

motec part 2

by Matthew Perry

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Aerodynamic Vehicle Testing and
analysis (F3 Car)

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Abstract:

This report has look at the basics of the front and rear wing of an f3 car and how it affects the car, also looks how it effects the aerodynamic drag and lift. Talks about what is aerodynamic and how the adjustments of the front and rear wing have impact on the vehicle and how it changes the grip of the vehicle to the track. This looks at the motec data and how it displays data and the expression used, also there few formulas in the report showing how data from the straight line tested is all entered into excel and how the cd value is found and put into the motec data. Vehicle simulator is discussed and the advantages of a race team owning one and why one would be need and what would it be used for. Also discuss how the test went for this report and brief statement of why would test the vehicle in these ways with the different wing setups.

Contents Page:

1. List of figures	Page: 4
2. Introduction	Page: 5
3. Literature Review	Page: 6-7
4. Methodology	Page: 8-9
5. Results and analysis	Page: 10-16
6. Conclusions	Page: 17
7. References	Page: 18
8. Appendices	Page: 19-23

1. List of figures:

Figure.1 total lift over Lap distance	Page: 10
Figure.2 total drag force overlap distance	Page: 10
Figure.3 total lift over speed	Page: 11
Figure.4 G force lateral over Speed	Page: 11
Figure.5 Front aero overlap distance	Page: 12
Figure.6 Rear aero overlap distance	Page: 12
Figure.7 Cop	Page: 13
Figure.8 Cop overlap distance	Page: 13
Figure.9 Understeer overlap distance	Page: 14
Figure.10 Understeer over Cop	Page: 14
Figure.11 lateral against understeer	Page: 15
Appendix.1 G force later over Speed (F18 R18)	Page: 19
Appendix.2 G force later over Speed (F9 R9)	Page: 19
Appendix.3 G force later over Speed (F1 R6)	Page: 20
Appendix.4 Maths expression	Page: 20
Appendix.5 Cd value	Page: 21
Appendix.6 Driver feedback	Page: 22
Appendix.7 spread sheet straight line testing	Page: 23

2. Introduction:

This report is looking at the aerodynamics of a formula 3 car, it's going to discuss the impact it has on the handling performance by altering the front and rear wing angle. The test procedure carried out to retrieve the relevant data will be discussed, the software used to read the data collected will be shown and what is needed to be able to show understeer, aerodynamic Lift and aerodynamic drag and many more. The data being used will be display in scatter plots and histograms, these graphs allow anyone to be able see two or three sets of data displayed for example total lift overlap distance. The three sets of data displayed can be seen in different colours on the graph to see the difference in them and compare them.

3. Literature Review:

What is aerodynamic? Aerodynamic is the flow of air over and under the vehicle, by having this flow it generates drag and lift, by having lift and drag it's good to get as much clean air as possible over and under the car. The drag force is the air resistance go against the car in the option direction to the vehicle. Aerodynamic lift consist of positive and negative lift, negative lift is what a race car would want more of as it pushes down on the vehicle which means improved grip between tyre and surface, however positive lift is something a race team will try to avoid due to the fact it does the opposite of negative and reduces tyre grip. There caused by different pressures above and below vehicle which results in vehicle positive lift or vehicle negative lift (down force) (wilde and johnson, 2019).

The aerodynamics can affect how the car handles, alterations to the angle of the front and rear wing can change the vehicle performance in handling, fuel consumption and top speed. The front wing can have such an impact on the vehicle downforce, the vehicle front wing can produce so much down force that its equivalent to twice the vehicle weight just in down force on the front end (Computational Fluid Dynamics | CFD | TotalSim, 2019). The front wing is very sensitive the smallest adjustment makes a very big difference in vehicle handing and how it feels to drive. By making the alterations to the front wing will alter how much downforce is produced on the front wing, due to the changes on front wing this can change the total amount of down force between front and rear of the vehicle, this would allow the team to eliminate over or understeer by making the correct adjustments. The advantage of being able to adjust the front wing means the ability to change the setup of the vehicle depended of circuit, weather tyre wear and driver preference. The main point of the front wing is not only to create downforce but to also be able to pass good clean air from the front to the diffuser and underfloor.

The rear wing has a big impact on the vehicle downforce to put it into perspective a third of the vehicles downforce comes from the rear wing. The rear wing creates downforce by altering the direction of airflow over the car, "using Newton's third law, every force has an equal and opposite force" according to F1insight.co.uk, 2019. By making the air particles move upwards (vertically) this will the then push the car down creating good downforce which means more grip. The rear wing is one of the components that gets altered quite a lot for each and every track, being that the wing creates a lot of drag the race teams use this to their advantage by being able adjust the rear aerodynamic load to suit the track. As the air flows over the rear wing it is then interrupted by design of the wing, which creates a drag force. The rear wing can reduces the top speed of the vehicle by a significant amount which is very noticeable, the fuel consumption can change due the vehicle trying to get through the air resistance (Groote and team, 2019).

The use of a race simulator has many advantages, a race simulator is setup of a computer programme to simulate the real life thing, it a very useful tool. It's very realistic the feedback through the steering wheel and pedals is as if actually driving a real life car, visual close to realistic it's like actually being there and the sounds. This way can test also sorts of setup and its safer for the driver as can't physically get hurt. The main advantages of this is can set up the simulator to represents the race teams vehicle and little fine tuning of the vehicle can be done on the simulator first before doing it on the actual car, this will also save time and money. This can not only be used to improve the vehicle also the drivers skills can be improved by the practice of many setups and learn the corners of tracks in more detail as well. If the vehicle was to have a big change in design for example front wheel drive to rear wheel drive the driver can get a feel through the simulator before getting into the real vehicle (Simulator, 2019). Using the same is good easy safe way to retrieve data and saves a lot of money as don't have to take car to the actual track, can just practice and do a test plan and retrieve data. The other advantage is if want to train people in different area such as driver, collecting and reading data, car setup, and recording drivers feedback all of these areas can be improved or train to a new team member.

