

Race Engineering 2

by Josh William Youngs

FILE	4769_JOSH_WILLIAM_YOUNGS_RACE_ENGINEERING_2_159509_86557580.DOCX (5.32M)		
TIME SUBMITTED	01-APR-2019 02:38AM (UTC+0100)	WORD COUNT	2990
SUBMISSION ID	103748987	CHARACTER COUNT	17356

University of Wales Trinity Saint David

School of Engineering

Race Engineering



PRIFYSGOL CYMRU

Y Drindod Dewi Sant

UNIVERSITY OF WALES

Trinity Saint David

Written by: Josh William Youngs

Student Number: P146500

BSc Motorsport & Automotive Engineering

2019

Contents

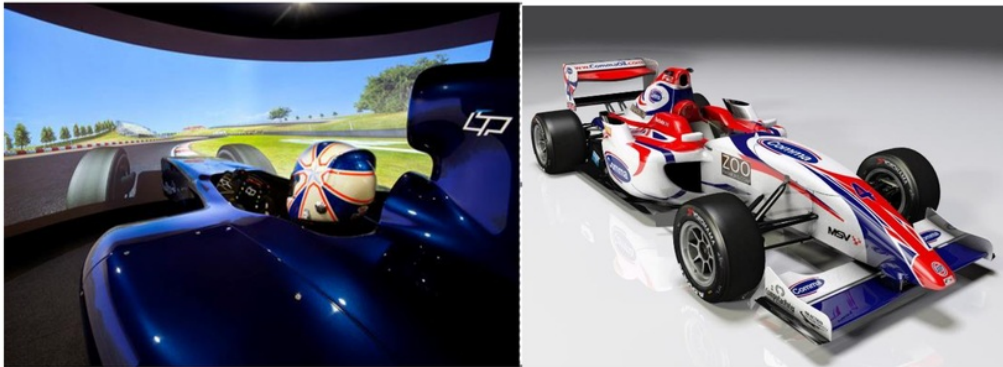
1.0 Introduction	3
2.0 Session Planning	4
2.1 Session 1 – Coast Down testing.	4
2.2 Session 1 Test Criteria	5
2.3 Team Roles	5
2.4 Session 2 – Setup Track testing.....	6
3.0 Results	7
3.1 Test Session 1 Results	7
3.2 Test Session 2 Results	8
3.3 Driver Feedback	9
4.0 Data Comparison	10
4.1 X/Y Total Aero Force vs Speed m/s	10
4.1.1 Comparison of Total Aero Force	10
4.2 Aero Force vs Lap Distance	11
4.2.1 Comparison of Aero Force over a lap	11
4.3 Wing Aero vs Lap Distance	12
4.4 Later Acceleration vs Lap Distance	13
5.0 Evaluation	13
6.0 Conclusion	13
7.0 Table of Figures	14
8.0 References	14
9.0 Appendices.....	15

1.0 Introduction

The base of this report will revolve around Aerodynamic testing that will be carried out within 2 simulations sessions. These sessions had to be planned to gather specific data needed to manipulate aerodynamics to improve overall car performance. The marker of “overall car performance” will be judged by lap time and also how comfortable the driver of the vehicle was during the testing sessions. Some of the vehicle setups will be analysed to see where they either gain or lose overall performance. Some of the defining factors that’ll be analysed:

- Negative Lift (Downforce)
- Longitudinal Weight Transfer
- Centre of pressure
- Downforce affect on front and rear axles.
- Driver Feedback

Platform



The platform for this report will be based on a Formula 2 car similar to the image above. The vehicle will be recreated in a Baseline Performance simulator so data can be gathered and compared. The gathering of the data is with the hope to find a good Aerodynamic balance for the vehicle. Formula 2 Cars like the one above, have prominent aerodynamic features like the front and rear wings. These are the devices in play which create the downforce. The manipulation of these components to increase vehicle performance will be the aim of the investigation

“Although human factors are frequently publicized as the reason behind the success or failure of one racing team or another, engine power, tire adhesion, chassis design and, recently, aerodynamics probably play a more important role in winning this technology race” (Katz 2006)

2.0 Session Planning

When testing in motorsport a definitive plan can prove essential to get the most out of time. Ensuring enough information can be gathered with a single session can make a difference. Setting goals to hit during each session can enable a team to gather the desired data. The goals within these sessions were made into “setups”. These setups were changes in the aero dynamic balance of the vehicle which will affect the overall handling.

