



Sports2000 Aero Map

MCR S2N

Splitter & Gurney Flap Investigation

Engineer – John Hughes

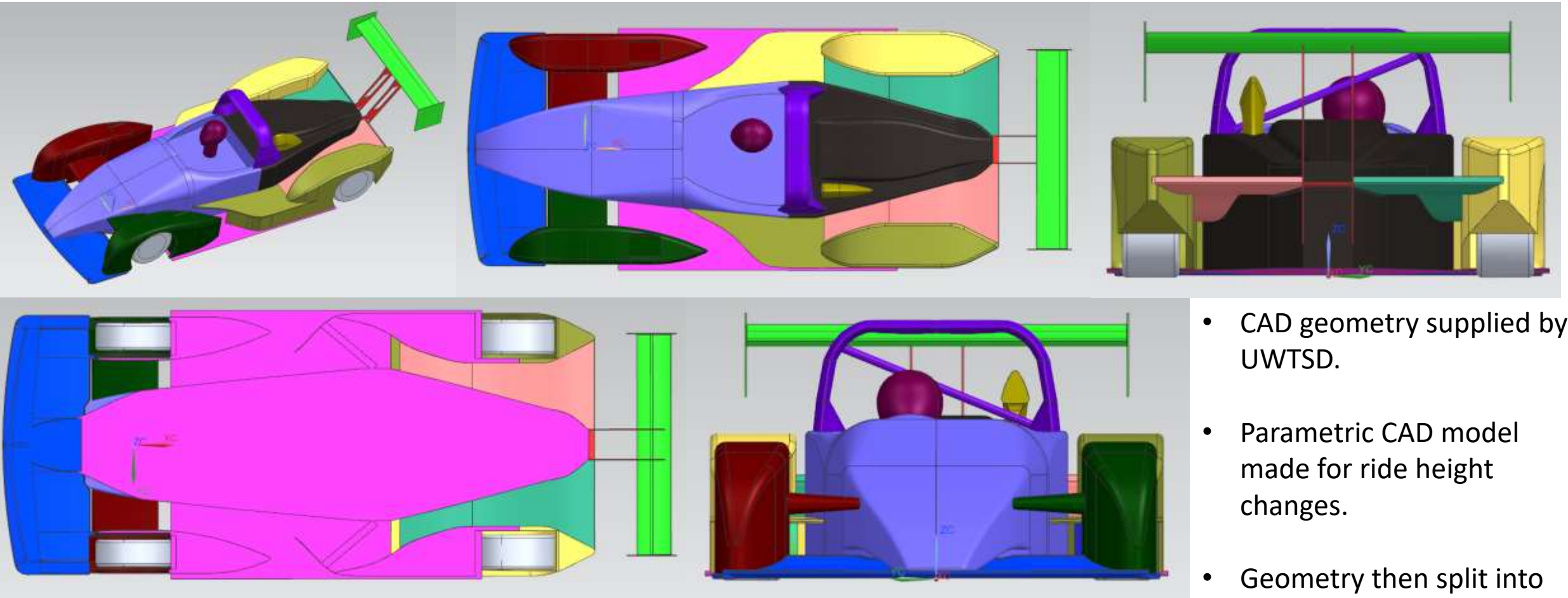
Introduction & Objectives

- This project was conducted in conjunction with the University of Wales Trinity Saint David.
- MSc student constructing a “Driver Out of the Loop” simulation model for an MCR S2N Sports2000 race car.



- Student required a “mini” aerodynamic map for resistive forces and balance to be applied into his simulator model.
- The student defined the matrix points (front and rear ride heights).
- It was decided that only ride height changes shall be made, therefore keeping the pre and post processing simple (no yaw, roll or slip angles applied).

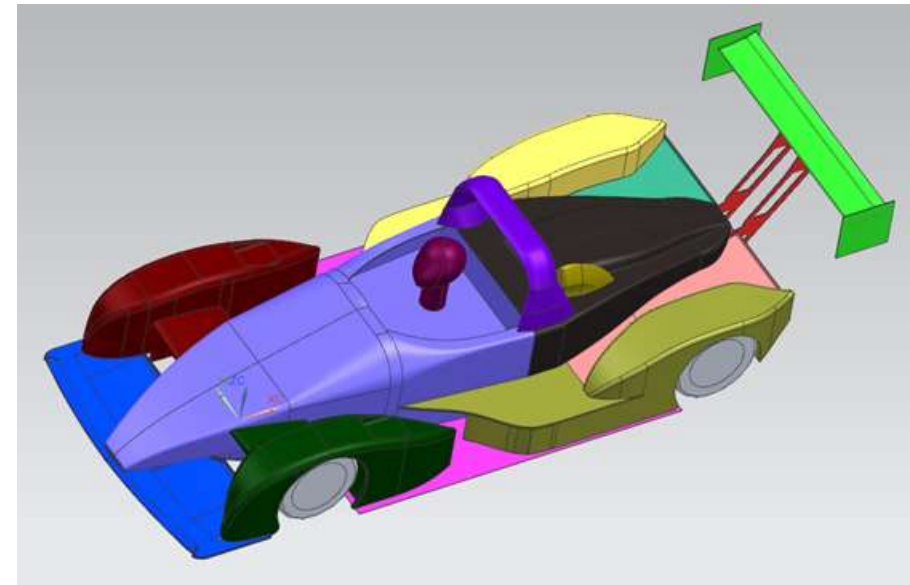
Geometry



- CAD geometry supplied by UWTSD.
- Parametric CAD model made for ride height changes.
- Geometry then split into relevant surface groups.

Geometry Surface Groups

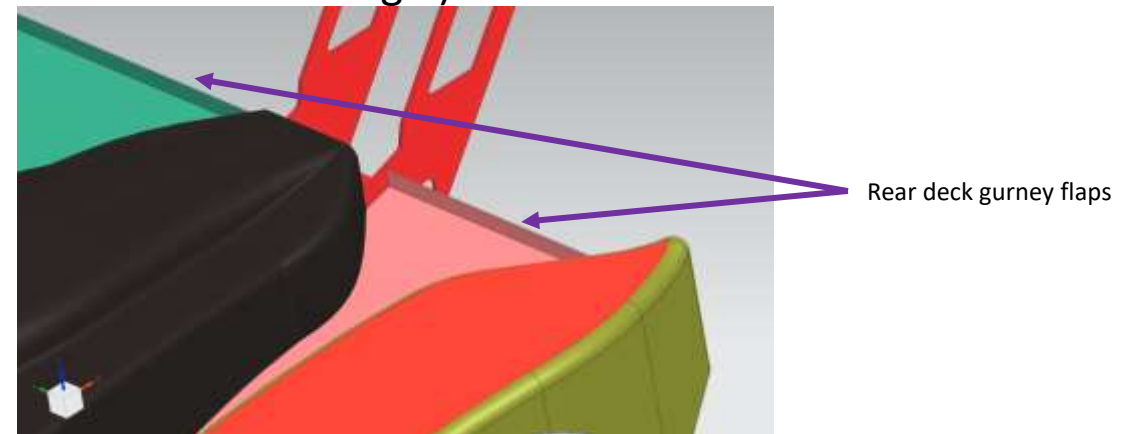
- 01 Monocoque Front
- 01 Monocoque Rear
- 01 FL Pontoon
- 01 FR Pontoon
- 01 RL Pontoon
- 01 RR Pontoon
- 02 Floor
- 02 RL Deck
- 02 RR Deck
- 03 Front Splitter
- 04 Rear Wing
- 06 FL Wheel
- 06 FR Wheel
- 06 RL Wheel
- 06 RR Wheel
- 07 Engine Air Intake
- 08 Rear Wing Mount
- 09 Driver Head
- 10 Radiator LH Core In
- 10 Radiator LH Core Out
- 10 Radiator LH Core Sides
- 10 Radiator RH Core In
- 10 Radiator RH Core Out
- 10 Radiator RH Core Sides
- 13 Radiator LH Domain In
- 13 Radiator LH Domain Out
- 13 Radiator LH Domain Sides
- 13 Radiator RH Domain In
- 13 Radiator RH Domain Out
- 13 Radiator RH Domain Sides



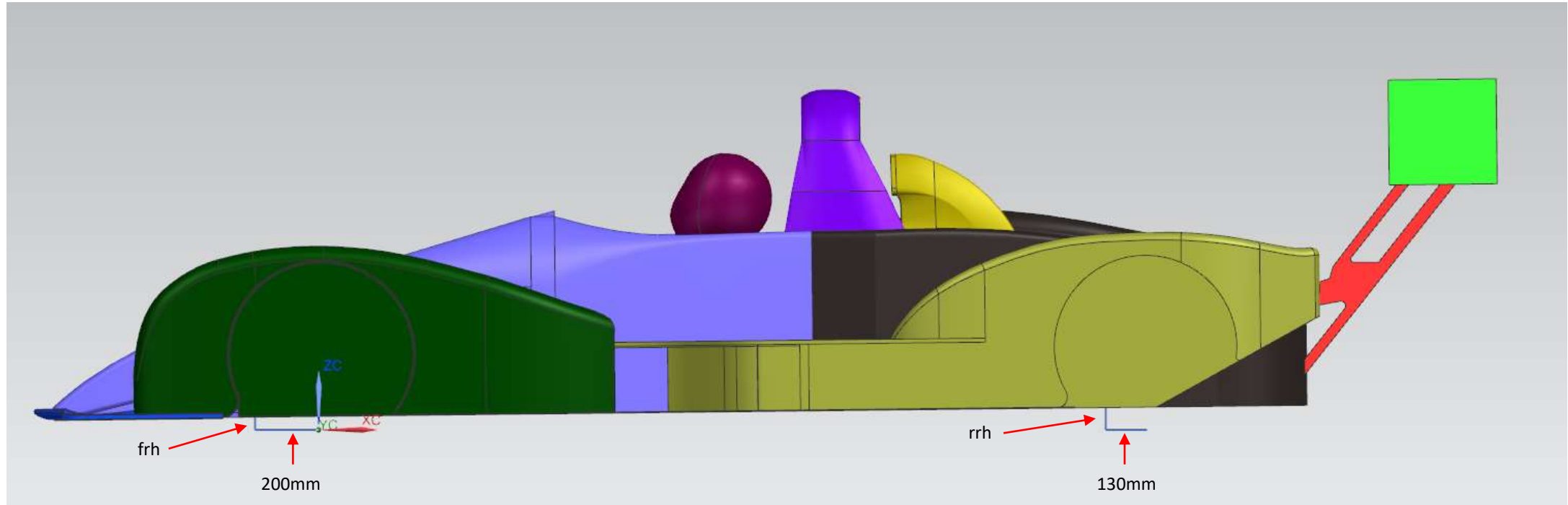
Methodology

w/ 25mm Gurney		FRH (mm)										
		10	15	20	25	30	35	40	45	50	55	60
RRH (mm)	30	1		6								
	35					10						
	40		8		9							
	45											
	50			4		2	11					
	55								12			
	60				5							
	65						3					
	70											13
	75					7						
	80											
	85											
	90											
w/o Gurney		FRH (mm)										
		10	15	20	25	30	35	40	45	50	55	60
RRH (mm)	30											
	35											
	40											
	45											
	50											
	55											
	60											
	65											
	70											
	75											
	80											
	85											
	90											

- 15 ride height combinations were defined by the student.
 - Selections made in an operating window where the car is known to perform well.
- 13 points using the rear deck 25mm gurney flaps and 2 with the rear deck gurney flaps removed.
- Wind tunnel data showed the gurney flaps to be effective in generating downforce.
- Rear wing angle of attack remained at its baseline position, therefore only its angle of incidence would change (relative to the cars rake angle).



