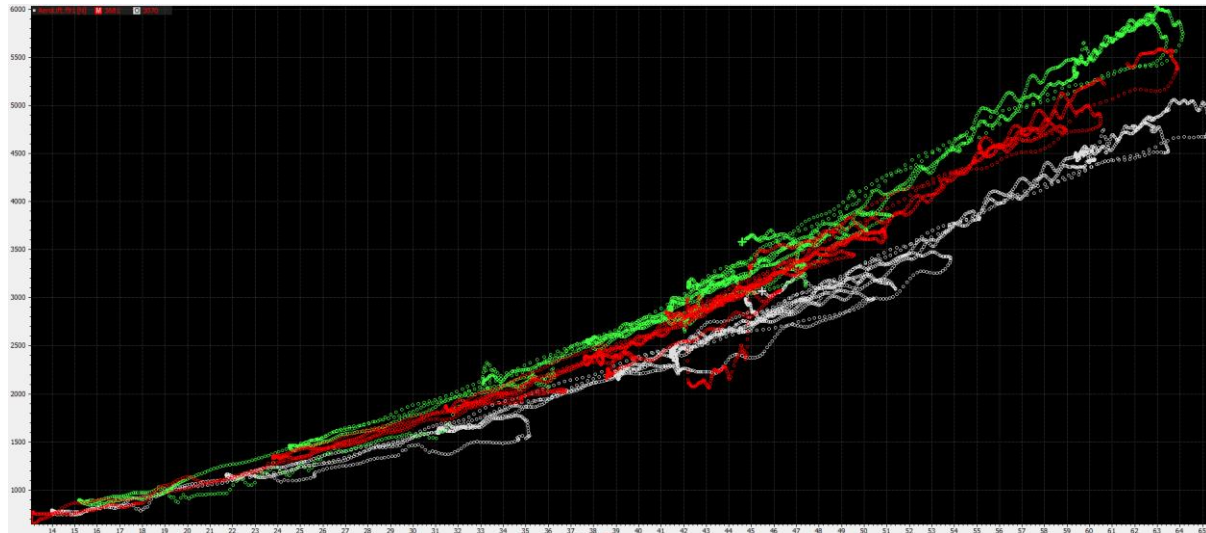


Figure 3: Aerodynamic Lift (N) vs. Speed (m/s) for default setup, max wing and min wing

The graph above shows the squared relationship between aerodynamic lift and the vehicle's speed expected as a result of looking at Equation 2. Investigating the different wing settings further confirms the accuracy of this equation, as the value for lift force increases with the increased frontal surface area as a result of the increased wing angle.

A point of interest in the graph above, is the noise of the values, some of which has already been removed to allow easier comparison. The equation for lift would suggest that the three different wing settings should produce results following a single perfect $y = x^2$ shaped curve for each setting. The deviation of the results from the expected curves is likely down to the suspension behaviour of the vehicle. The frontal surface area of the car is affected by the pitch and yaw which are in turn effected by the lateral and longitudinal acceleration of the car. As a result, not only the cars speed, but also its acceleration at any given point, will affect the aerodynamic forces acting on it. If Equation 2 had been used to calculate the lift, a graph more like Figure 30 would have been produced, as the coefficient of lift is assumed to be constant.

Centre of Pressure

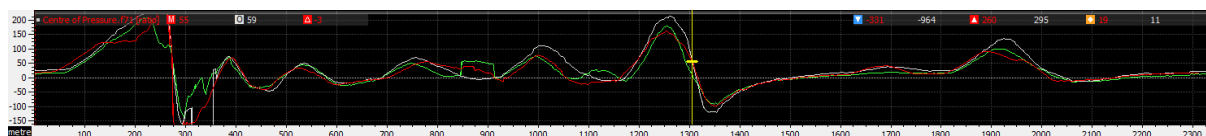


Figure 4: Centre of Pressure (%) vs. Distance (m) for default setup, max wing and min wing

The centre of pressure graph further shows how the coefficients of lift and drag move around the vehicle under acceleration, breaking and cornering. The value shows what proportion of the total aerodynamic lift is situated above the front axle. Under steady state conditions, this would be expected to remain constant, however as the pitch of the vehicle changes, as can be seen in the figure above, the centre of pressure moves between the axles. This is as a result of front and rear ground effect varying as the vehicle pitches forwards or backwards. Furthermore, different aerodynamic features at the front and rear of the car will have varying sensitivity to pitch, resulting in some features changing the amount of lift they produce more than others.

Lateral Acceleration vs. Speed

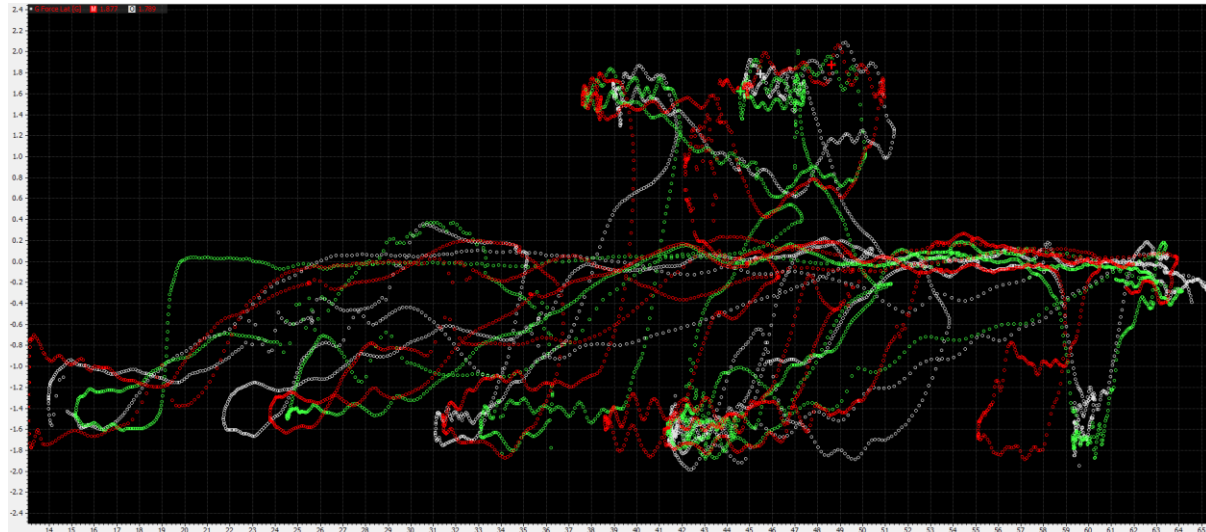


Figure 5: Lateral Acceleration (G) vs. Speed (m/s) for default setup, max wing and min wing

Comparing the lateral acceleration to the speed shows that speed is not the only thing that effects the magnitude of the lateral acceleration. The graph above visually confirms this. Steering angle also plays a major role. When moving in a straight line on a straight road, a vehicle lateral acceleration might never change, regardless of its speed. This is what has caused seemingly random results in the figure above showing no strong correlation between velocity and lateral acceleration.