2.1 Session 1 – Coast Down testing.

Coast down testing was carried out in the first session. A test plan was put together to gather data on different aerodynamic setups. A coast down test was carried out. “The coast down method has been successfully used, over a number of years by different researchers, in an attempt to determine the tyre and aerodynamic drag coefficients for normal road cars from track data”.C.M.Crewe 1994.

By using the coast down method, with the analysis tool motec, the aerodynamic properties can be collected to see how altering the front and rear spoilers affects the vehicle. By increasing and decreasing the angle of the spoilers, the amount of negative lift can be manipulated. Negative lift is also referred to as downforce, which is the amount of pressure, acting downward on the vehicle. It's this force which can aid handling performance.

The simulator used in the test sessions had 18 options (1 the lowest, 18 the highest) for spoiler angle. The testing session was limited to 1 hour per session. This meant that a plan needed to be devised to make the best of the time available. Ideally every single setting combination could be tested to gather the data from, but this wasn't an option within the time constraints. Within the team, a table was created of the best compromise setting, essentially leaving some of the possible wing angles out. Three specific points were identified along the range within the simulator, and these were used to create a test plan.

Wing Setting	Setting Value
Minimum wing	1
Medium wing	9
Maximum wing	18

With these settings confirmed, 9 combinations were created in order to test setup variations.

Front Wing Setting	Rear Wing Setting
Minimum (1)	Minimum (1)
Minimum (1)	Medium (9)
Minimum (1)	Maximum (18)
Medium (9)	Minimum (1)
Medium (9)	Medium (9)
Medium (9)	Maximum (18)
Maximum (18)	Minimum (1)
Maximum (18)	Medium (9)
Maximum (18)	Maximum (18)

2.2 Session 1 Test Criteria

At its core, coast down testing is to take a vehicle up to a specified speed, then “coast” to a stop. The term coast means to disengage drive and allow environmental forces to slow the car. These forces are the forces that act upon the car such as the Aerodynamic Drag force (drag created by the front and rear spoilers) and the resistance created by tyres.

Within the testing, the only variable changed was the amount of Aero Drag force. This was achieved by altering the amount of wing previously mentioned.

Coast Down testing Plan

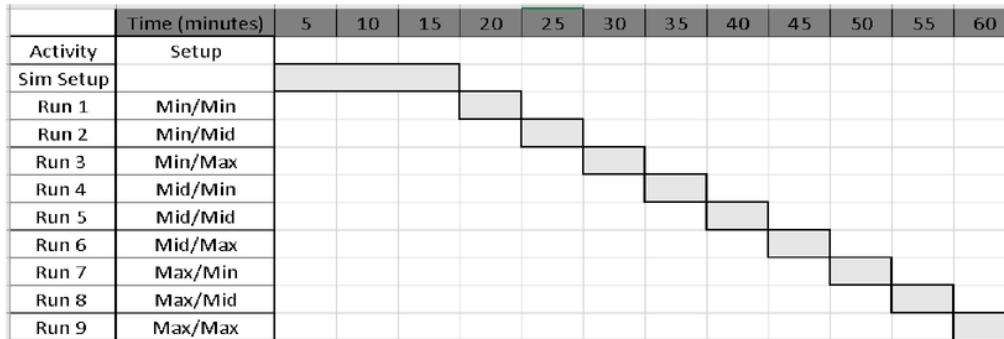


Figure 1 : Gantt Chart displaying the time scale for Test session 1

The plan was made to fill the whole hour productively. It was estimated that setup could take up to 15 minutes. This included briefing the driver on what we wanted him to perform. Then the term divided the remaining time by the minimum amount of session we wished to carry out (45minutes/9setups). This test plan is what was followed to carry out the coast down test. Although these are the selected time slots for the testing.

2.3 Team Roles

Motec Analyst – Someone needed to ensure that at the start and end of every session the computer using the Motec logging data was collected the data as required

Setup Technician – At the start of the session and the start of every test, a team member was required to start the race simulator, as well as change the vehicle setups. The Setup technician was also required to change the setup after every test run.

Live Race Analyst/Adviser – It was this team members role to make sure that the driver was driving consistently and keeping good time.