Ride Height Control

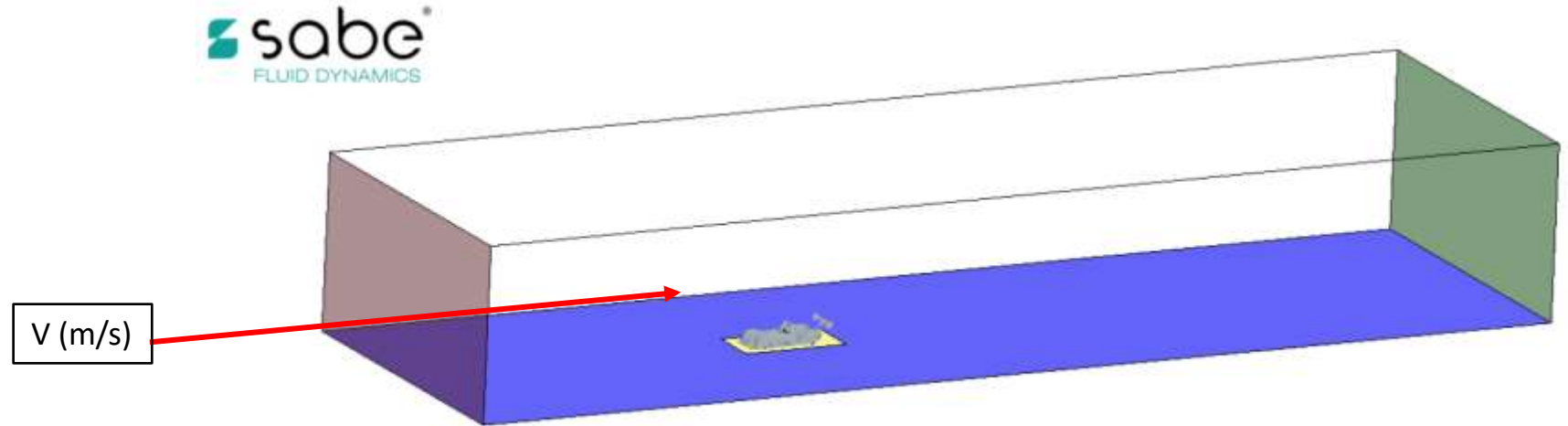


- Ride height changes were made from specific datum points related to the axle centres.
 - Front = -200mm.
 - Rear = -130mm.
- These points are in accordance with the measuring points located on the actual car.

Domain & Boundary Conditions

- Boundary Conditions:

- Velocity Inlet - 35m/s.
- Reference Density – 1.2Kg/m³.
- Pressure Outlet.
- Ground (No-Slip).
- Rolling Road (No-Slip with tangential velocity applied).
- Sides (No-Slip).
- Top (No-Slip).
- Tyres/Wheels (No-Slip with tangential velocity applied).
- Car (No-Slip).
- Heat Exchanger Porosity:
 - Inertial Resistance – 459 (Alpha).
 - Viscous Resistance – 432 (Beta).



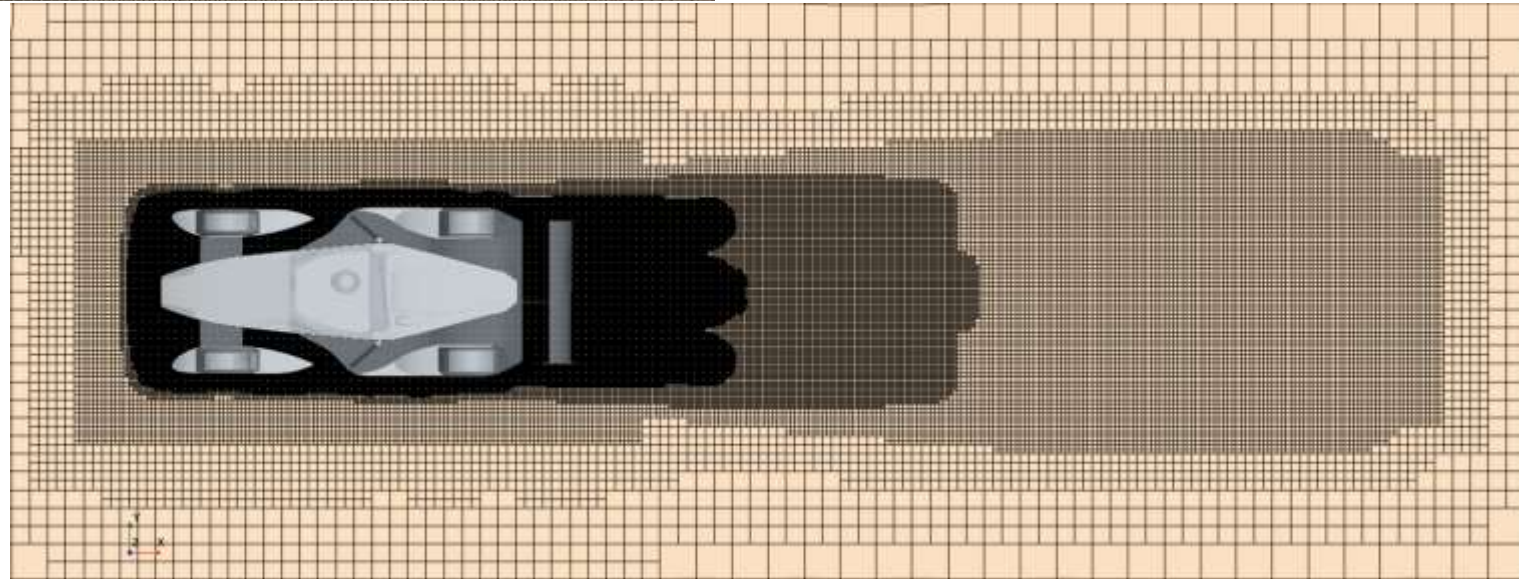
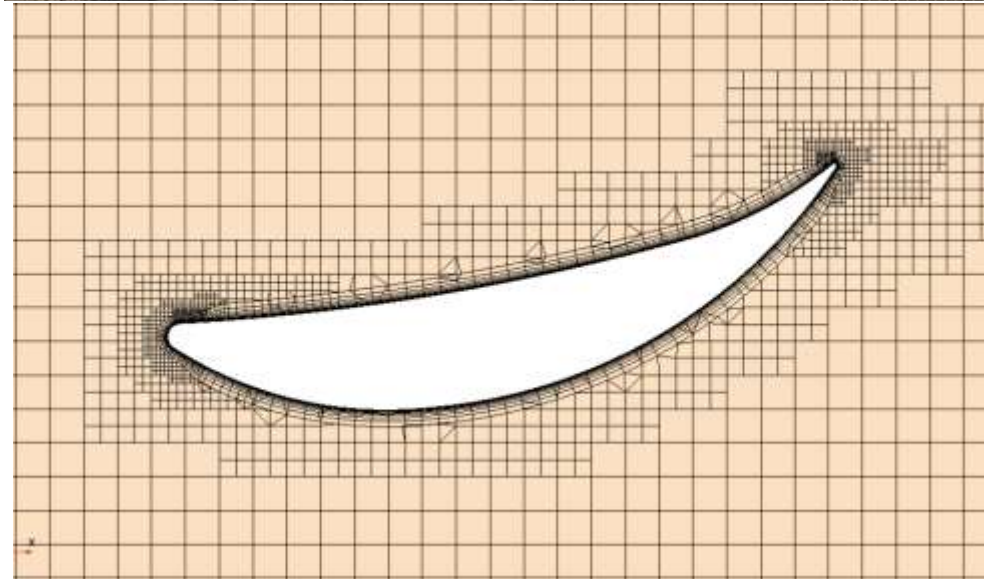
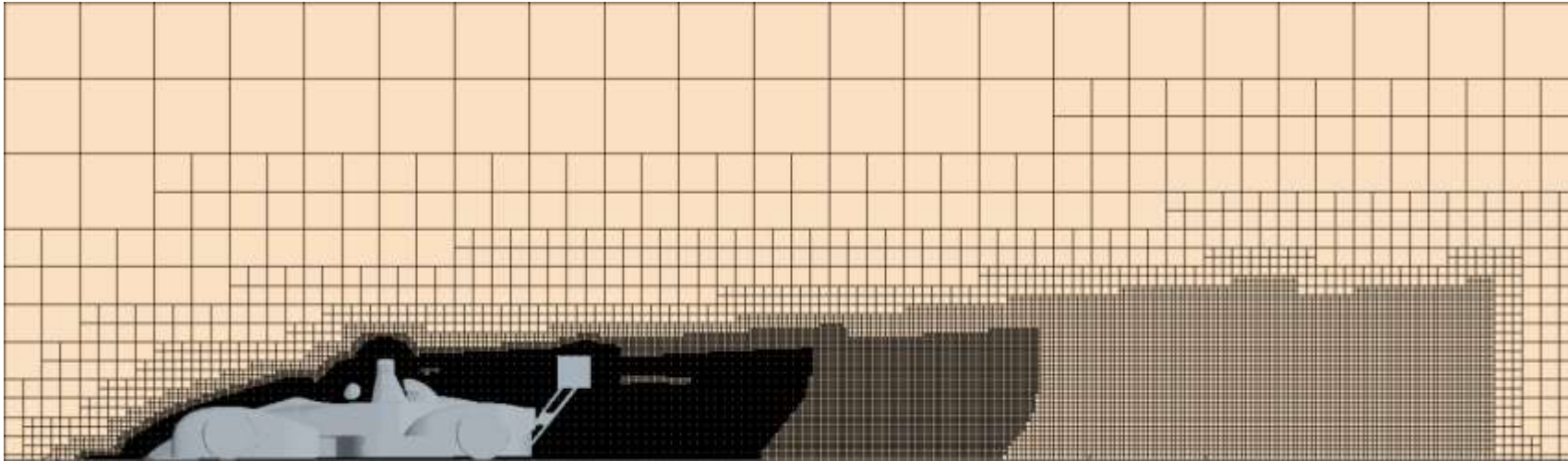
- Dimensions:

- L 60m x W 18m x H 9m
- Wheelbase – 2.6010704m

Mesh

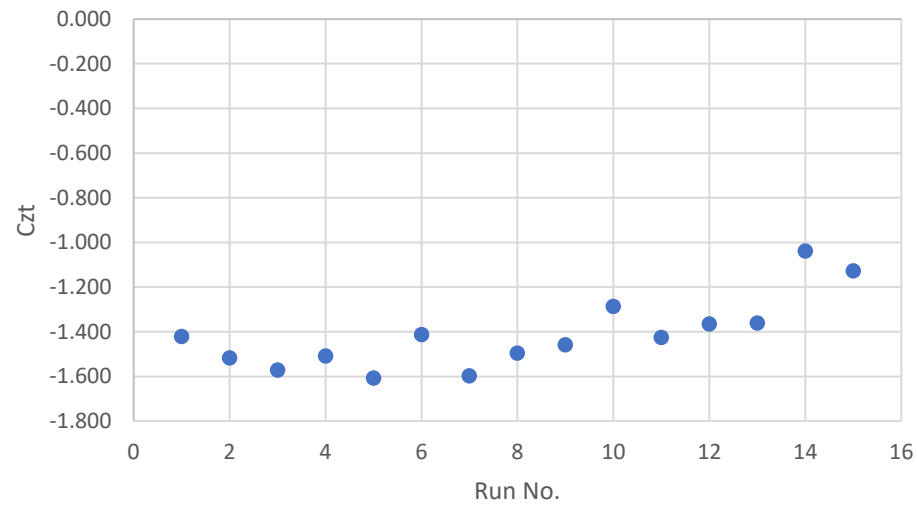
Total Cell Count:

- 62,914,981

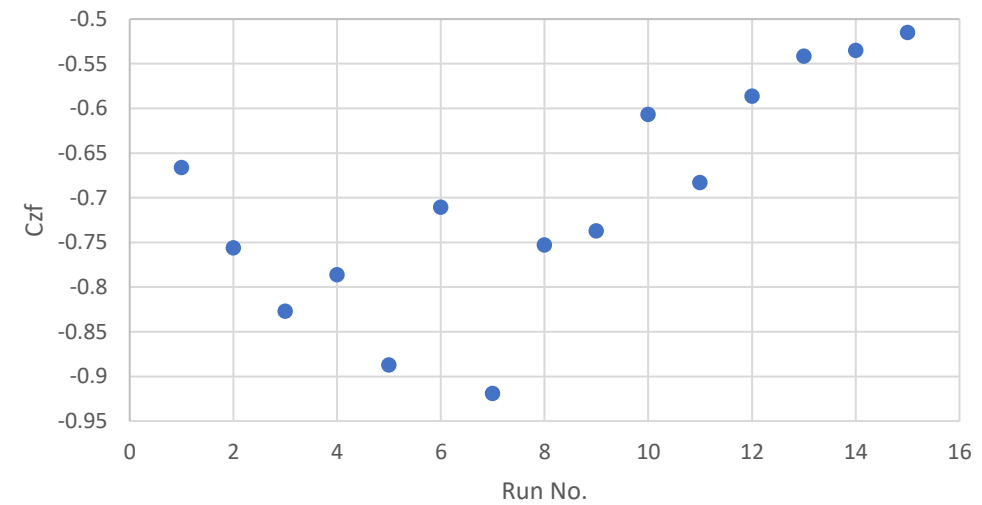


Results – Run Graphs

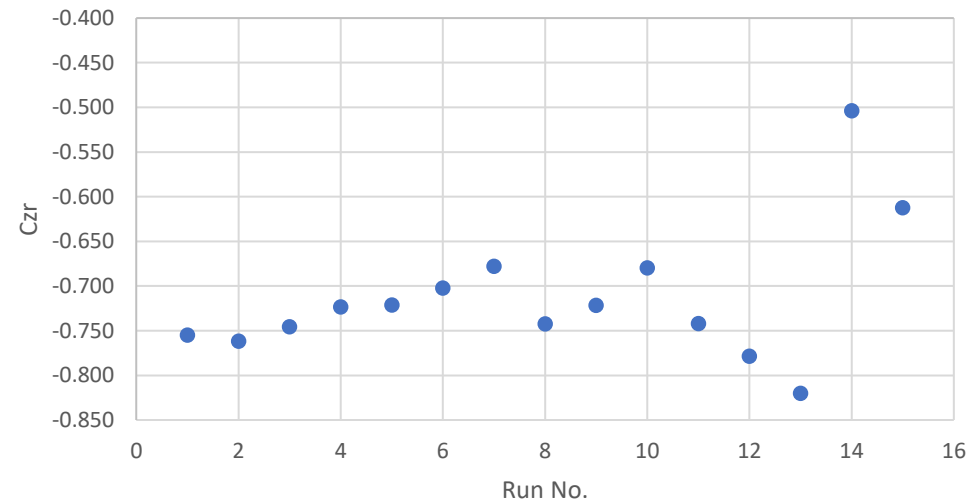
Czt



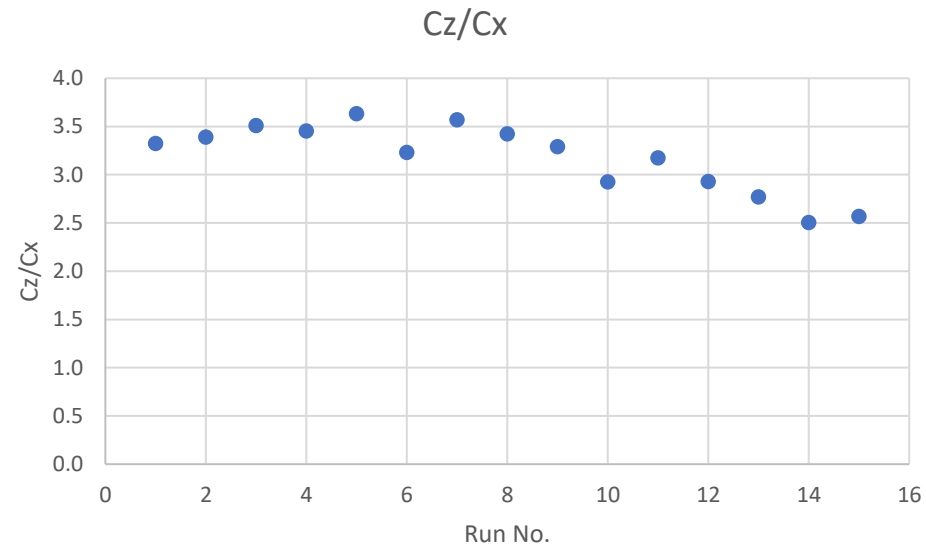
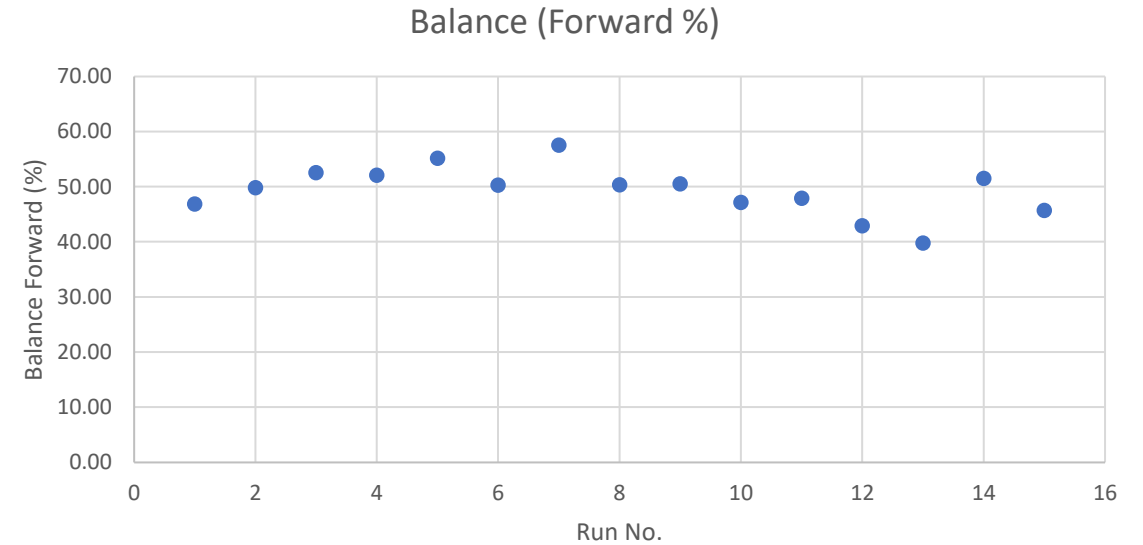
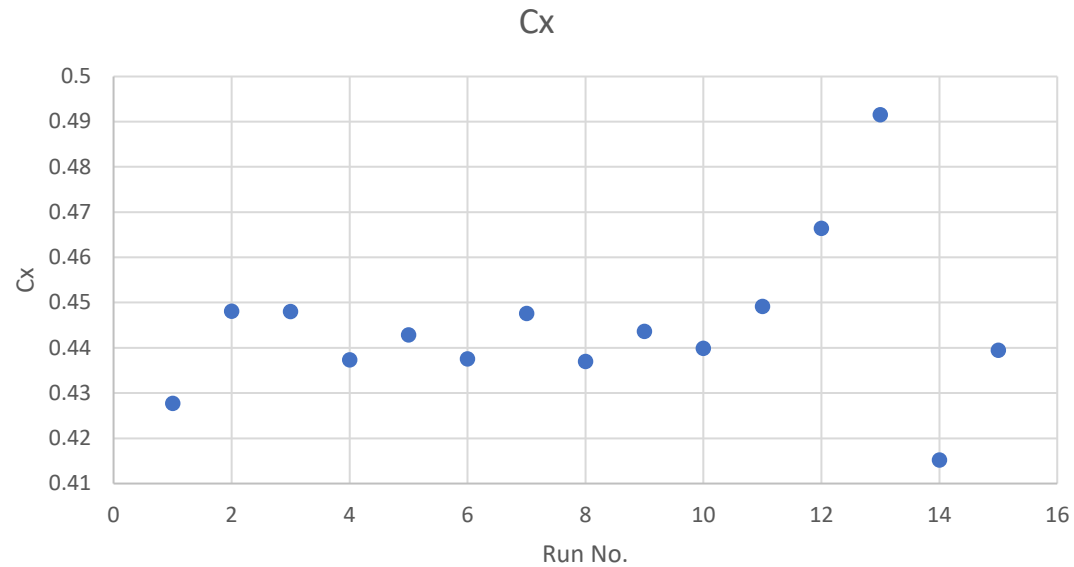
Czf