Forces per axle

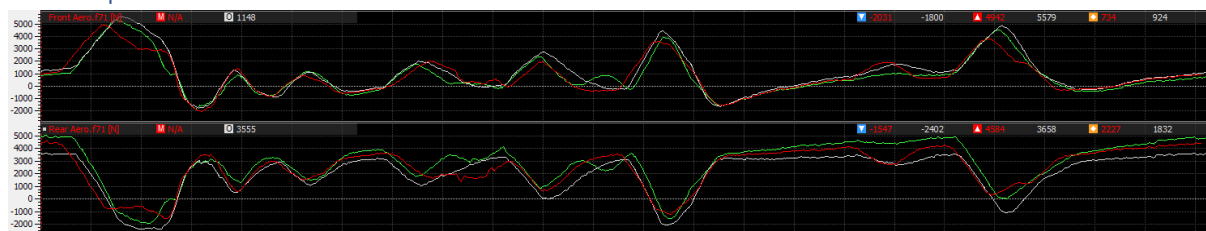


Figure 6: Axle Forces (N) vs. Distance (m) for default setup, max wing and min wing

Looking at the aerodynamic lift on a single axle reveals the importance of ground effect on the vehicle. Comparing the data from Figure 6 to the longitudinal G Force (Figure 31) helps in understanding what the vehicle is doing, and how ground effect is changing the magnitude of the aerodynamic loads.

Usually, if the loads were only being compared to the speed of the vehicle, we would expect both forces to follow the same trend, increasing and decreasing with speed. The figure above shows that this is not the case. The figure suggests that as the vehicle accelerates, causing weight transfer towards the rear and the nose to lift, the front aero decreases due to the reduced ground effect whilst the rear aero decreases. The opposite is true under braking.

Contact Patch Loads and Load Transfer

In a dynamic situation, the aerodynamic properties of a vehicle are only one of multiple areas that can affect a cars performance on track. Spring stiffness, anti-roll bar stiffness and damping rates can also significantly affect how much grip a car has. This dictates how much lateral force can be exerted to get the car around the corner (Blundell and Harty, 2004).

Investigating first the effect of spring rates in a low speed corner it becomes evident that changes can cause a significant difference in the way a driver needs to handle a vehicle, depending on how it is set up. Looking at Figure 7 the effect of the spring rates on the breaking point becomes immediately obvious. The yellow line shows the position of the apex of corner one, whilst the red line shows the speed of the car with the same spring rate front and rear and the white line represents the car with the minimum spring rate at the front and maximum at the rear. We can see that the more balanced car breaks before the apex and is able to accelerate around the corner whilst the white line seems to have overshoot its breaking point, breaking way after the apex and exiting the corner with far less speed, reducing the amount of speed it can carry into the next corner. The tire loads seen in Figure 8 show that the vehicle would have been capable of a higher speed in the corner as the tire loads for the more balanced car are far higher on the outside of the corner than for the other setup. This demonstrates a lack in trust between the driver and the given set-up.



Figure 7: Speed (m/s) vs. Distance (m) at Corner 1 for two spring rates

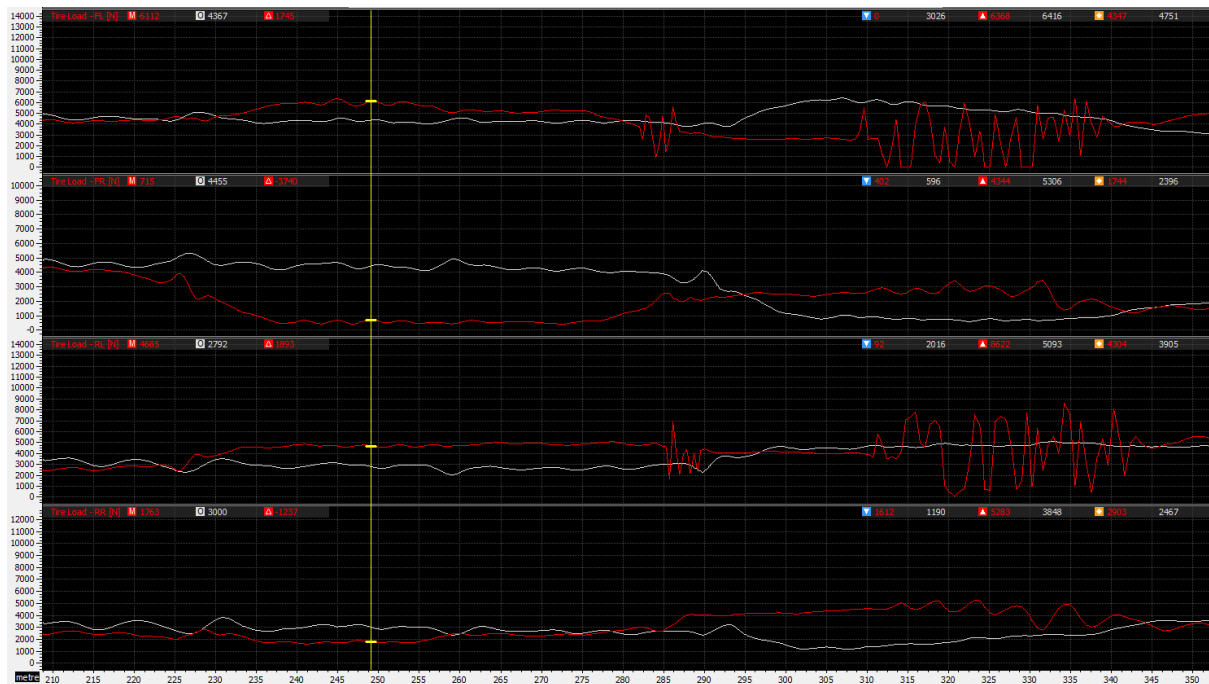


Figure 8: Tire Load (N) vs. Distance (m) at corner 1 for spring comparison

The increased loads on the outside tires indicate a higher lateral weight transfer for the balanced setup. This is supported by Figure 9 showing the weight transfer of the car around the same corner. This also shows clearly that the white setup is still fighting to get around the corner long after the red setup has begun accelerating into the straight.