Event Analyst – It was this team members role to ensure that any mistakes made by the driver was taken note. These events can then be analysed post test session to see where the driver went wrong.

2.4 Session 2 – Setup Track testing

Test session 2 also took place in the simulator. But instead the setups were used around a track in a hot lap simulation. Similar to session 1, motec was in use during this test to collect data as the car went around the track with the different setups. With this data then, comparisons can be made with the data traces.

As the same with the first session, the team was set a strict time frame where we needed to get all the testing done. At the end of the first session, the team had finished slightly ahead of schedule. This mean the team could run a lap of pembrey race track to gather an idea on how long each lap will take. A lap was completed that the driver was confident was a decent pace, and then the second session was planned according to this laptime. Similar to first session, the same nine setups would be selected to test.

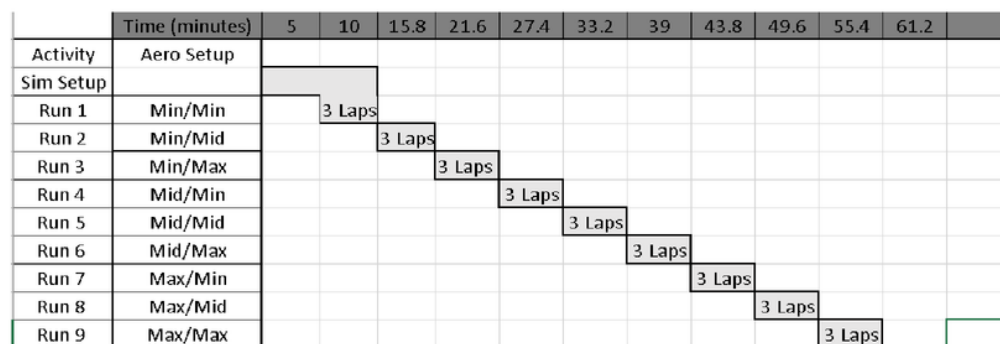


Figure 2 : Gantt Chart displaying the time scale for Test session 2

The timings worked out similar to the first session. In the first session the team wasn't sure on how long each coast down test would take, but after learning how long a lap will take, an estimation that each setup would take 5.8 minutes was made. After the first session, the team was more familiar with the simulator and could operate it faster, this needing less time to initially setup.

3.0 Results

3.1 Test Session 1 Results

After combining the coast down test with the data collection on Motec, values were able to be collected from each run which could be used in turn to calculate the individual drag coefficients of each setup.

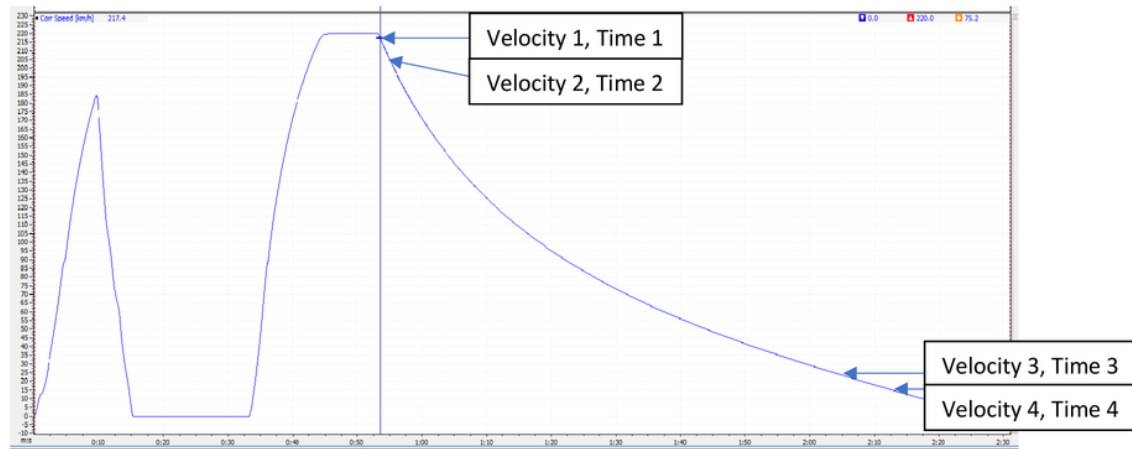


Figure 3: Table showing points where Velocity and Time frame is taken

The above image (figure 3) shows the speed of the car in the coast down testing. From left to right the trace shows the vehicle initially accelerating to the starting point. Then waiting for the go ahead to launch. The vehicle then accelerates to maximum speed and once the speed levels off, the car is set into complete neutral and let coast down to a stop.