Czr



Results – Run Graphs

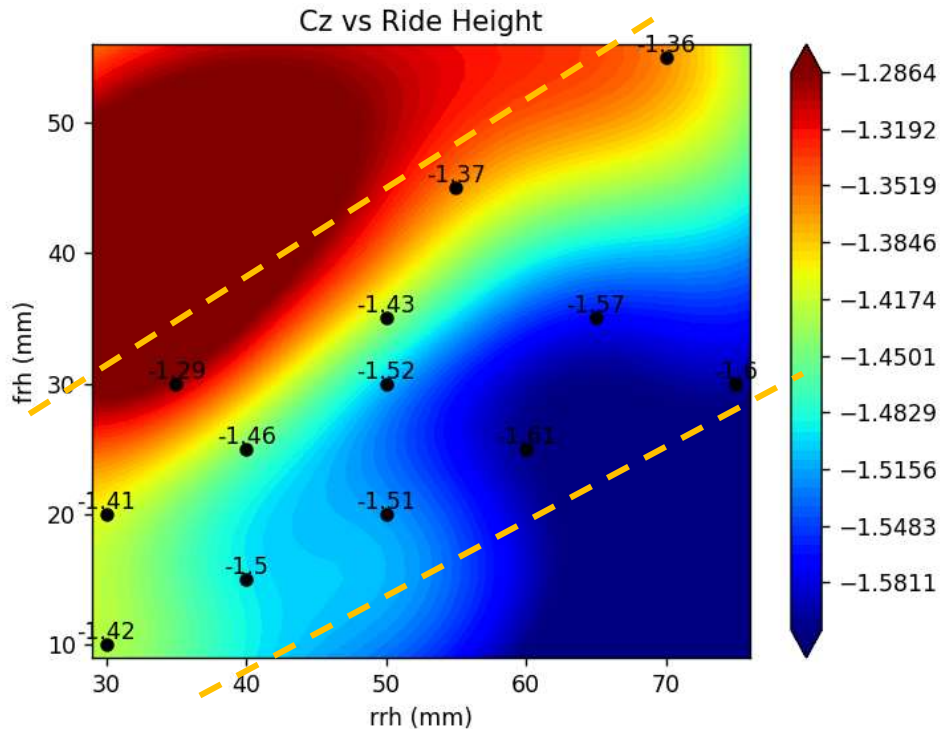


Results - Data

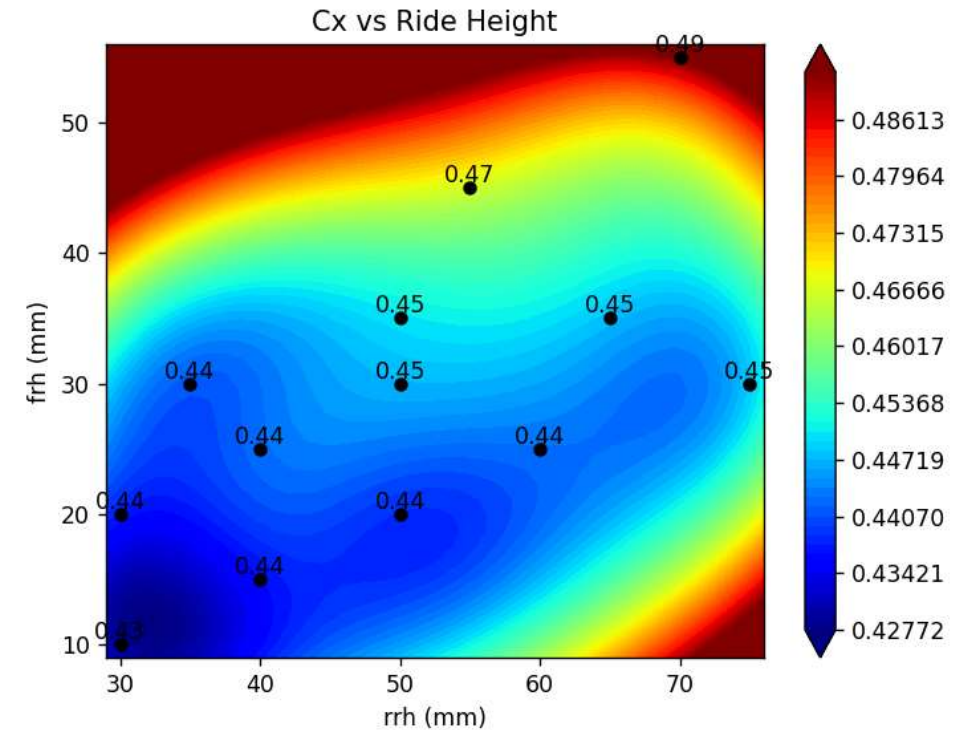
RUN No.	Fztotal (N)	Fztotal (Kg)	Czt	Fzfront (N)	Czf	Fzrear (N)	Czr	Balance (Forward %)	Fxtotal (N)	Fxtotal (Kg)	Cx	Cz/Cx	Frontal Area (m²)	Rake Angle (Deg)	FRH (mm)	RRH (mm)
1	-2812.071	-286.654	-1.421	-1318.388	-0.666	-1493.678	-0.755	46.88	846.214	86.260	0.428	3.323	1.346	0.430	10	30
2	-3023.547	-308.211	-1.518	-1506.127	-0.756	-1517.420	-0.7619	49.81	892.435	90.972	0.448	3.388	1.355	0.430	30	50
3	-3172.579	-323.403	-1.573	-1668.343	-0.827	-1504.236	-0.7456	52.59	904.025	92.153	0.448	3.509	1.372	0.640	35	65
4	-3030.696	-308.939	-1.510	-1578.219	-0.786	-1452.457	-0.7235	52.07	878.046	89.505	0.437	3.452	1.366	0.640	20	50
5	-3252.458	-331.545	-1.608	-1794.031	-0.887	-1458.427	-0.7212	55.16	895.657	91.300	0.443	3.631	1.376	0.750	25	60
6	-2773.224	-282.694	-1.413	-1394.777	-0.711	-1378.448	-0.7024	50.29	858.739	87.537	0.438	3.229	1.335	0.220	20	30
7	-3274.300	-333.772	-1.597	-1884.343	-0.919	-1389.957	-0.678	57.55	917.774	93.555	0.448	3.568	1.395	0.960	30	75
8	-2980.441	-303.817	-1.496	-1500.712	-0.753	-1479.729	-0.7426	50.35	870.905	88.777	0.437	3.422	1.356	0.540	15	40
9	-2884.762	-294.063	-1.459	-1457.792	-0.737	-1426.969	-0.7217	50.53	877.188	89.418	0.444	3.289	1.345	0.320	25	40
10	-2520.040	-256.885	-1.286	-1188.381	-0.607	-1331.642	-0.680	47.16	861.705	87.839	0.440	2.924	1.333	0.110	30	35
11	-2827.926	-288.270	-1.425	-1355.446	-0.683	-1472.480	-0.7422	47.93	891.158	90.842	0.449	3.173	1.350	0.320	35	50
12	-2702.936	-275.529	-1.365	-1161.074	-0.587	-1541.862	-0.7789	42.96	923.417	94.130	0.466	2.927	1.347	0.220	45	55
13	-2719.765	-277.244	-1.362	-1081.558	-0.541	-1638.207	-0.820	39.77	981.813	100.083	0.492	2.770	1.359	0.320	55	70
14	-2054.414	-209.420	-1.039	-1057.947	-0.535	-996.467	-0.5041	51.50	820.823	83.672	0.415	2.503	1.345	0.220	45	55
15	-2248.987	-229.254	-1.128	-1027.614	-0.515	-1221.373	-0.6123	45.69	876.609	89.359	0.439	2.566	1.357	0.320	55	70

- Runs 14 and 15 have the Rear Deck Gurney Flap Removed (they are comparable to runs 12 and 13).
- Initial figures show the cars aerodynamic balance is fairly neutral, though this is most likely due to the map matrix of ride heights not having a large spread of points.
- Removal of the rear deck gurney flaps provides a significant loss in Czt.

Results – Contour Plots

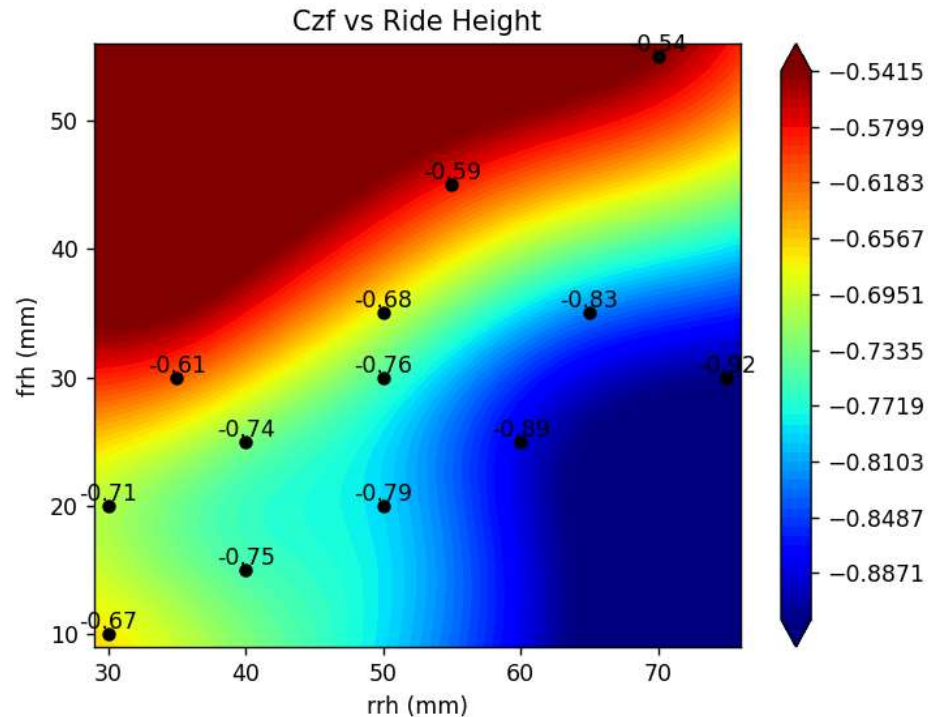


- It is advised that for Czt, Czf and Czf:
 - Blue = Increased Downforce.
 - Red = Decreased Downforce.
- The lack of point spread is evident, therefore results are reliant on the extrapolation of data.
- Increased rake angle with low frh provides the highest values of Czt.
- 25mm frh and 60mm rrh produced the highest value of Czt.