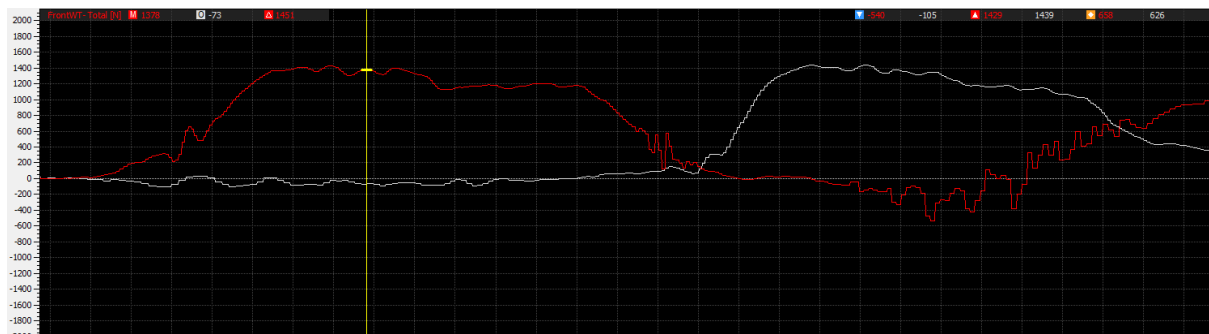


Figure 9: Calculated Weight Transfer (N) vs. Distance (m) at corner 1 for spring comparison

Comparing these findings from a low speed corner, the data collected on a high-speed corner further confirms the conclusions drawn above. Comparing the speed of the two different setups as the move through the high-speed corner shows the balanced car accelerating up to the corner, breaking before turning in and accelerating out of the corner. The white set-up, as suggested before, is not able to carry as much speed out of the previous corner, meaning that it is accelerating all the way through turn 7, resulting in it exiting the corner faster, despite a slower entry.

This is supported by the tire loads, showing a higher load on the outside wheels by the red spring setup as the car moves through the corner, with the white car's tire loads coming up as its speed surpasses that of the red car. The same can be said for the lateral weight transfer of the car, being consistently higher for the red car, until the exit of the corner, where the white car becomes faster.

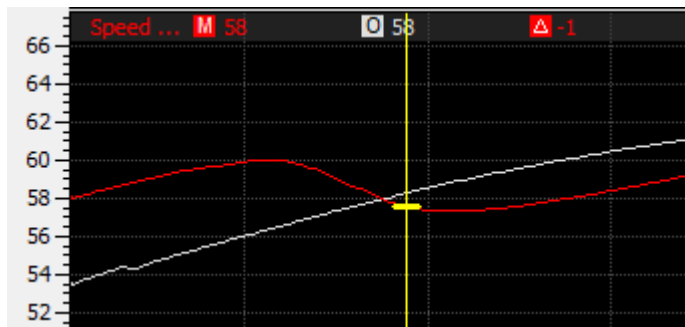


Figure 10: Speed (m/s) vs. Distance (m) at corner 7 for spring comparison

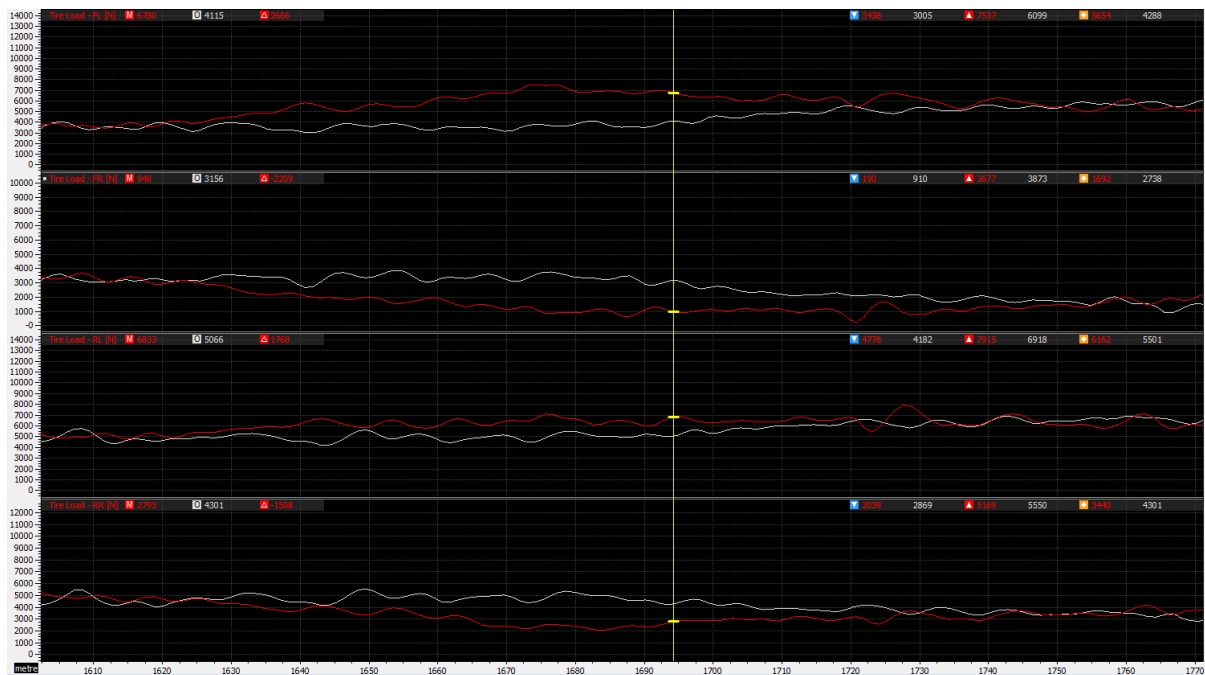


Figure 11: Tire Load (N) vs. Distance (m) at corner 7 for spring comparison

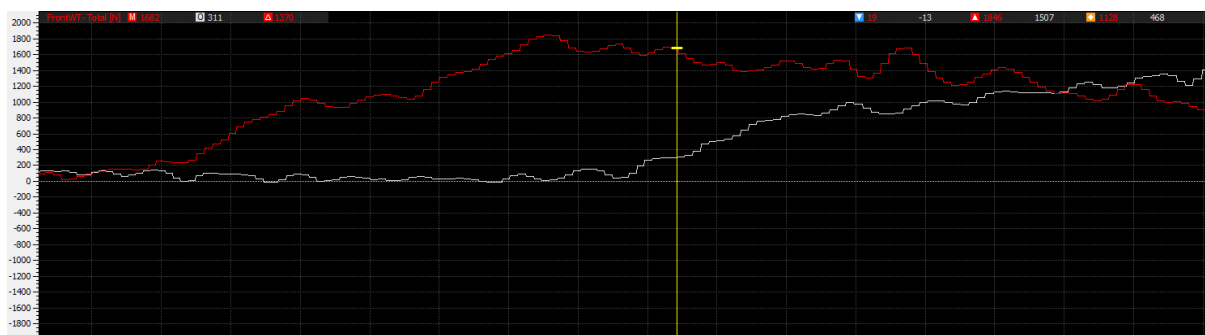


Figure 12: Weight Transfer (N) vs. Distance (m) at corner 7 for spring comparison

Looking at is the anti-roll bar and how it effects the weight transfer of the car, we would generally expect the anti-roll bar to reduce weight transfer (Weber, 2011), due to the way in which it attempts to reduce the difference in the level of bounce and rebound from left to right.