From the slope where the car is coasting, the location of Velocities and time scales are taken. By doing this, the speed at the top of the slope at X:seconds, and be compared to the speed at the bottom by Y:seconds.

Between the Velocity points in the deceleration force;

$$\frac{(Velocity\ 2 - Velocity\ 1)}{(Time\ 2 - Time\ 1)}$$

This equation will be used to calculate the deceleration force between the first point, and also the second. The second deceleration points is used to calculate the rolling resistance:

$$(Mass * Deceleration\ rate\ 2)$$

From this point the Aerodynamic Drag can be calculated:

$$(Mass * Deceleration\ Rate\ 1) - Deceleration\ rate\ 2$$

The Ultimately the Coefficient of Drag can be calculated:

$$\frac{-((Mass * Decel1) - (Rolling\ Resistance))}{(0.5 * Air\ Density * ((Velocity\ 1 + Velocity\ 2)) / 2}$$

All equations – T.Tudor 2019.

		Static Loads				Constant Velocity loads				Aero Loads & Balance				Aero Lift Coefficients					
Aero Balance	Setup	Left front	Right Front	Rear Left	Rear Right	Vc(Km/h)	Vc (m/s)	Left front	Right Front	Rear Left	Rear Right	Aero F	Aero R	Aero Total	Center of pressure	VC (m/s)	Cl	Clr	ClT
Min-Min	1	1162	1163	1580	1580	220	61.11111	1764	2780	3310	3330	3210	3497	6716	47.35032166	61.11111	1.409562	46.78956	2.940857
Min-Mid	2	1162	1163	1580	1580	219.2	60.88889	1716	2709	3678	3670	3100	4188	7288	42.53567508	60.88889	1.36738	56.23959	3.214666
Min-Max	3	1162	1163	1580	1580	218.4	60.66667	1639	2656	4047	4066	2970	4953	7923	37.48580083	60.66667	1.319633	66.75622	3.520407
Mid-Min	4	1162	1163	1580	1580	219.9	61.08333	1873	3007	3301	3239	3755	3380	7135	52.62785068	61.08333	1.645786	45.24488	3.127174
Mid-Mid	5	1162	1163	1580	1580	219.1	60.86111	1954	3036	3390	3641	3635	4071	7706	47.17103556	60.86111	1.604827	54.69336	3.402145
Mid-Max	6	1162	1163	1580	1580	218.5	60.63889	1917	2910	4002	3995	3502	4837	8339	41.9934431	60.63889	1.557461	65.22264	3.708643
Max-Min	7	1162	1163	1580	1580	219.8	61.03333	1954	3331	3214	3185	4360	3249	7609	57.30056512	61.03333	1.912668	43.51109	3.337957
Max-Mid	8	1162	1163	1580	1580	219	60.83333	1987	3364	3563	3530	4295	3939	8175	51.81651376	60.83333	1.871877	52.94414	3.612502
Max-Max	9	1162	1163	1580	1580	218.2	60.61111	3216	3206	3938	3921	4099	4696	8795	46.8062615	60.61111	1.824639	63.3594	3.915028