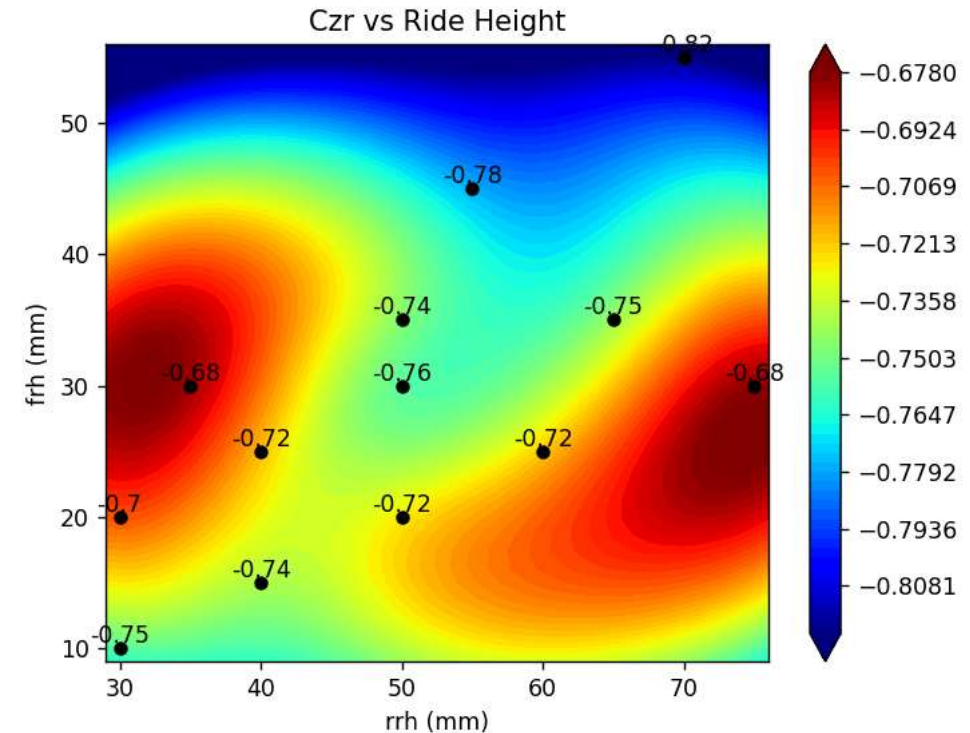


- Cx is lowest when low ride heights and reduced rake angle are applied.
- The plot implies that as ride height increases, Cx increases, though these areas on the plot are outside of the point map.
- 10mm frh and 30mm rrh produced the lowest value of Cx.

Results – Contour Plots

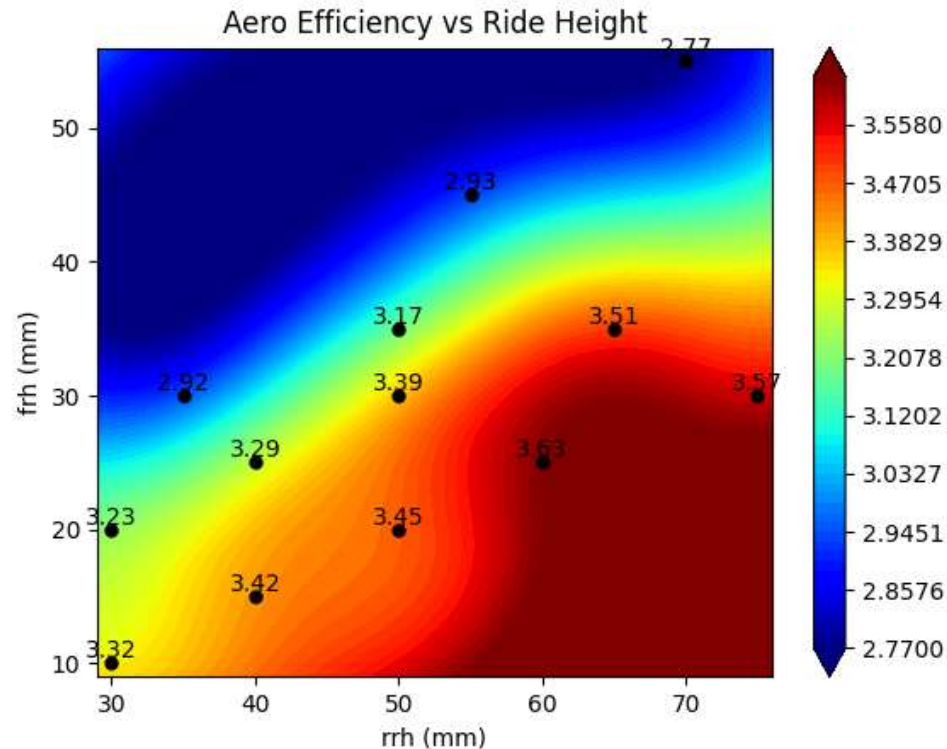


- Czf is increased using the same function as Czt (increased rake and low frh).
- This may suggest that a significant percentage of downforce is being produced by the front splitter.
- Though it is noted that Czf max was produced with higher ride heights than those for Czt max.
- Czf begins to decrease when frh is below 20mm and rake angle is reduced.

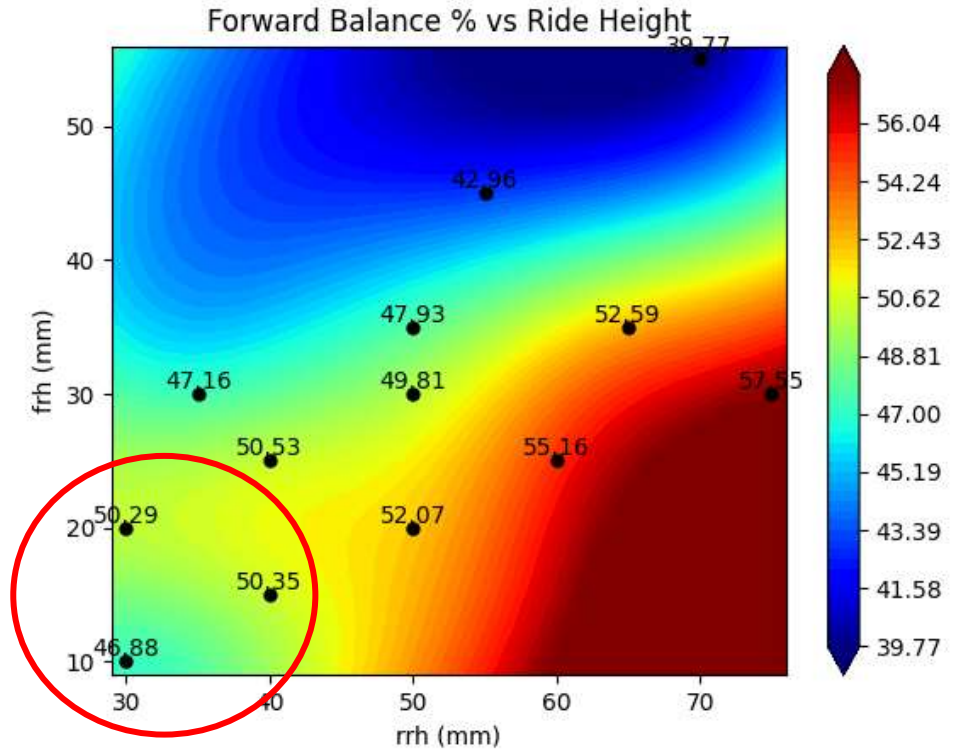


- Czr max was produced using high front and rear ride heights.
- The plot suggest that increasing the ride heights in a linear fashion will produce superior Czr performance.
- According to the plot, Czr is highly dependent on frh. The greater the frh, the better Czr becomes.
- As the car does not have a rear diffuser, Czr is not significantly driven by expansion, therefore remains fairly neutral.