Coast down test is a way of calculate or seeing the vehicle aerodynamic drag, this is done by getting driver the vehicle to a set speed for every setup and then putting it in neutral and coast (free rolling) to a stop. Different setups being adjusting front and rear wing to see the effects on drag it has.

By adjusting or changing the car components, circuit testing is good to see how the vehicle performs around the track and how the acceleration, braking, aerodynamic, drag, and lift to see the affects that the vehicle lap time and how much fuel is used also can learn what setup is needed for what track. Helps with driver to learn the feel for the car for each and every setup and what he feels his best for his driving style, which will allowing him to give feed back to the team which they interpreted that into the car by adjusting the vehicle components, if the team have two drivers may have two setups for two drivers.

4. Methodology:

For this report to be completed a few things had to be done such as simulator testing, excel sheet, equation and motec. Motec is a data logger which records all the information of the vehicle which can then be displayed in motec and the equation and math channel can be added to display varies things for example speed, lap distance and total aerodynamics lift and many more. Using an excel spread sheet means information from the testing can be entered and formulas can be added to calculate many things. The testing consisted of a coast down test with different setups got the vehicle up to speed then neutral and coast down this was used to calculate cd and many other as will be shown below of the formulas. The other test procedure after the straight line testing is a silver stone track which has fast straight parts and corners and why would a race team want that so can see the effects of the different set ups have on the vehicle not only in a straight line but round the tight corners and slow speed and the high speed corners to see how the setup effect cornering acceleration braking and over and understeer.

- Excel sheet formulas:
 - Static loads below are taken of motec by using tyre loads and values are entered depended of set up.
 - Left front
 - Right front
 - Left rear
 - Rear right
 - Constant Velocity, take tyre Loads at top speed in motec and take the tyre loads.
 - Velocity (km/h)
 - Left front
 - Right front
 - Left rear
 - Right rear
 - Aero loads and balance
 - Aero front = front static loads + front constant velocity loads
 - Aero rear = rear static loads + rear constant velocity loads
 - Aero total = aero front + Aero rear
 - Centre of pressure = aero rear / aero rear + aero front * 100
 - Aero Lift Coefficient
 - Velocity (m/s) = velocity (km/H) * 1000/3600
 - Lift coefficient front = $2 * \text{aero front} / \text{air density} * \text{velocity m/s}^2$
 - Lift coefficient rear = $2 * \text{aero rear} / \text{air density} * \text{velocity m/s}^2$
 - Lift coefficient total = Lift coefficient front + Lift coefficient rear
 - Coast down Data
 - Velocity 1 = just after put in neutral
 - Time 1 = time of velocity 1
 - Velocity 2 = 5 clicks after velocity 1
 - Time 2 = time of velocity 2

- Velocity 3 = just before the end of coasting
- Time 3 = time of velocity 3
- Velocity 4 = 5 clicks after velocity 3
- Time 4 = time of velocity 4
- Acceleration 1 = velocity 1 – velocity 2 / time 1 – time 2
- Acceleration 2 = velocity 3 – velocity 4 / time 3 – time 4
- Drag Forces
 - Rolling resistance = acceleration * mass
 - Aero drag = mass * acceleration 1 * - mass * acceleration 2
 - $Cda = 2 * (mass * acceleration 1) - (mass * acceleration 2) / air\ density * (velocity 1 + velocity 2) / 2 ^2$
 - Mass = static loads left front + right front + left rear + right rear / gravity
 - Ava RR = average of the rolling resistance
 - $Cd = Cda / 1.2$
- As you can see the motec Equation below, all these equation used in motec to display the relevant data. The list below are all the equation used to plot the graphs. The cd value for the setup is taking of the straight line testing of the same setup and entered into the motec excel sheet to use the cd value for the setups. Akarman steer was calculate by going at a slow steady speed so can calculate the ratio between steering wheel angel and the actual wheel angle.
 - Total aero
 - Aero drag force
 - Speed ms
 - G force lateral
 - Front aero
 - Rear aero
 - Cop
 - Lap distance
 - Understeer

Name	Summary
Expressions	
☒ speed ms [m/s]	(Corr Speed' [km/h] * 1000) / (60*60)
☒ Long WT [N]	(Mass KG' [kg] * ('G Force Long' [G]*-1)*'g' [m/s/s]*'CoG' [m])/wheelbase' [m]
☒ Front aero [N]	('Tire Load - FL' [N] + 'Tire Load - FR' [N]) - ('FLO' [N] + 'FRO' [N]) + 'Long WT' [N]
☒ rear aero [N]	('Tire Load - FL' [N] + 'Tire Load - RR' [N]) - ('RLO' [N] + 'RRO' [N]) - 'Long WT' [N]
☒ total aero [N]	'Front aero' [N]+rear aero' [N]
☒ COP [ratio]	('Front aero' [N] / total aero' [N]) * 100
☒ aero drag force [N]	$0.5 * 'air\ density' [kg/m^3] * 'CD' * 1.2 * ('speed\ ms' [m/s] * 'speed\ ms' [m/s])$
☒ comer radius [m]	$('speed\ ms' [m/s] * 'speed\ ms' [m/s]) / ('g' [m/s/s] * 'G\ Force\ Lat' [G])$
☒ akaman wheel steer [rad]	$('wheelbase' [m]) / ('comer\ radius' [m])^-1$
☒ akaman steering pct [%]	'akaman wheel steer' [rad] * (28.55/0.1080)
☒ understeer [%]	abs ('Steering Wheel Pct' [%]) - abs ('akaman steering pct' [%])
Constants	
☒ air density [kg/m³]	1.223
☒ CoG [m]	0.23
☒ FLO [N]	1162
☒ FRO [N]	1162
☒ g [m/s²]	9.81
☒ Mass KG [kg]	560
☒ RLO [N]	1580
☒ RRO [N]	1580
☒ wheelbase [m]	2.73