Aero Lift Coefficients				Coast down data												
VC (m/s)	Cl	Clr	ClT	V1 (m/s)	T1 (s)	V2	T2	V3	T3	V4	T4	A1	A2	Rolling res	Aero drag	Cl
61.11111	1.409562	46.78956	2.940857	60.43	53.479	58.16	54.455	6.22	123.958	5.96	124.82	-2.32582	-0.30162	-168.0095128	-1133.549504	0.439366
60.88889	1.36738	56.23959	3.214666	60.22	15.914	57.63	16.959	6.18	85.699	5.85	86.713	-2.47847	-0.31609	-177.0114943	-1220.931089	0.475272
60.66667	1.319633	66.75622	3.520407	60.48	16.148	57.8	17.157	6.38	82.591	6.11	83.432	-2.6561	-0.32105	-179.7859691	-1307.627311	0.509499
61.08333	1.645786	45.24488	3.127174	60.43	15.831	57.9	16.837	26.08	41.529	25.37	42.519	-2.49508	-0.70577	-395.2286282	-1001.988072	0.390218
60.86111	1.604827	54.69338	3.402145	60.23	15.621	57.58	16.628	6.78	81.463	6.06	82.47	-2.63158	-0.31778	-177.9543198	-1295.729891	0.5089
60.63889	1.557461	65.22264	3.708643	60.47	15.657	57.71	16.64	26.61	37.885	25.83	38.867	-2.80773	-0.7943	-444.8055173	-1127.523086	0.440068
61.05556	1.912668	43.51109	3.337957	60.32	15.744	58.99	16.469	25.54	40.843	24.85	41.851	-2.66207	-0.69838	-391.0951174	-1099.645503	0.425371
60.83333	1.871877	52.94414	3.612502	60.4	15.432	57.5	16.469	26.7	37.736	25.95	38.732	-2.79653	-0.76844	-430.3278689	-1135.728062	0.445378
60.61111	1.824639	63.3594	3.915028	60.2	15.972	57.27	16.462	6.38	79.075	5.96	80.071	-2.94472	-0.32129	-179.9195787	-1468.125547	0.580346

3.3 Driver Feedback

Before analysing any of the data collected in the second session, one of the team members ensure to get the driver opinion of each setup as the setup was changed. When the making a race, driver may have a preference when it comes to handling. One may like a car that tends to oversteer, another may like a car that is loose at the back, in this case gathering the drivers feedback can be essential. In some cases a driver may put in a good lap in a setup they don't particularly like, so it's important they're comfortable.

Setup 1 – Min/Min (6/10)

- Low grip (understeer)
- Balanced
- COP close to centre

Set 2 – Mid/Mid (7/10)

- More grip than first setup
- Slightly Less understeer than setup 1

Setup 3 – Max/Max (9/10)

- Well Balanced
- Much better grip although still tends to understeer at speed
- Very comfortable

Setup 4 – Max/Min (1/10)

- Undriveable
- Way too much oversteer
- Feels like zero Downforce at rear

Setup 5 – Min/Max (5/10)

- Sluggish through corners
- Understeer at high speed
- Feels worse than setup 1

Setup 6 – Mid/Max (3/10)

- Oversteer
- Can feel rear downforce, but very unstable

These are some of the setup reviews from the driver. Including both the fastest lap and the slowest. When talking to a driver about which setup they felt was good, helps the data analysts searching for the ideal setup.

4.0 Data Comparison

4.1 X/Y Total Aero Force vs Speed m/s

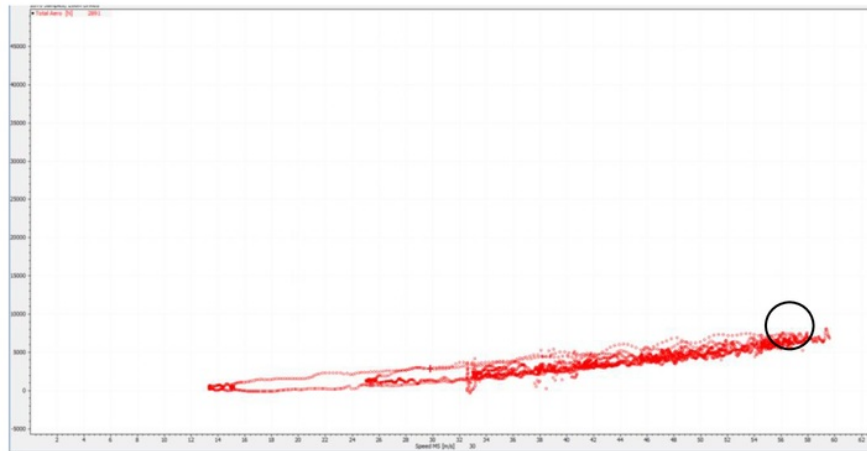


Figure 6 : X/Y Graph of Slowest Lap (Setup = Max-Min)

Figure 6 displays the amount of Total Aero Force as speed increases. It can be seen, as the speed increases there is an increase of the Aero Force. This is due to the vehicle passing through the air, and the vehicles wings creating negative lift.