Looking at the weight transfer graph in the figure below, confirms that this does happen. As before, the red line shows the vehicle in its standard set-up, whilst the white line in this graph shows the car setup with an anti-roll bar of much lower stiffness. In this case this has the result of allowing more roll, as the inside wheel does not lift as much as it does with the stiffer ARB rate. As Figure 14 shows,

the stiffer ARB rate allows the car to carry more speed into the corner, allowing it to break much later. The reduced weight transfer means that as well as less weight being shifted onto the outside wheels, more is being kept over the inside wheels. This has the result of significantly increasing the amount of grip available allowing this increased speed through the corner.

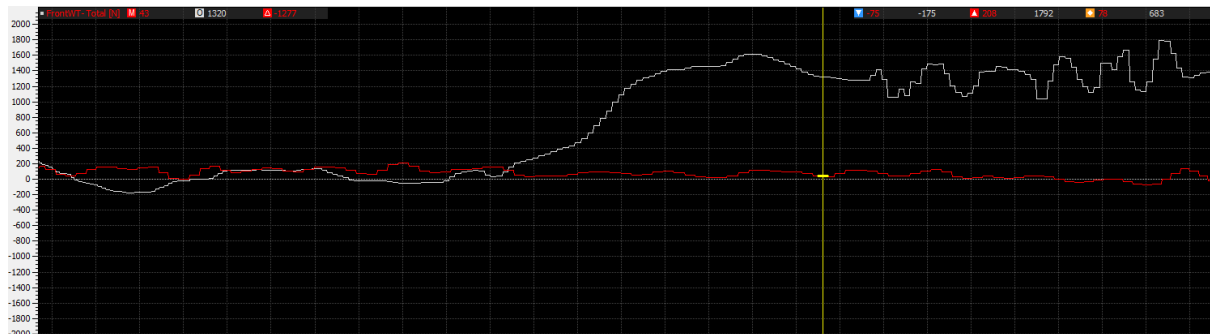


Figure 13: Weight Transfer (N) vs. Distance (m) at corner 1 for ARB comparison

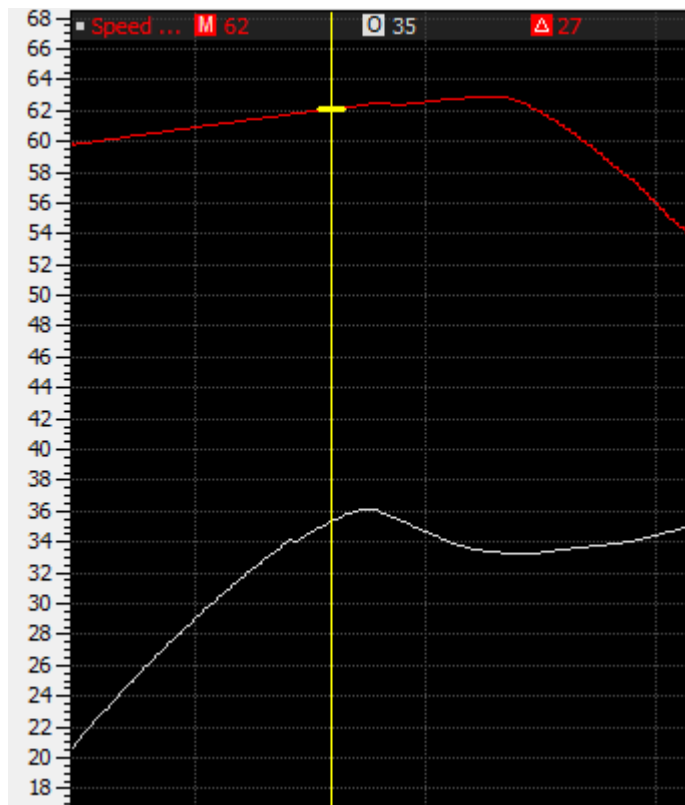


Figure 14: Speed (m/s) vs. Distance (m) at corner 1 for ARB comparison

Figure 15 to Figure 18 show how the dampers effect the weight transfer of the vehicle, over the course of an entire lap around the Pembrey circuit. Investigating the effect of a full sweep of the range of settings available shows that their effect on the weight transfer of the car is far less significant than might usually be expected. Furthermore, only weak correlations are evident from the data collected suggesting that perhaps the change in average weight transfer is in fact not, in this case, down to the damper settings, but down to the inconsistency of the driver. A driver out the loop simulation might reveal even smaller changes in weight transfer, than what is seen in the figures below.

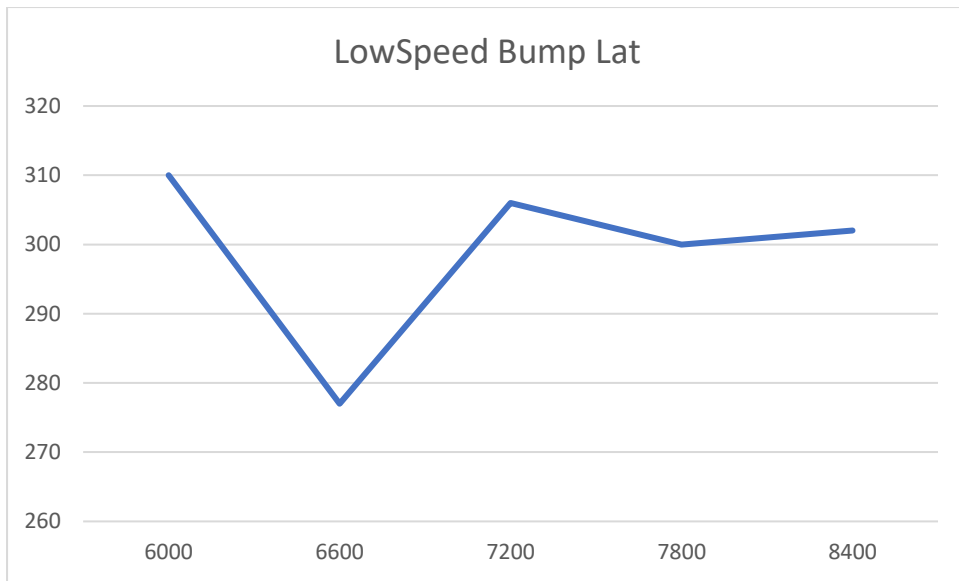


Figure 15: Average Weight Transfer (N) vs. Damp Rate (N/mm) for varying low speed bump settings