Appendix.4 Maths

5. Results and analysis:

Red F18 R18

Black F9 R9

Green F1 R6

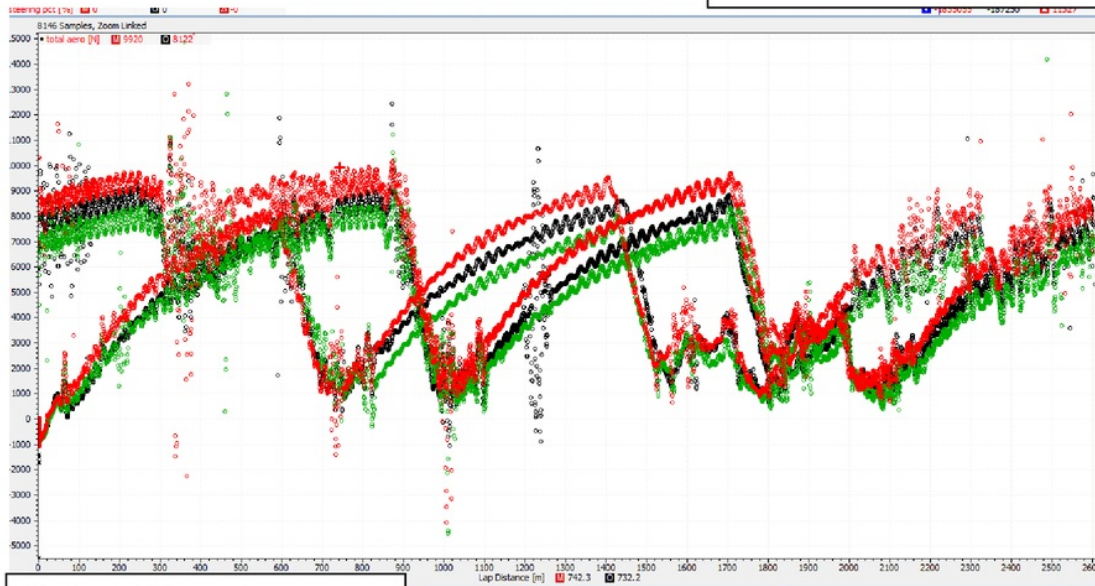


Fig.1 total lift over Lap distance

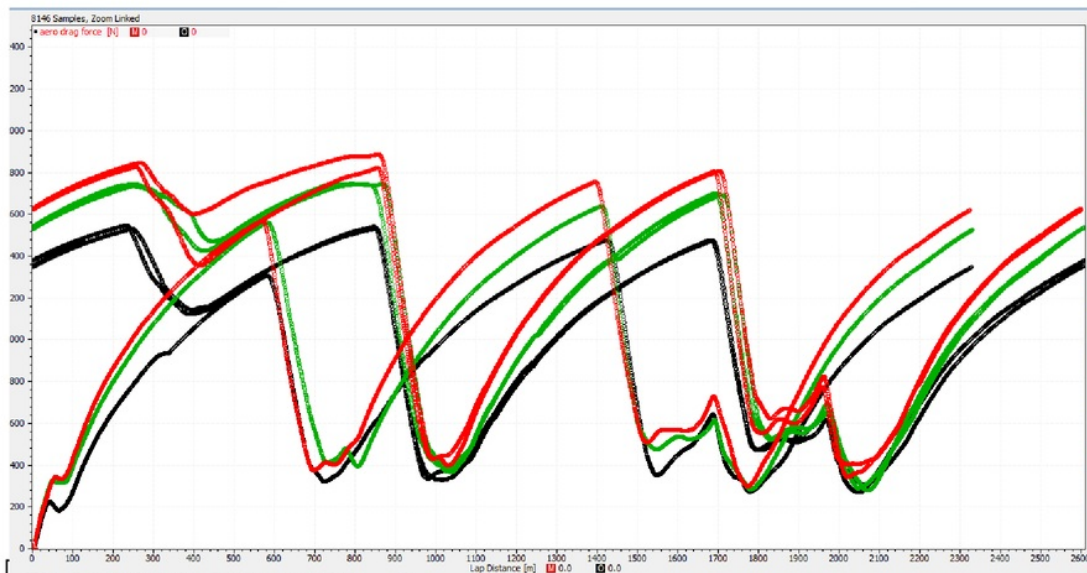


Fig.2 total drag force overlap distance

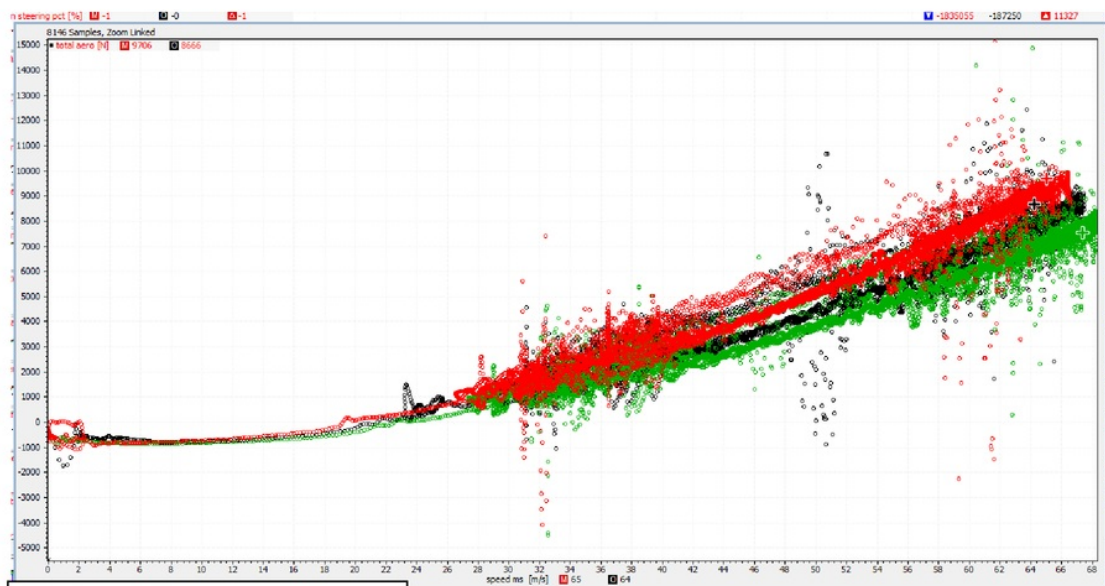


Fig.3 total lift over speed

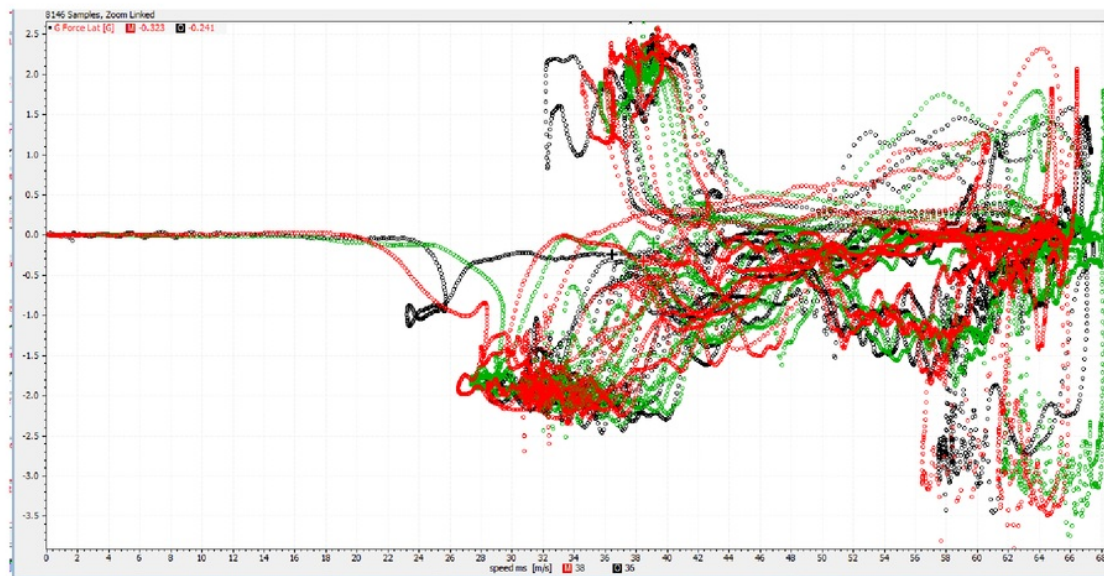


Fig.4 G force lateral over Speed

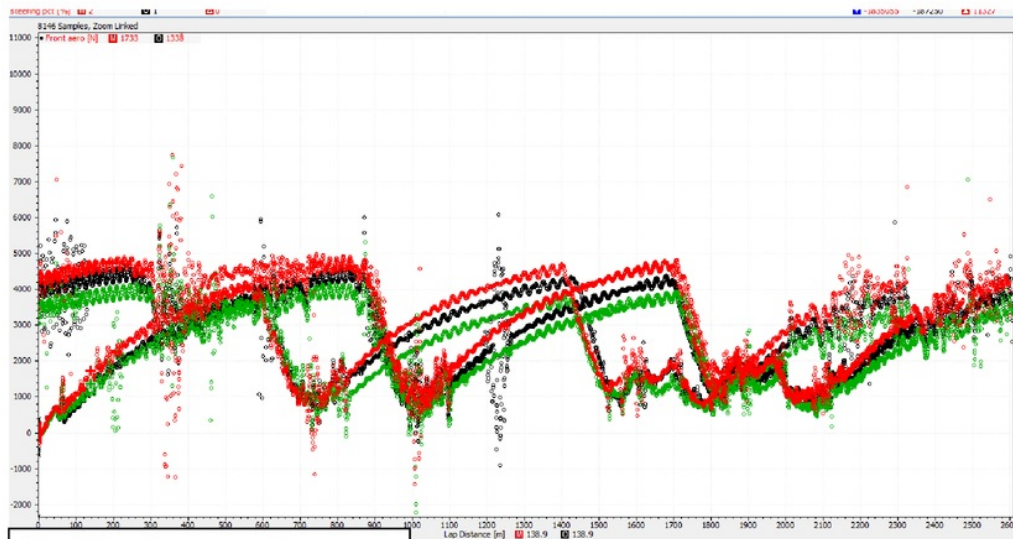


Fig.5 Front aero overlap distance

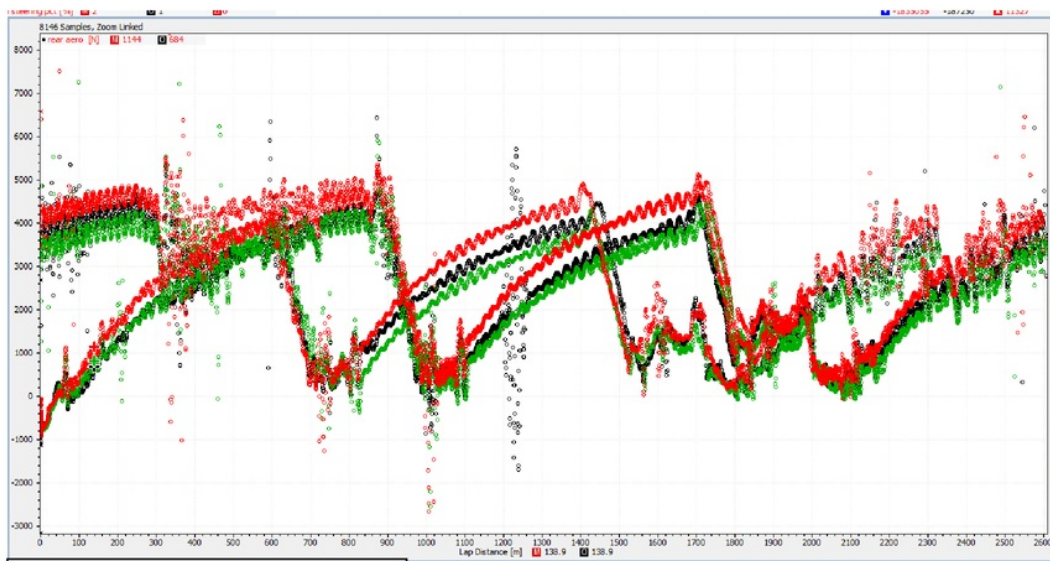


Fig.6 Rear aero overlap distance

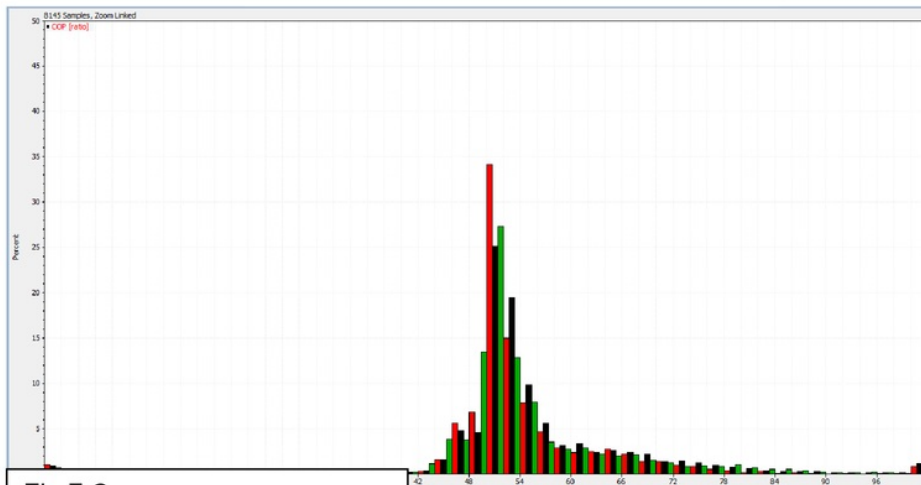


Fig.7 Cop

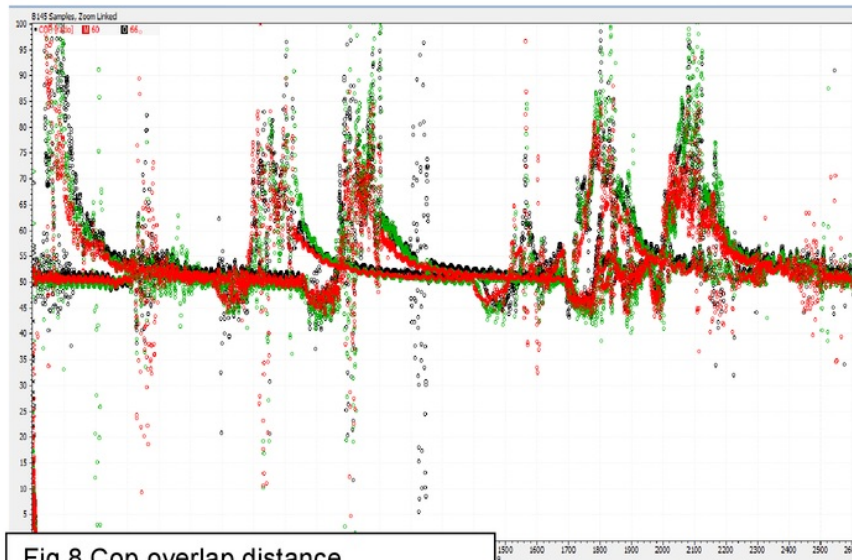


Fig.8 Cop overlap distance

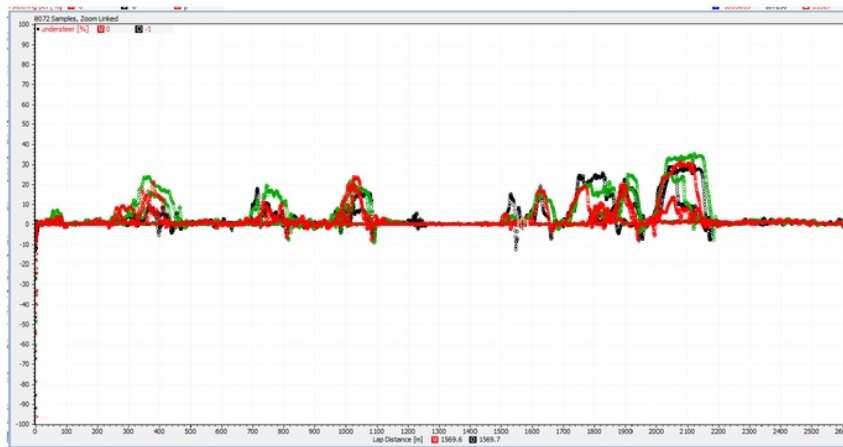


Fig.9 Understeer overlap distance

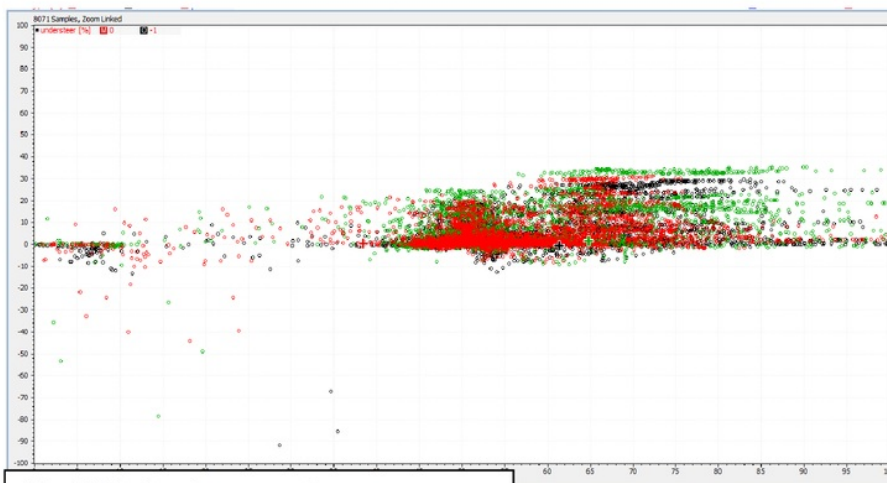


Fig.10 Understeer over Cop

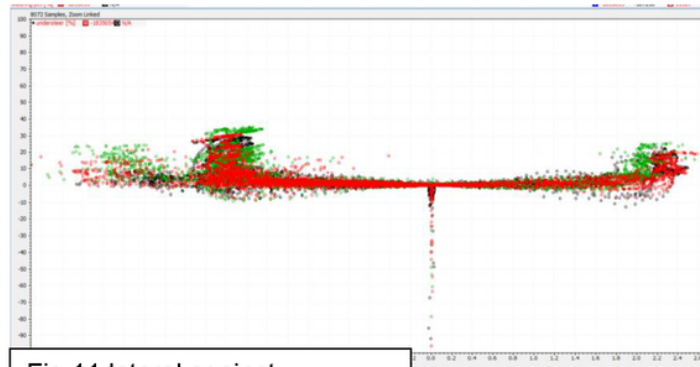


Fig.11 lateral against understeer