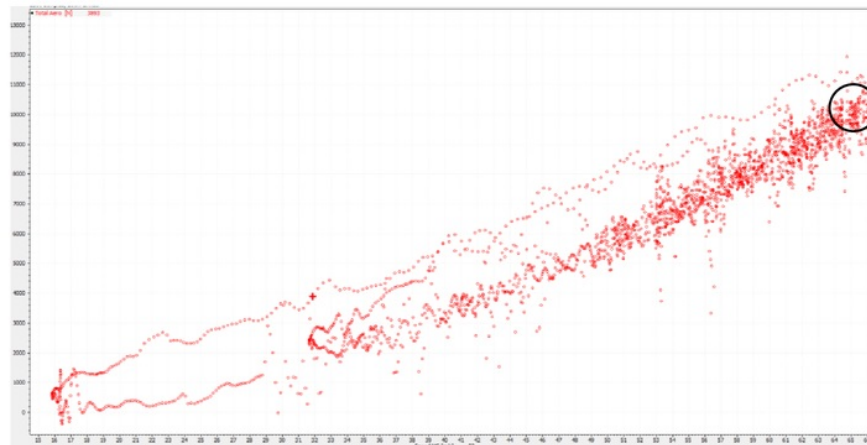


Figure 7: X/Y Graph of Fastest Lap (Setup = Max-Max)

4.1.1 Comparison of Total Aero Force

Figure 7 shows the same graph as figure 6, but for the fastest lap completed in Test Session 2. When comparing the graphs of Figure 6 & 7 it's quite obvious to see the sheer magnitude of the Total Aero force easily visible. The areas in both the graphs marks the highest average area of Aero Force. Figure 6 has a average of around 5000N, whereas Figure 7 shows much higher figures of around 11000N. This almost double amount of Aero force has enabled the driver to be over 7 seconds a lap faster. This comparison alone shows a balanced Aero setup makes all the difference.

4.2 Aero Force vs Lap Distance

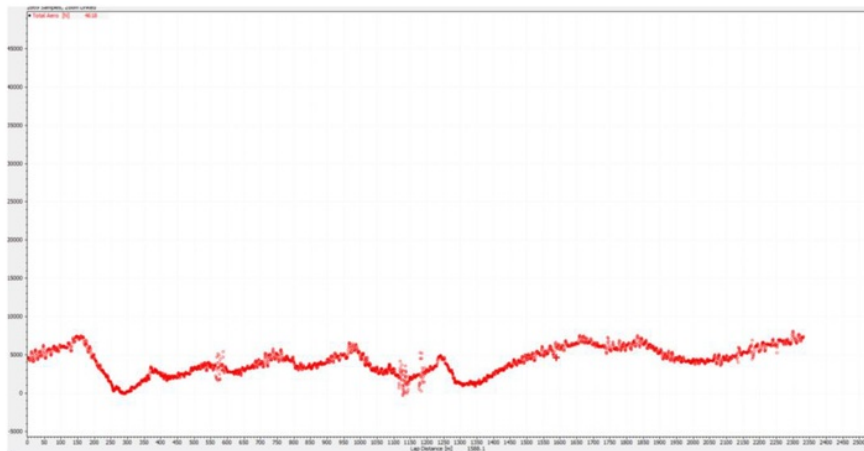


Figure 8 : X/Y Graph of Slowest Lap Aero vs Lap Distance

Figure 8 shows the aero force over the course of the lap distance. This graph depicts where on the track the car picks up its Aero Force. If the driver can drive at a higher speed, the aero force is naturally going to be higher. But if the driver is using an unbalanced setup like in figure 6&8, the overall speed is affected, lowering Aero Force.