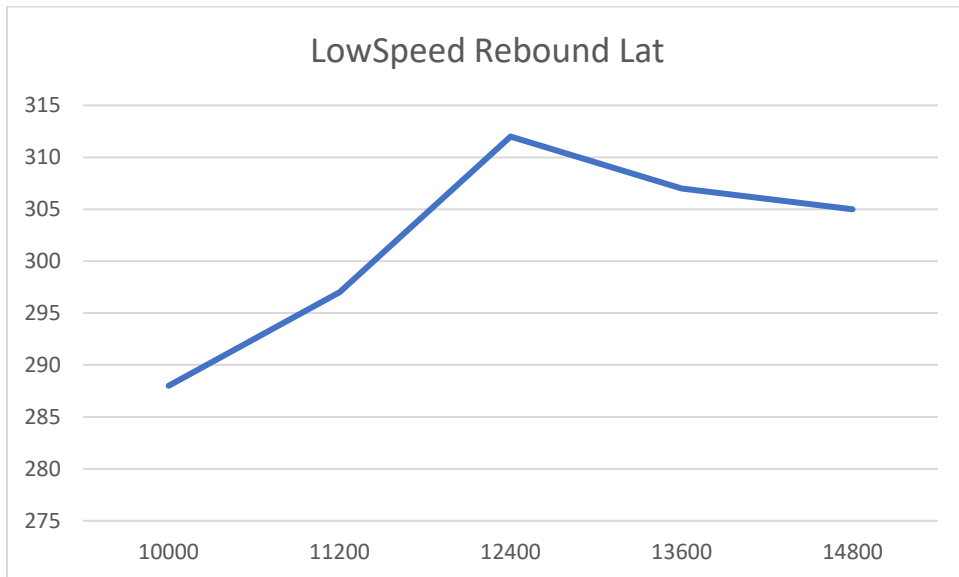


Figure 16: Average Weight Transfer (N) vs. Damp Rate (N/mm) for varying low speed rebound settings

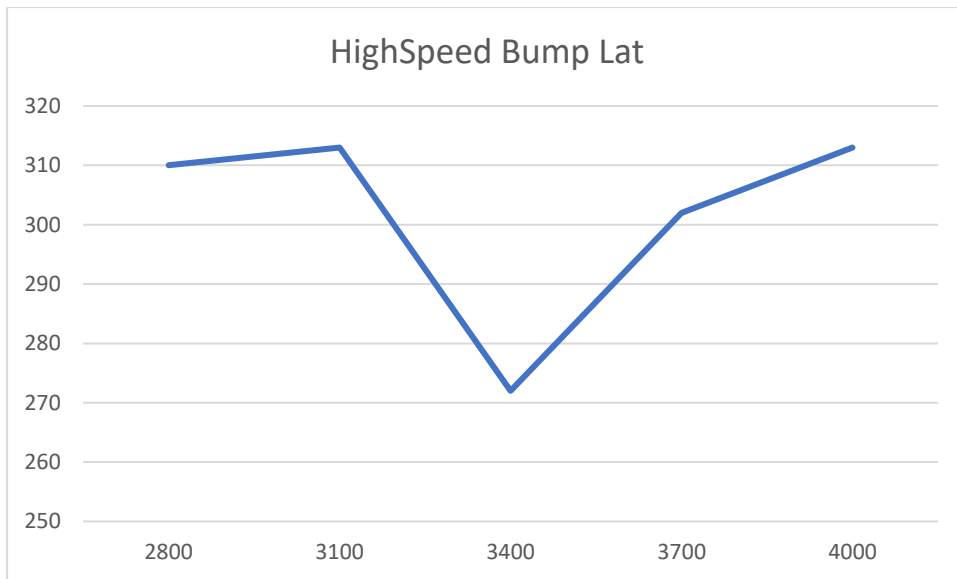


Figure 17: Average Weight Transfer (N) vs. Damp Rate (N/mm) for varying high speed bump settings

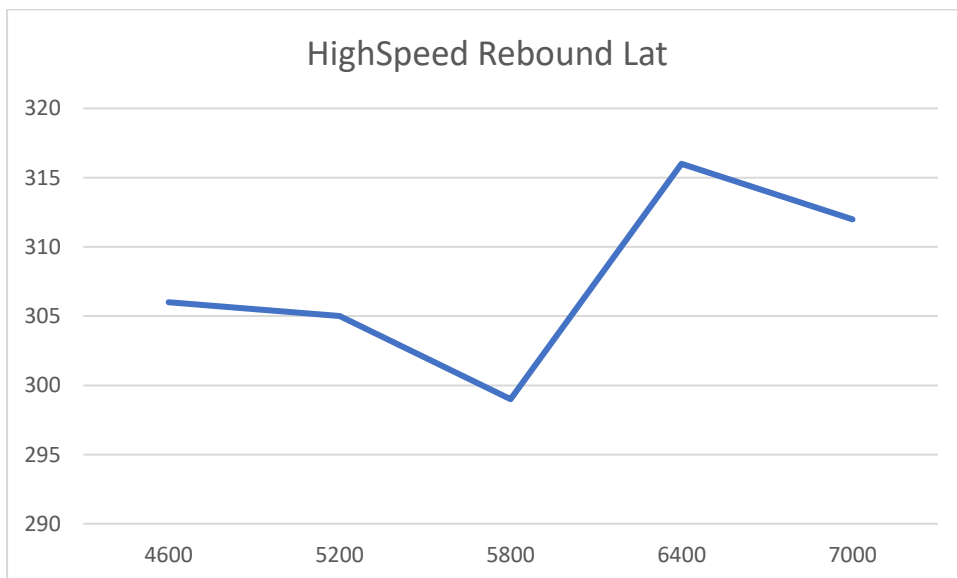


Figure 18: Average Weight Transfer (N) vs. Damp Rate (N/mm) for varying high speed rebound settings

Conclusion

Investigating the aerodynamic behaviour of the car has shown that there is always a trade off between drag and lift that must be considered when setting up the car. These factors must be considered in a dynamic state as well as in a steady state scenario and the motion of the vehicle can have a large effect on the loads.

To summarise the results and conclusions drawn throughout, it is evident that although a wide range of sections of the vehicles suspension are important when setting up a car for the ideal lap time and must work in sync with aerodynamic elements. No one area is more important than another. All the components work together in order to deliver the right levels of grip, whilst still allowing for drivability and without excessive levels of aerodynamic drag. However, at the end everything is down to the driver's ability and preferences as even the most perfectly set-up car will not work well if a driver does not like the way it behaves.