Results – Contour Plots



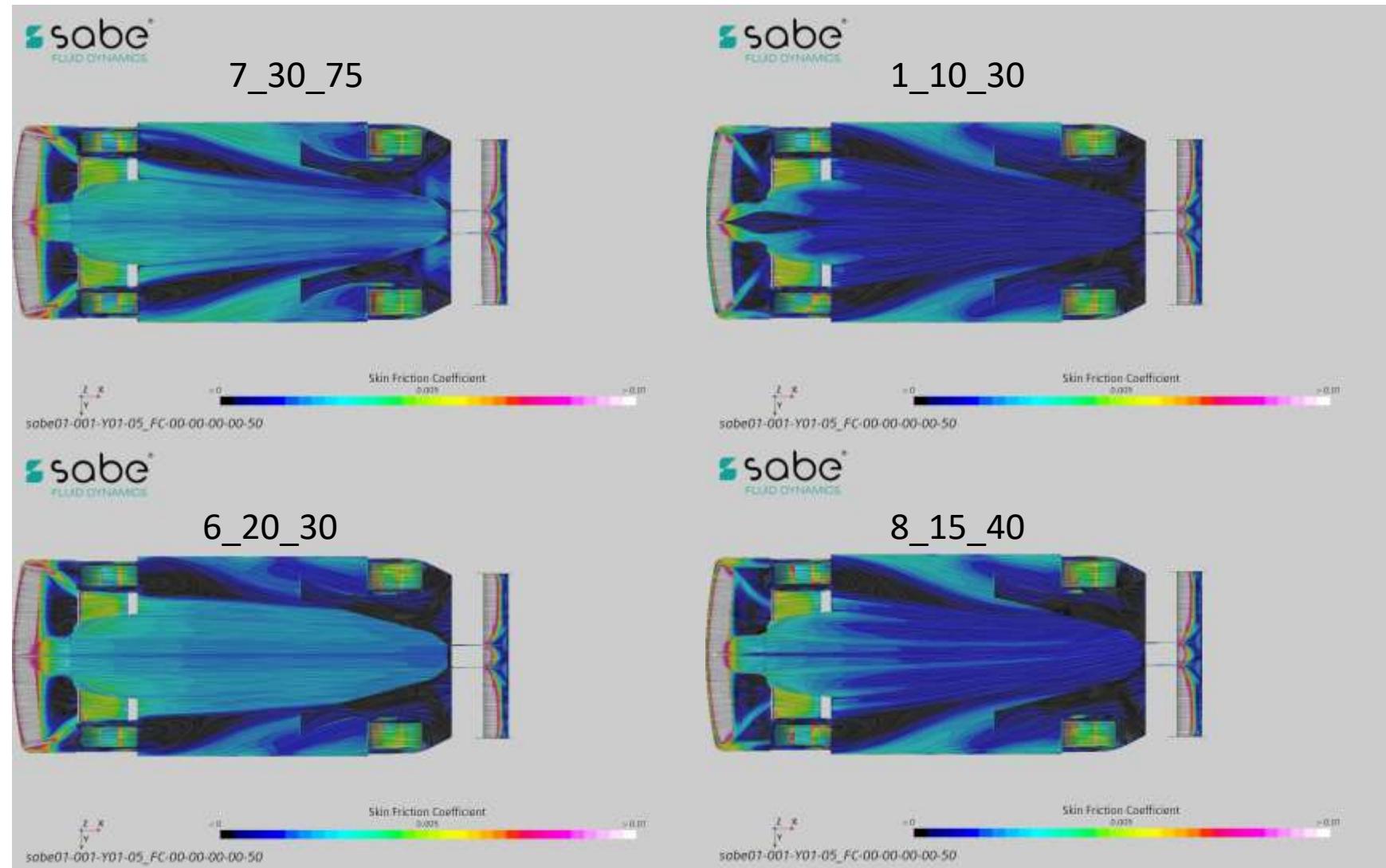
- Maximum efficiency is achieved using low frh (30mm max) and high rrh (55mm min).
- This would suggest increasing rake angle is beneficial, as it produces increased C_{zt} with little C_x penalty.
- Efficiency is severely reduced at higher frh (reduction in ground effect).
- However, this is merely an assumption based on extrapolated data.
- Minimum efficiency was achieved at the highest frh.



- As rrh is reduced, a significant reduction in forward balance is apparent.
- It also shows a significant loss in forward balance when frh is below 20mm.
- This suggests that forward balance is not linearly proportional to frh and rrh.
- As this loss is within an area of 3 matrix points, extrapolation inaccuracies are less likely.
- This was also highlighted when studying C_{zf} .
- These three points shall be investigated (Runs 1, 6 and 8).

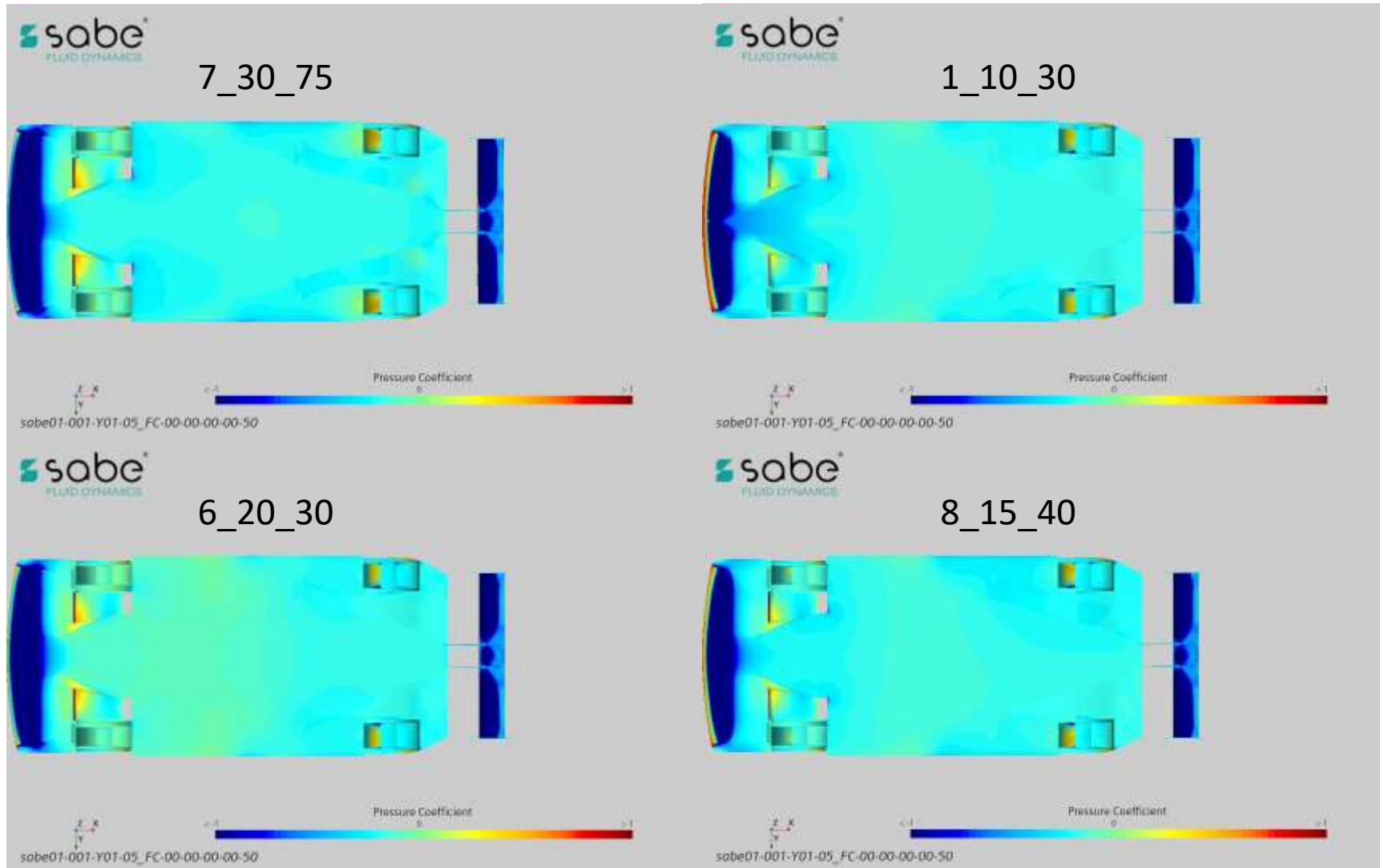
Splitter Investigation

Surface Contours – Skin Friction



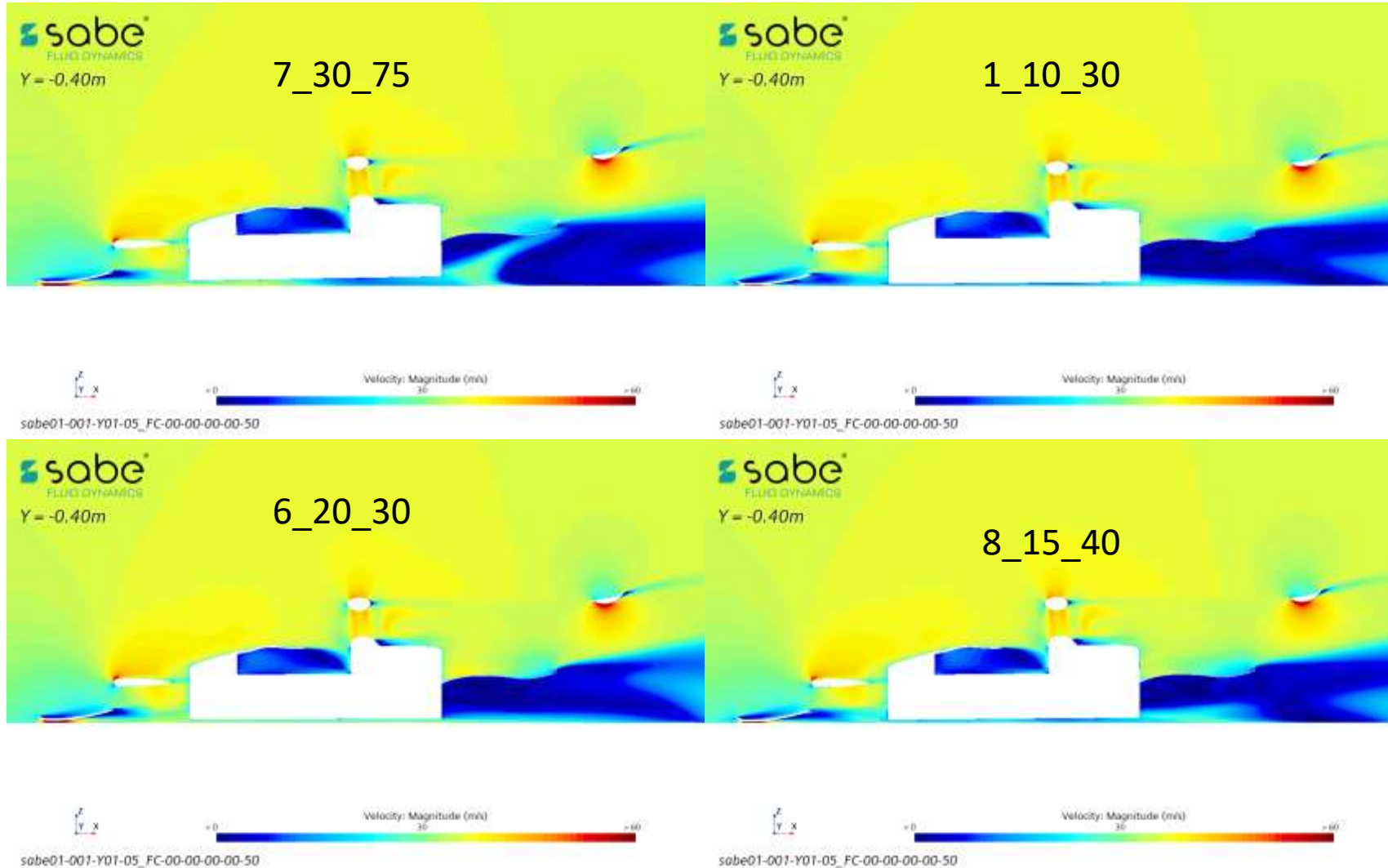
- Image titles denote:
 - Run No_frh_rrh
- Run 7 has the highest C_{zf} , therefore is being used as a baseline.
- T_w reductions can be seen on Runs 1 and 8.
- This is apparent around the leading and outboard edges of the front splitter.
- This would suggest a reduction in flow energy.
- Large reductions in T_w are also apparent on the floor sections.
- This would suggest that the reduced frh is having a large impact on T_w .
- C_z Front Splitter
 - 7 = -0.987
 - 1 = -0.704
 - 6 = -0.913
 - 8 = -0.812