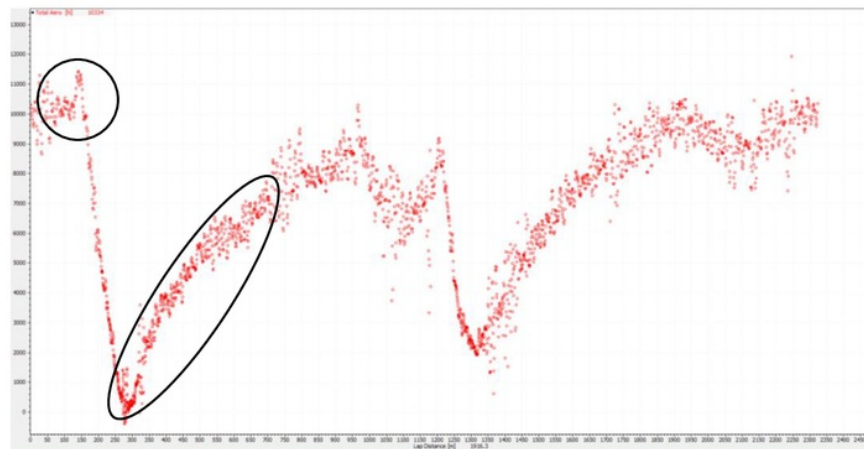


Figure 9 : X/Y Graph of Fastest Lap Aero vs Lap Distance

4.2.1 Comparison of Aero Force over a lap

Every lap logged is a “hotlap”, which means the driver will never start from zero. The lap starts as the car passes the start finish line at speed. Considering this, the starting magnitude of the aero force between Figure 8&9 shows how much impact a higher amount of wing angle has at speed. Looking at the circled areas on Figure 9, comparing the same areas on Figure 8, the rise and fall of Aero force between the 2 setups is blatant. Factors such as corner speed, and speed transitions (braking) show the dramatic inclination of Figure 9 compared to Figure 8. Figure 9 is much more sensitive to speed.

4.3 Wing Aero vs Lap Distance

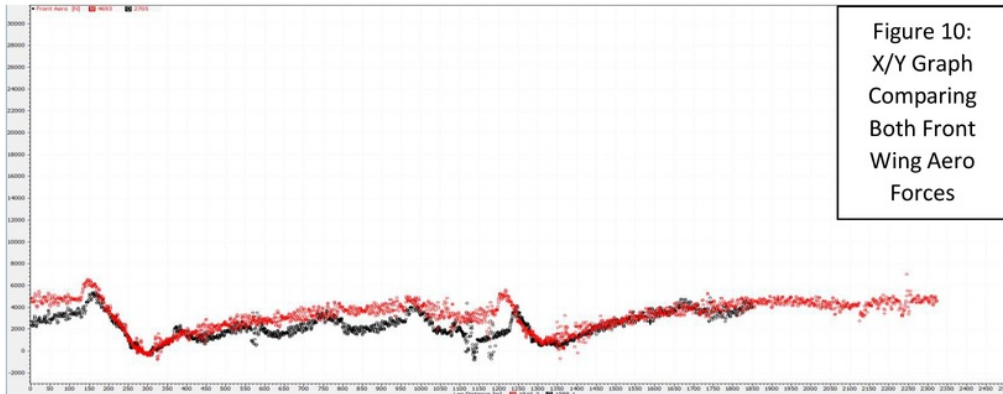


Figure 10:
X/Y Graph
Comparing
Both Front
Wing Aero
Forces

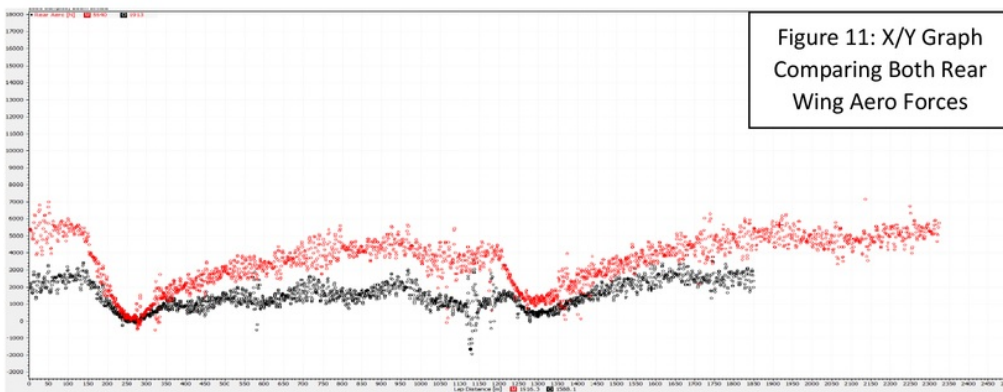


Figure 11: X/Y Graph
Comparing Both Rear
Wing Aero Forces



Figure 12:
Data Trace
Showing
Vehicle
Speed

When comparing the setups it's worth noting they have the same amount of front wing angle. But when analysing the data of the faster lap (Red trace) the front wing Aero Force is higher. When Looking at Figure 12, it's clear to see there is much more rear aero force, but this is because the setups represent the least and most amount of wing angle available.