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Appendix

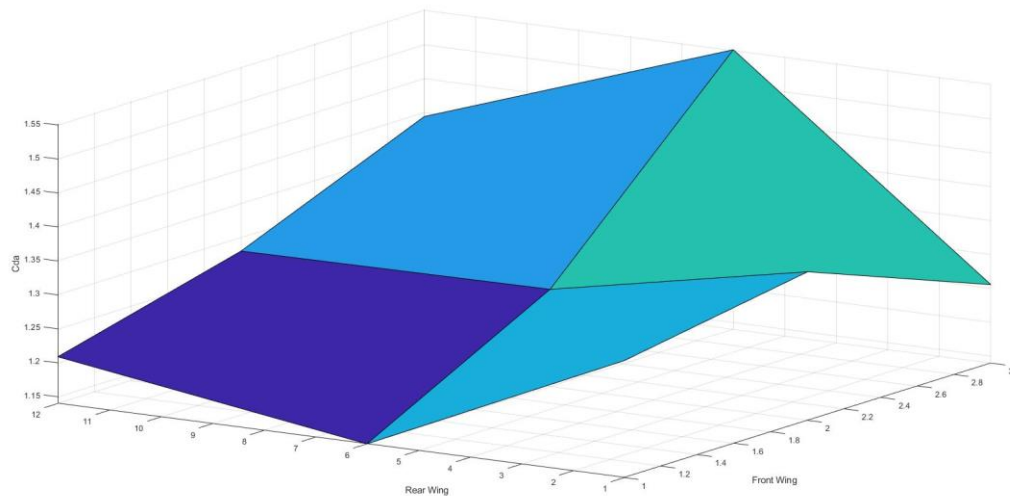


Figure 19: Coefficient of Drag vs. Splitter Setting vs. Wing Setting

Name	Summary
Expressions	
☒ Centre of Pressure [ratio]	'Front Aero' [N]/'Total Aero' [N])*100
☒ Coefficient of Lift [ratio]	'Total Aero' [N]/(0.5*1.223*'Speed' [m/s])
☒ AeroDrag [N]	'Cd'*0.5*1.223*('Speed' [m/s]^2)*1.2
☒ AeroLift [N]	'Total Aero' [N]
☒ Front Aero [N]	('Tire Load - FL' [N]+Tire Load - FR' [N])-(Total Weight Front' [kg]*9.81)+Long WT' [N]
☒ Rear Aero [N]	('Tire Load - RL' [N]+Tire Load - RR' [N])-(Total Weight Rear' [kg]*9.81)-Long WT' [N]
☒ Total Aero [N]	'Front Aero' [N]+Rear Aero' [N]

Figure 20: MoTeC Maths Channel Equations – Aero

Name	Summary
Expressions	
☒ Long WT [N]	((Total Weight Front' [kg]+Total Weight Rear' [kg]) * 'G Force Long' [G] * 9.81 * 'Centre of Gravity Height' [m]) / 'Wheelbase' [m]
☒ Lat WT [N]	((Total Weight Front' [kg]+Total Weight Rear' [kg]) * 'G Force Lat' [G] * 9.81 * 'Centre of Gravity Height' [m]) / (('Front Track' [m]+Rear Track' [m])/2)
☒ FrontWT-Actual [N]	('Tire Load - FL' [N]-Tire Load - FR' [N])/2
☒ RearWT-Actual [N]	('Tire Load - RL' [N]-Tire Load - RR' [N])/2
☒ FrontWT-Elastic [N]	('KwF' [N.m]*'Front Track' [m]*'RollAngle' [rad])/2
☒ RearWT-Elastic [N]	('KwR' [N.m]*'Rear Track' [m]*'RollAngle' [rad])/2
☒ KwF [Nm]	((Spring Rate FL' [N/m]+Spring Rate FR' [N/m])/2)*('Motion Ratio'^2)+Roll Bar Rate Front' [N/m]
☒ KwR [Nm]	((Spring Rate RL' [N/m]+Spring Rate RR' [N/m])/2)*('Motion Ratio'^2)+Roll Bar Rate Rear' [N/m]
☒ OverturningMoment [Nm]	'Vehicle Sprung Mass' [kg]*(9.81*'G Force Lat' [G])*((('Front Roll Centre Height' [m])'Rear Roll Centre Height' [m])/2)-CoG Height' [m])
☒ RollStiffnessRear	('Rear Track' [m]^2)*'KwR' [N.m]/2
☒ RollStiffnessFront	('Front Track' [m]^2)*'KwF' [N.m]/2
☒ RollAngle [rad]	'OverturningMoment'/'('RollStiffnessFront'+RollStiffnessRear)
☒ FrontWT - Damper	('FrontLeftDamperForce' [N] - 'FrontRightDamperForce' [N])/2
☒ RearWT - Damper	('RearLeftDamperForce' [N] - 'RearRightDamperForce' [N])/2
☒ Magic Number [ratio]	('FrontWT-Actual' [N])/('FrontWT-Actual' [N]+RearWT-Actual' [N])
☒ Magic Number (Actual) [ratio]	('FrontWT- Total' [N])/('FrontWT- Total' [N]+RearWT - Total' [N])
☒ FrontWT- Total [N]	'FrontWT-Elastic' [N] + 'FrontWT - Sprung Geometric'+FrontWT - Unsprung Geometric'+FrontWT - Damper'
☒ RearWT - Total [N]	'RearWT-Elastic' [N] + 'RearWT - Sprung Geometric'+RearWT - Unsprung Geometric'+RearWT - Damper'
☒ FrontWT - Sprung Geometric	('Vehicle Sprung Mass' [kg]/2)*('G Force Lat' [G] * 9.81*'Front Roll Centre Height' [m])/Front Track' [m]
☒ RearWT - Sprung Geometric	('Vehicle Sprung Mass' [kg]/2)*('G Force Lat' [G] * 9.81*'Rear Roll Centre Height' [m])/Rear Track' [m]
☒ FrontWT - Unsprung Geometric	'Front Corner Unsprung Mass' [kg]*('G Force Lat' [G]*9.81*'Tyre Rolling Radius' [m])/Front Track' [m]
☒ RearWT - Unsprung Geometric	'Rear Corner Unsprung Mass' [kg]*('G Force Lat' [G]*9.81*'Tyre Rolling Radius' [m])/Rear Track' [m]