- Fig.1: You can see that the red line has the maximum downforce which is what is expected considering the front and rear wing are at maximum angle to allow for maximum negative lift.

Fig.2: the red line has the disadvantage of being the one that has the highest drag force, black has the lowest drag force than the green line would think the black line has more drag due to the rear and front are angled where as the green line is just the rear wing.

- Fig.3: shows the increase in speed also increase the downforce will improve handling.
- Fig.4: Showing G force lateral over speed by looking at the graph can see which one has more lateral g meaning which one can carry more speed through the corners.
- Fig.5: Front lift over distance red has the most front negative lift or downforce due to the angle of the wing.
- Fig.6: Rear aero can see the red has the most rear aero meaning has most negative lift or downforce due to angle of rear wing not much difference in other two set ups.
- Fig.7: Cop (Cop Centre of pressure) percentage of how long can spend at that centre of pressure out of whole lap.
- Fig.8: (Cop Centre of pressure) over distance.

- Fig.9: Understeer overlap distance shows that there a lot more understeer in the three set ups than over steer the red line set up the maximum angle on both wings has the least amount of understeer.
- Fig.10: Understeer over Cop
- Fig.11: lateral against understeer

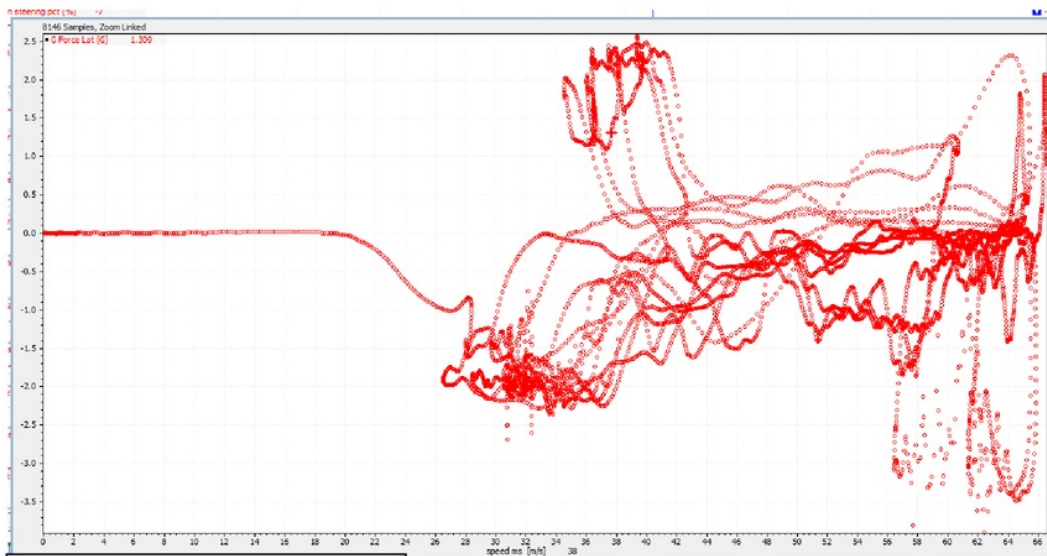
6. Conclusions and evaluation:

The motec data containing f1 r1 is corrupted so this can't be used as it won't be very accurate and difficult to use due to the fact that the car going round the track is behind compared to the data showing. The simulators are good but never be the real thing as the driver won't feel the outside air and g force of acceleration and the force of braking. The computer is never going to be as good as the real life think. Using the excel to calculate the drag and lift is very good as can see how the effects of the front and rear wing impact the vehicle handling performance. By being able to look at the data and produce the graphs can see where improvements can be made and even the impacts of mistake have, by having a fault with the vehicle by using this data can be easily found and rectified. The testing could have gone better if one group did ride heights and the other did front and rear wing adjustments or a different way round just to be able to get more data. Both groups forgo. About akarman steer due to this a check list should have be done of what data needed use same check list for both groups so can see what been done,