Figure 13 Shows the speed difference between the 2 setups. In the middle section of the graph alone the faster setup (red trace) is around 30k/ph faster than the slower setup. This would explain the increase in front wing aero as the vehicle has more drag created by the front wing going at a faster speed.

4.4 Later Acceleration vs Lap Distance

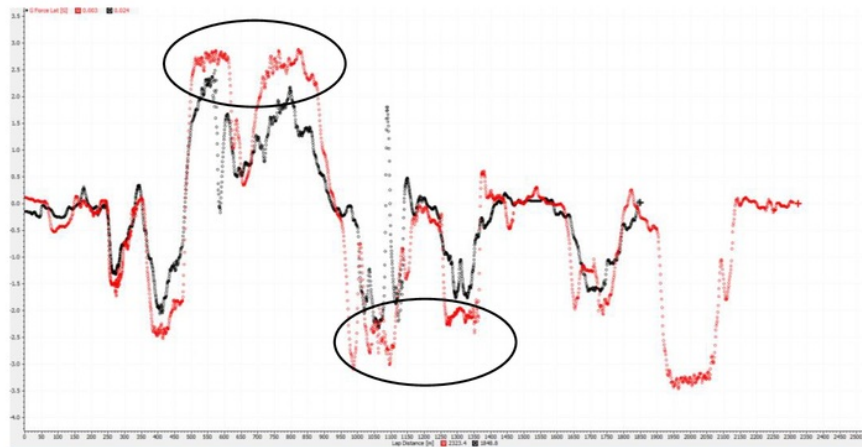


Figure 13: Data Trace showing Later Acceleration vs Lap Distance

Following on from Figure 13, the faster lap (red trace), shows a higher magnitude of Later Acceleration in general when compared to the slower lap (black trace). The setup on the faster lap also enabled the driver of the vehicle to hold onto the higher amount of Lateral acceleration. This is a sign that the car is able to keep better grip of the track surface.

5.0 Evaluation

When looking at the data presented, there is no arguing with the times. The driver was able to perform a quicker lap when the vehicle was subject to more downforce. This meant the driver of the vehicle was able to carry more speed through corners, attaining a better lap time.

When looking at all the data, the driver of the vehicle was most comfortable in the car when the wings both front and back were set to a similar setting. The fastest lap time was setting with the maximum amount of wing angle available. This means the track was suited to a heavier downforce requirement of the car

6.0 Conclusion

If given more time, there could have been more inquiries made into the different amount of wing angles. Within the test there was only 3 options that were applied to each of the wings, although the wings had 18 individual settings each. For instance, the wing setting "12" could be used in a future test to see how the driver would perform with this setting. The driver was able to achieve a time only 0.5 seconds slower than their fastest lap, with half as much wing angle (9). It would be interesting to run the test again to see if a balanced wing setting between 9 and 18 could provide a better marriage between cornering AND straight-line speed.

At the end of the second test there was some time left over. At this time because the team was happy the goals had been achieved, not much was done with this spare time. In a future test, contingency plans could be made to make sure if the test is completed early, something else could be changed in order to improve lap time i.e tire pressure, ride height or damper stiffness.

7.0 Table of Figures

Figure 1 : Gantt Chart displaying the time scale for Test session 1

Figure 2 : Gantt Chart displaying the time scale for Test session 2

Figure 3: Table showing points where Velocity and Time frame is taken

Figure 4 : Tables of figures found after the first test session

Figure 5 : Table of Laptimes found during test session 2. Green = Fastest Lap, Orange = 2nd Fastest Lap , Red = Slowest Lap

Figure 6 : X/Y Graph of Slowest Lap (Setup = Max-Min)

Figure 7: X/Y Graph of Fastest Lap (Setup = Max-Max)

Figure 8 : X/Y Graph of Slowest Lap Aero vs Lap Distance

Figure 9 : X/Y Graph of Fastest Lap Aero vs Lap Distance

Figure 10: X/Y Graph Comparing Both Front Wing Aero Forces

Figure 11: X/Y Graph Comparing Both Rear Wing Aero Forces

Figure 12: Data Trace Showing Vehicle Speed

Figure 13: Data Trace showing Later Acceleration vs Lap Distance

8.0 References

Katz, J. (2006). Race car aerodynamics. Cambridge, MA: R. Bentley

Tudor, T. (2018). Introduction to Aerodynamics.

9.0 Appendices