Figure 21: MoTeC Maths Channel Equations – Weight Transfer

Figure 22: MoTeC Maths Channel Equations – User

Figure 23: MoTeC Maths Channel Equations – Damper

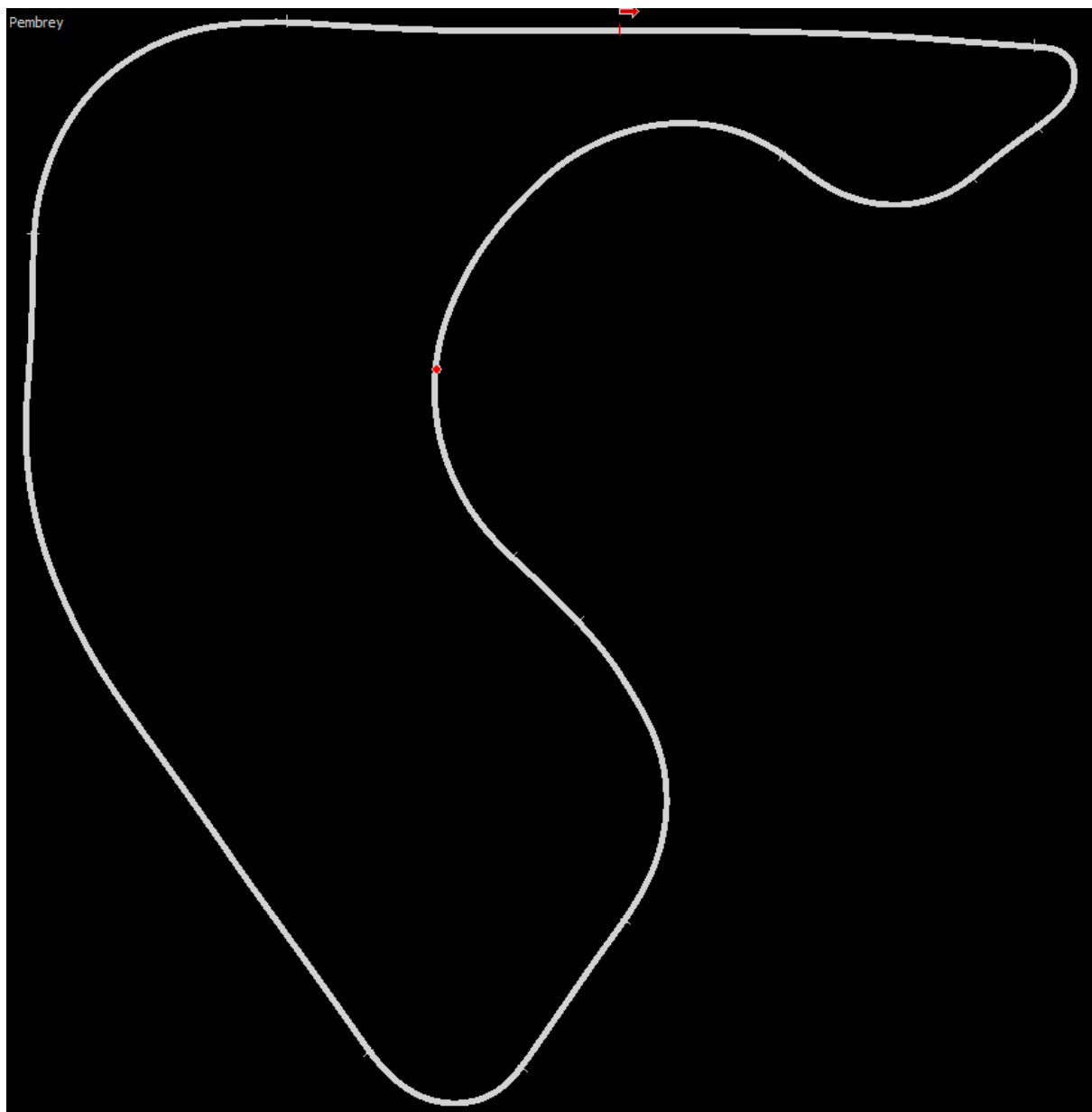


Figure 24: MoTeC Generated Track Map



Figure 25: Corner 1 used to investigate low speed cornering

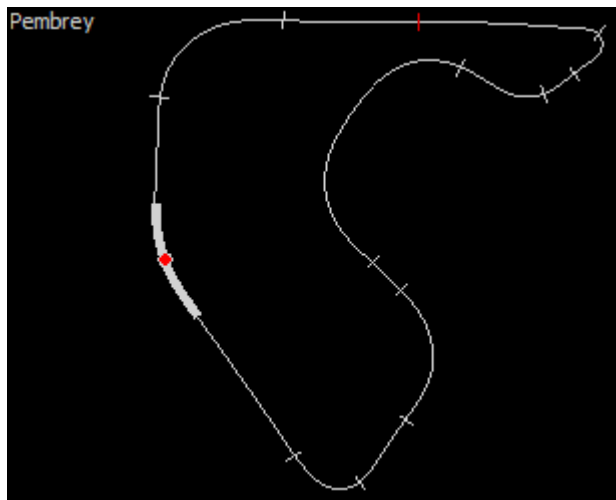


Figure 26: Corner 2 used to investigate high speed cornering



Figure 27: Longitudinal G Force (G) vs. Distance (m) for default setup, max wing and min wing

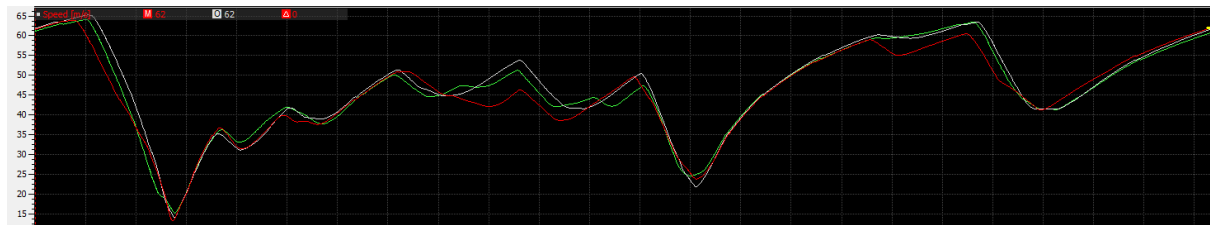


Figure 28: Vehicle Speed (m/s) vs. Distance (m) for default setup, max wing and min wing



Figure 29: Aerodynamic Lift (N) vs. Distance (m) for default setup, max wing and min wing – Unfiltered