Surface Contours – Pressure Coefficient



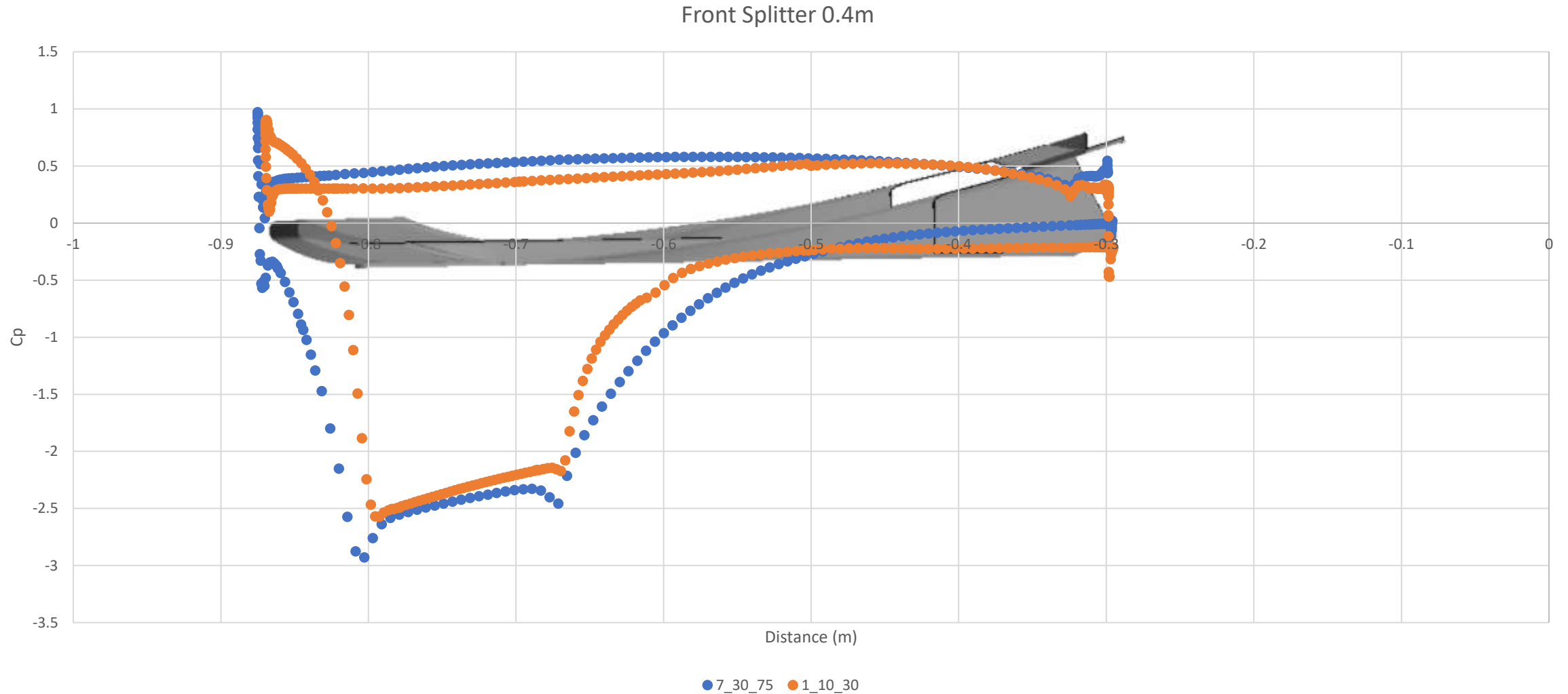
- Runs with a lower frh display a reduced area of low Cp on the underside of the splitter.
- Increase in Cp along the leading edges is also apparent for lower frh.
- This would suggest a reduction in flow velocity and mass flow.

Velocity Magnitude

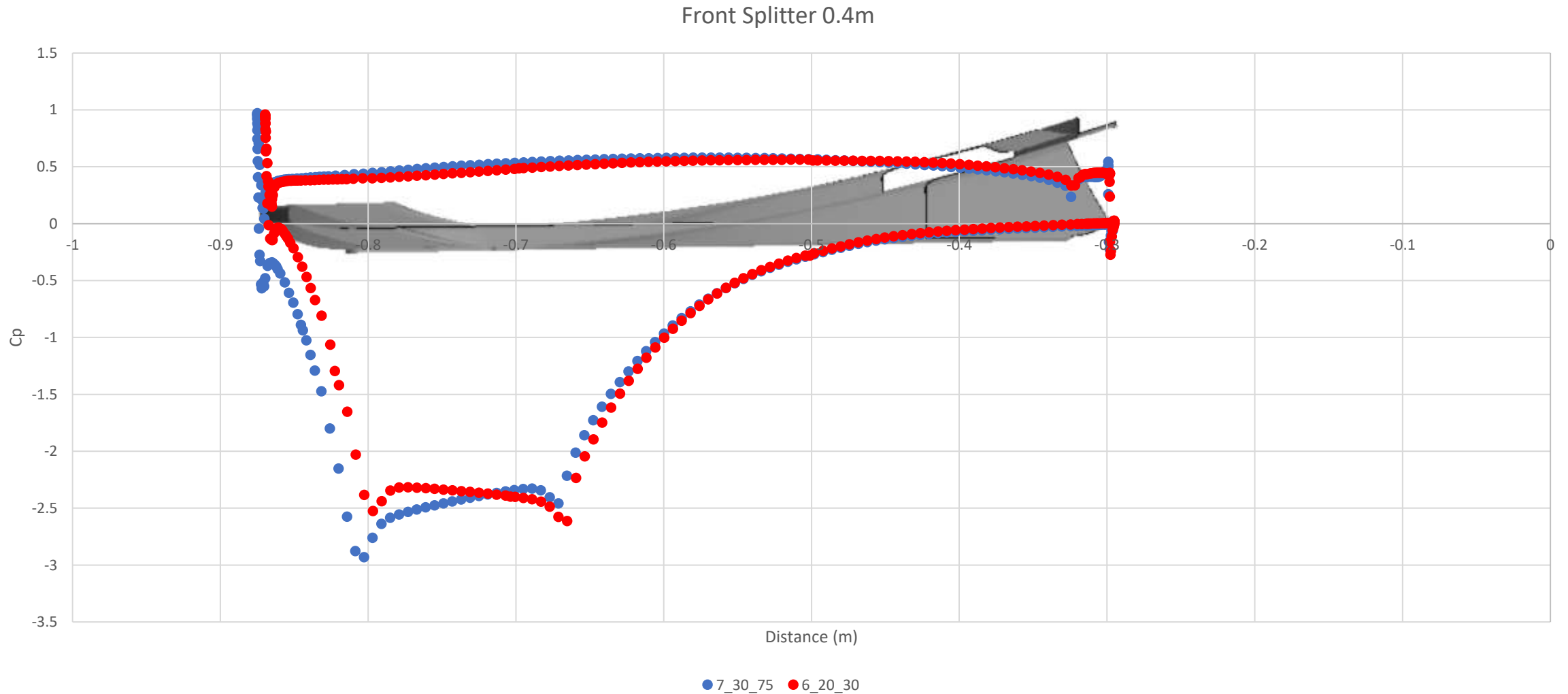


- Lower frh display an increased splitter wake.
- Separation on the upper leading edge is increased as frh is reduced.
- Reduced velocity area coverage correlates with the reduced Tw.
- Reduced working area results in a decrease of Czf.
- Run 7 has the highest rake angle.
- Run 6 has a reduced rake angle, therefore less splitter expansion.