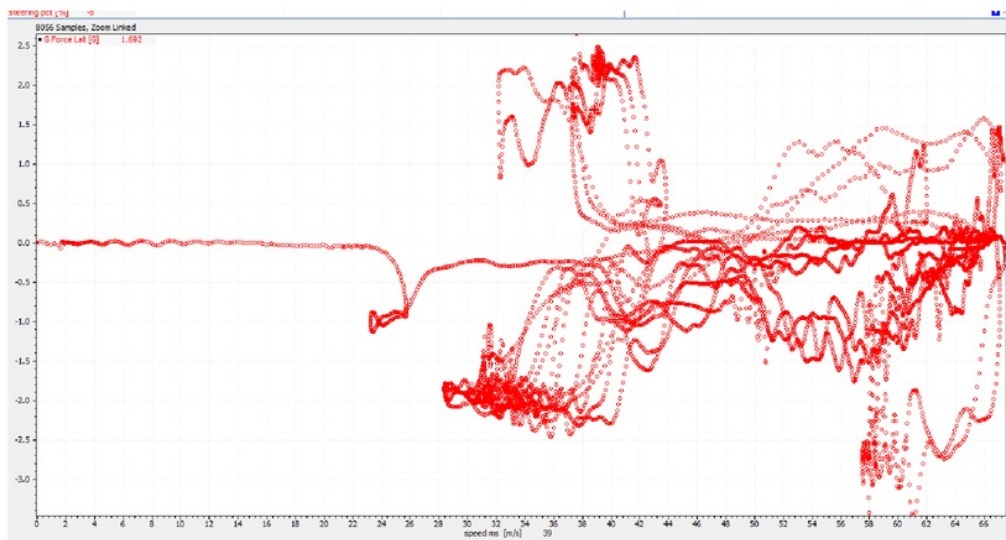
7. References:

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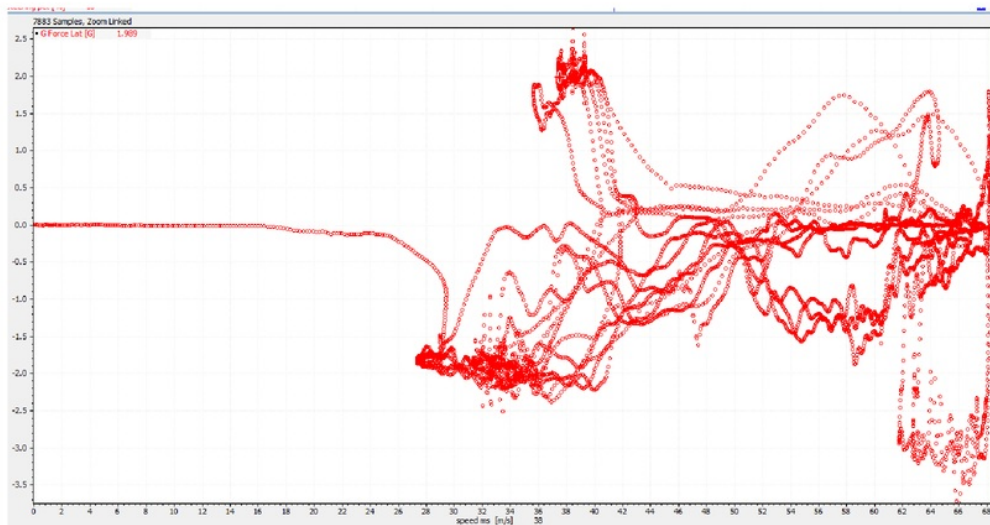
8. Appendices:



Appendix.1 G force later over Speed (F18 R18)



Appendix.2 G force later over Speed (F9 R9)



Appendix.3 G force later over Speed (F1 R6)

Maths

Math Files :

- Global Maths
 - User
 - MoTeC
 - Temporary
 - Local Maths
 - 14:08:52, 28/02/2019, +BPS, Silvers
 - 14:05:09, 28/02/2019, +BPS, Silvers
 - 14:28:50, 28/02/2019, +BPS, Silvers

Math Items :

Name	Summary
Expressions	
☒ speed ms [m/s]	(Corr Speed' [km/h] * 1000) / (60*60)
☒ Long WT [N]	(Mass KG [kg] * ('G Force Long' [G]*-1)*g' [m/s/s]*CoG' [m])/wheelbase' [m]
☒ Front aero [N]	(Tire Load - FL' [N] + 'Tire Load - FR' [N]) * (FL0' [N] + 'FR0' [N]) + 'Long WT' [N]
☒ rear aero [N]	(Tire Load - FL' [N] + 'Tire Load - RR' [N]) * (RL0' [N] + 'RR0' [N]) - 'Long WT' [N]
☒ total aero [N]	'Front aero' [N]+rear aero' [N]
☒ COP [ratio]	('Front aero' [N] / 'total aero' [N]) * 100
☒ aero drag force [N]	0.5 * 'air density' [kg/m3] * 'CD' * 1.2 * ('speed ms' [m/s] * 'speed ms' [m/s])
☒ corner radius [m]	('speed ms' [m/s] * 'speed ms' [m/s]) / ('g' [m/s/s] * 'G Force Lat' [G])
☒ akaman wheel steer [rad]	(wheelbase' [m]) / (corner radius' [m]) *-1
☒ akaman steering pct [%]	'akaman wheel steer' [rad] * (28.55/0.1080)
☒ understeer [%]	abs ('Steering Wheel Pct' [%]) - abs ('akaman steering pct' [%])
Constants	
☒ air density [kg/m³]	1.223
☒ CoG [m]	0.23
☒ FL0 [N]	1162
☒ FR0 [N]	1162
☒ g [m/s²]	9.81
☒ Mass KG [kg]	560
☒ RL0 [N]	1580
☒ RR0 [N]	1580
☒ wheelbase [m]	2.73

Buttons: Add Expression..., Add Scale/Offset..., Add Filter..., Add Plugin..., Add 2D Table..., Add 3D Table..., Add Constant..., Delete, Edit..., Move Up, Move Down, Close, Help

Appendix.4 Maths expression



	Hide Values	Date	Time	Vehicle General	Cd Value
1					
2	Set				
3	Set				
4	Difference			0	
5	F1 R1	26-Feb-19	14:01:00		0.44720: 2.1
6	F16 R16	26-Feb-19	14:05:00		0.58780: 3.1
7	F9 R9	26-Feb-19	14:08:00		0.51340: 3.4
8	F1 R6	26-Feb-19	14:28:00		0.40900: 3.1
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					