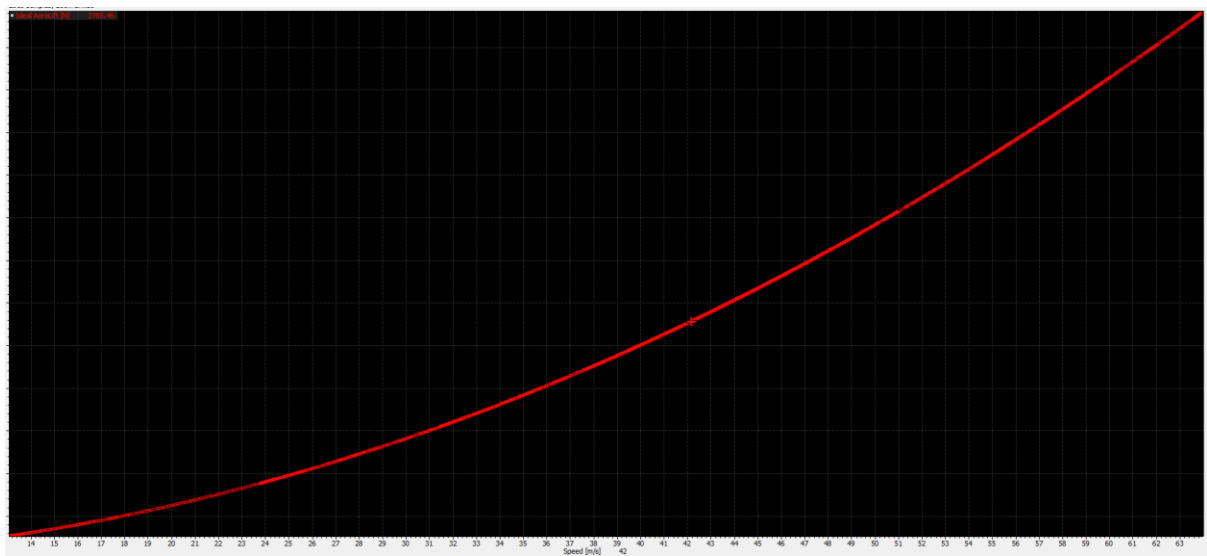


Figure 30: Ideal Aerodynamic Lift (N) vs. Speed (m/s)

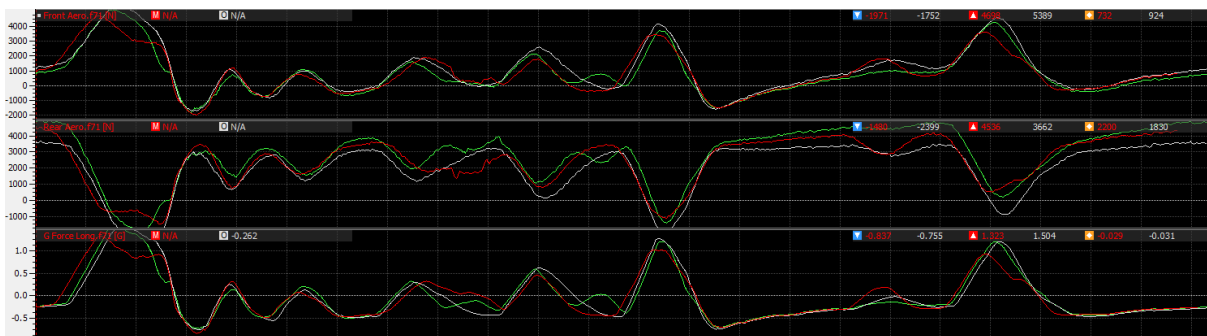


Figure 31: Axle Aero Loads (N) and G Force Long (G) vs. Distance (m)

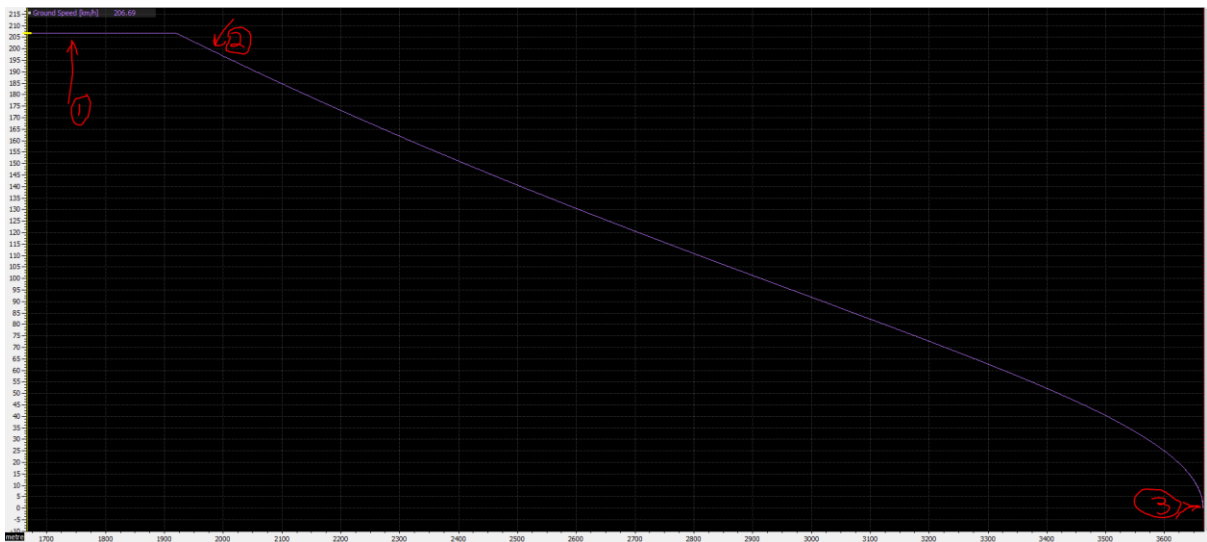


Figure 32: Aerodynamic Coast-Down

Aero	Front	2	ARB	Front	280 N/mm
	Rear	8		Rear	280 N/mm
Value		Units	Value		Units
Front Left			Front Right		

Tire pressure	195	Kpa	195	Kpa
Spring rate	237	N/mm	237	N/mm
slow bump	6600	N/m/s	6600	N/m/s
slow rebound	11800	N/m/s	11800	N/m/s
fast bump	3100	N/m/s	3100	N/m/s
fast rebound	5500	N/m/s	5500	N/m/s
packers	0	cm	0	cm
ride height	4.6	cm	4.6	cm
camber	-3.5	deg	-3.5	deg

	rear left		rear right	
Tire pressure	195	Kpa	195	Kpa
spring rate	237	N/mm	237	N/mm
slow bump	6600	N/m/s	6600	N/m/s
slow rebound	11800	N/m/s	11800	N/m/s
fast bump	3100	N/m/s	3100	N/m/s
fast rebound	5500	N/m/s	5500	N/m/s
packers	0	cm	0	cm
ride height	6.2	cm	6.2	cm
camber	-2.5	deg	-2.5	deg

Table 4: BPS Aston Martin default settings