Appendix.5 Cd value

Tim's test session 2 feed back

Ratings: Understeer oversteer

1 5 10

F= Front wing

R=Rear wing

FH= Front height (CM)

RH= Rear height (CM)

Adjustments	Ratings	Feed back
Default (F11,R12) (FH 3, RH 5)	N/a	Fairly balanced, limited grip, low speed okay, slight under steer.
F1,R1 (FH 3, RH 5)	N/a	Slightly more grip, oversteer slightly, slightly more stable.
F18,R18 (FH 3, RH 5)	6	Loads of grip, lot more stable, good front end, touch the apex much better.
F9,R9 (FH 3, RH 5)	7	Slight less stable, more to over steer. (no phone record)
F18,R1 (FH 3, RH 5)	8	Very oversteery, brakes okay (worst setup so far)
F9,R1 (FH 3, RH 5)	6.5	Slightly less oversteer
F1,R18 (FH 3, RH 5)	4	Slightly under steer, safe to drive as always find the limit on the grip, low speed understeer.
F1,R9 (FH 3, RH 5)	5	Nice balance good confidence in car high speed, understeer low speed corner.
F1,R6 (FH 3, RH 5)	4.8	Best setup, so far loads of grip, very stable slightest understeer.
F1,R12 (FH 3, RH 5)	4.8	Slight understeer, high speed still stable, top out at a higher speed.
F1,R10 (FH 3, RH 5)	4.5	Balance good, slight understeer, less grip overall, didn't feel good when planted at high speed corner.
F2,R12 (FH 3, RH 5)	5	Perfect balance, slight understeer low speed corner, felt much planted.
F3,R12 (FH 3, RH 5)	4.5	Balance very well, not as much grip as previous, low speed understeer, high speed corner scrubbing across track as not enough grip.
F2,R12 (FH 2CM, RH 4CM)	4	Felt more understeer, general good grip overall, low speed corner responded well to inputs.
F2,R12 (FH 2.5, RH 4.5)	4.8	Tiny bit understeer, flat out very good high speed through corner which couldn't previous low speed felt good.
F2,R12 (FH 2.7, RH 4.7)	4.8	Almost identical to previous, more understeer low and high speed

Appendix.6 Driver feedback

excel tem spreadsheet - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW

Clipboard Font Alignment Number Conditional Formatting Styles Cells Editing

SUM X $\frac{A5}{1.2}$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	static loads																			
2	set up	LF	RF	LR	RR	Vc (km/h)	LF	RF	LR	RR	Aero F	Aero R	Aero T	CoP	Vc (m/s)	CLP	CLr	CIT	V1	T1
3	A	1162	1163	1580	1580	154.8	2609	2609	3252	3252	-2893	-3424	-6317	54.20	54.11111	-1.61577	-1.91234	-3.52811	51.33	182.56
4	F1 R1	1164	1163	1579	1580	220	2772	2771	3329	3327	-3216	-3497	-6713	52.09	61.11111	-1.40825	-1.53129	-2.93954	59.64	45.5
5	FF1 RR1	1163	1163	1580	1581	220	2757	2785	3312	3344	-3216	-3495	-6711	52.08	61.11111	-1.40825	-1.53042	-2.93867	60.72	36.3
6	F1 R2	1163	1163	1580	1580	219.8	2757	2757	3416	3415	-2189	-2871	-6889	51.32	61.05556	-1.39853	-1.61041	-3.00394	60.66	36.93
7	F1 R6	1161	1164	1582	1579	219.5	2731	2738	3541	3549	-3144	-3929	-7073	55.55	60.97222	-1.383	-1.72831	-3.11131	59.3	36.64
8	F2 R1	1161	1165	1562	1567	220	2840	2837	3316	3312	-3251	-3478	-6810	50.79	61.11111	-1.48736	-1.51466	-2.98202	59.72	39.24
9	FF2 RR1	1165	1160	1578	1583	220	2835	2843	3310	3317	-3253	-3466	-6819	50.83	61.11111	-1.48524	-1.51772	-2.98396	60.09	41.36
10	F6 R1	1162	1163	1581	1580	219.9	2946	2934	3295	3290	-2555	-3434	-6879	49.06	61.08333	-1.55811	-1.50609	-3.05858	60.01	39.74
11	FF6 RR1	1165	1161	1578	1582	219.9	2937	2942	3289	3295	-2553	-3424	-6877	49.08	61.08333	-1.55723	-1.50609	-3.05792	60.14	39.74
12	F6 R6	1165	1161	1578	1582	219.5	2912	2893	3519	3498	-2479	-2857	-7336	52.58	60.97222	-1.53036	-1.69664	-3.227	60.01	35.25
13	F9 R9	1165	1160	1579	1583	219.1	2978	2992	3614	3617	-2635	-4069	-7704	52.82	60.86111	-1.60483	-1.79643	-3.40126	58.82	38.41
14	F12 R12	1162	1164	1582	1579	218.8	3068	3047	3732	3717	-2789	-4288	-8077	53.09	60.77778	-1.67741	-1.89832	-3.57572	58.83	37.55
15	F15 R15	1162	1161	1580	1580	218.5	3135	3135	3828	3828	-2945	-4496	-8441	51.26	60.69444	-1.75127	-1.99587	-3.74714	59.8	36.4
16	F18 R18	1161	1164	1582	1579	218.2	3217	3207	3937	3930	-4099	-4706	-8805	53.45	60.61111	-1.82864	-2.09484	-3.91948	59.1	39.96
17	FF18 RR18	1163	1163	1580	1580	218.2	3321	3303	3942	3925	-4198	-4707	-8905	52.86	60.61111	-1.86871	-2.09525	-3.96399	59.02	36.37

Appendix.7 spreadsheet straight line testing