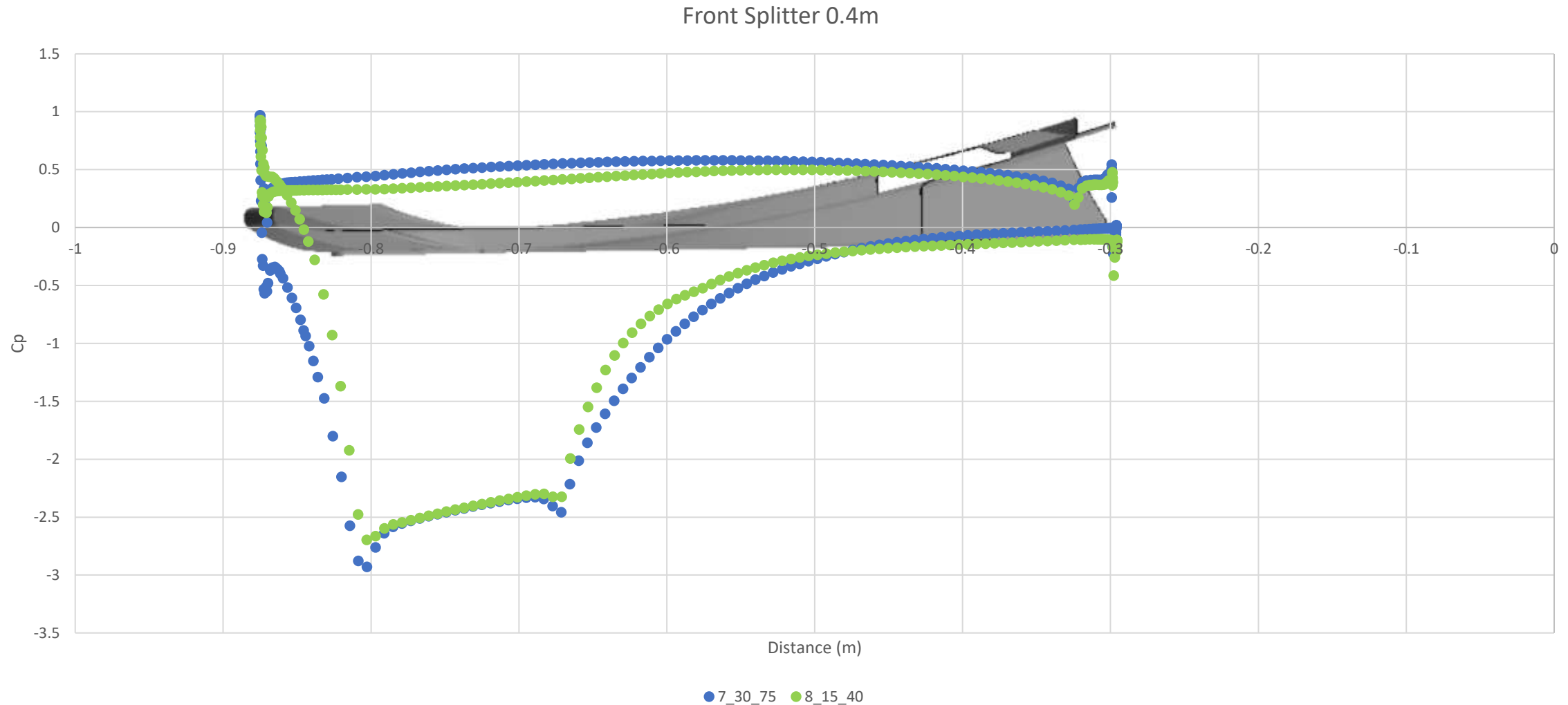
Front Splitter – Surface Plots



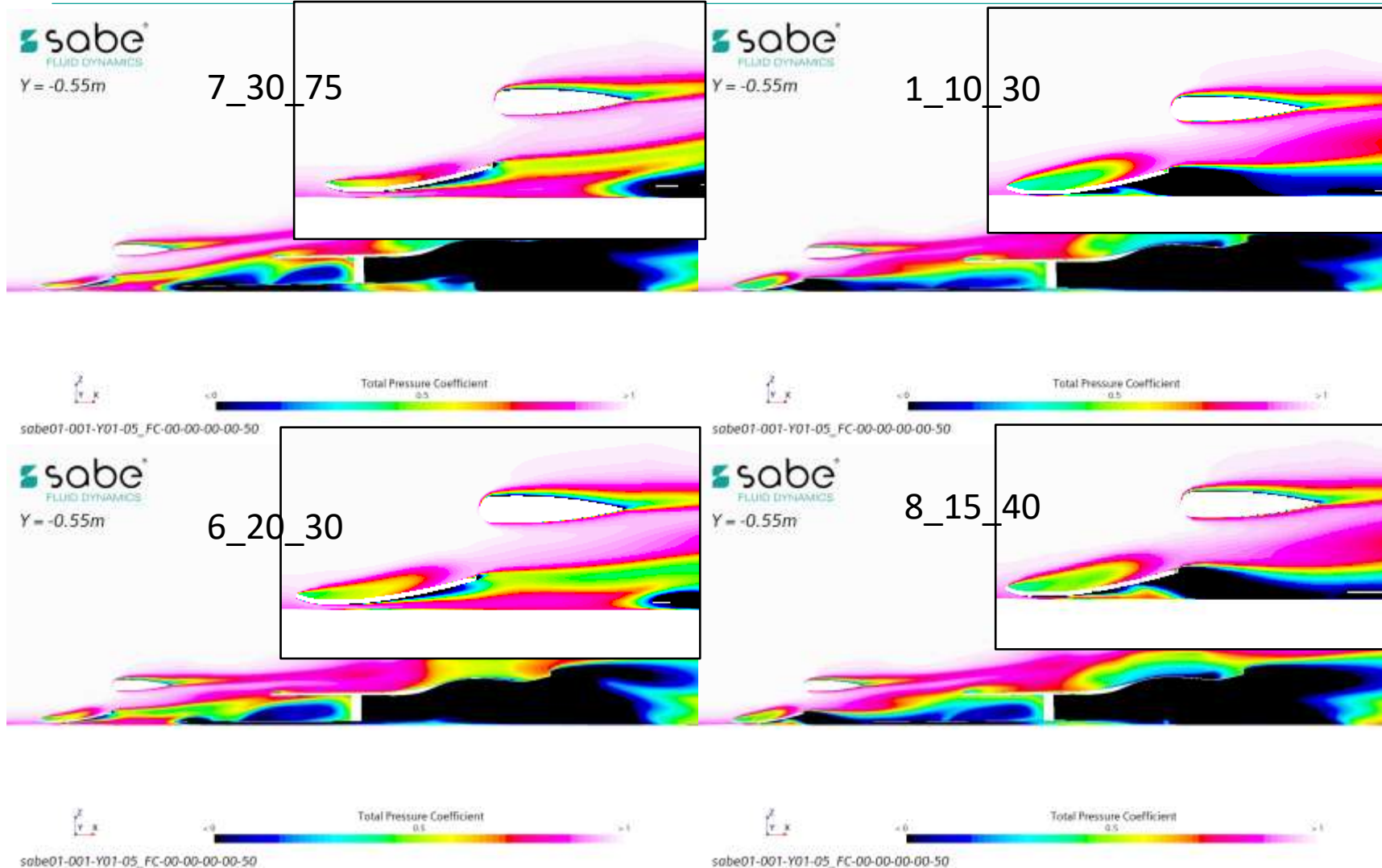
Front Splitter – Surface Plots



Front Splitter – Surface Plots

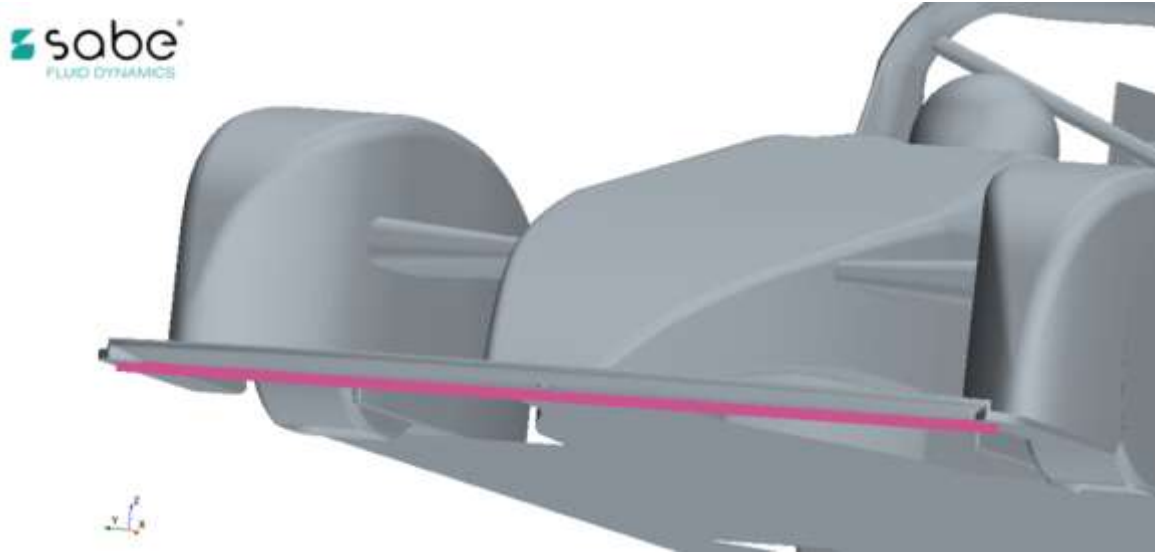


Total Pressure Coefficient

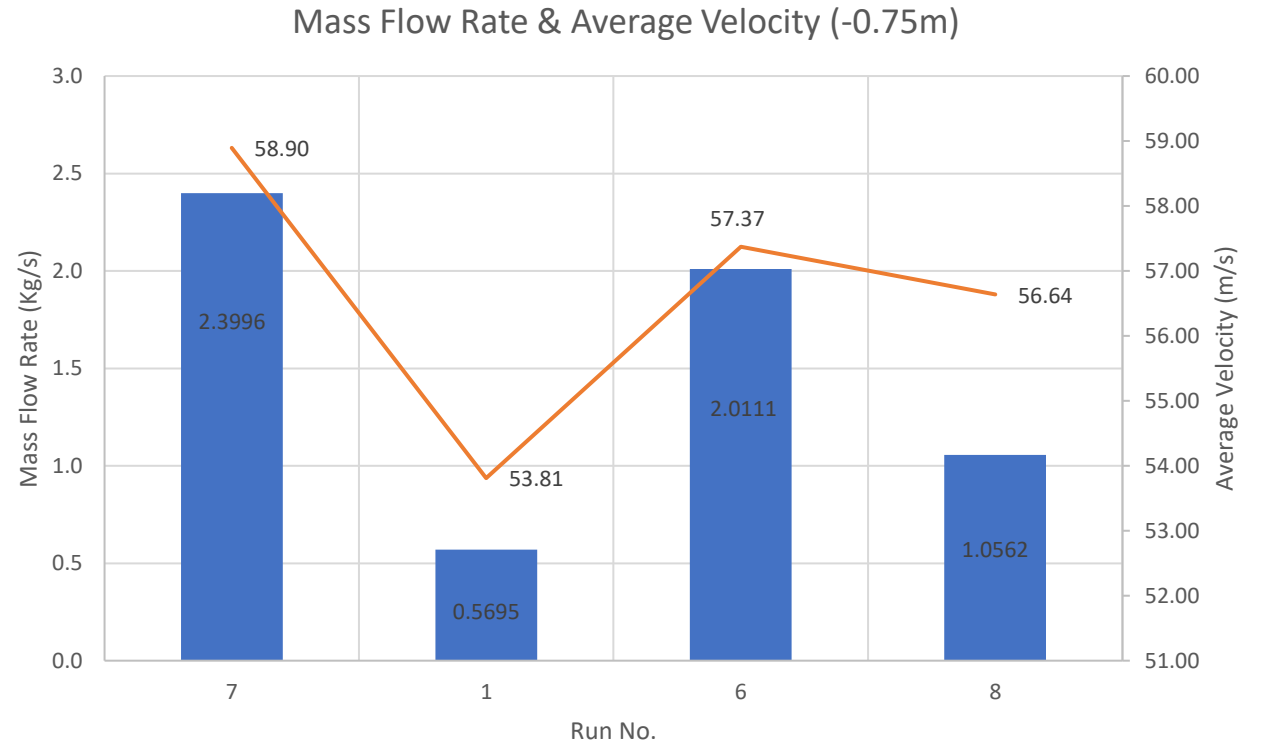


- Runs 7 and 6 display less trailing edge separation.
- Wake region from leading edge separation is apparent on runs 1 and 8.
- This leads to a reduction in C_p (static pressure) differential from upper and lower surfaces, thus a reduction in C_{zf} .

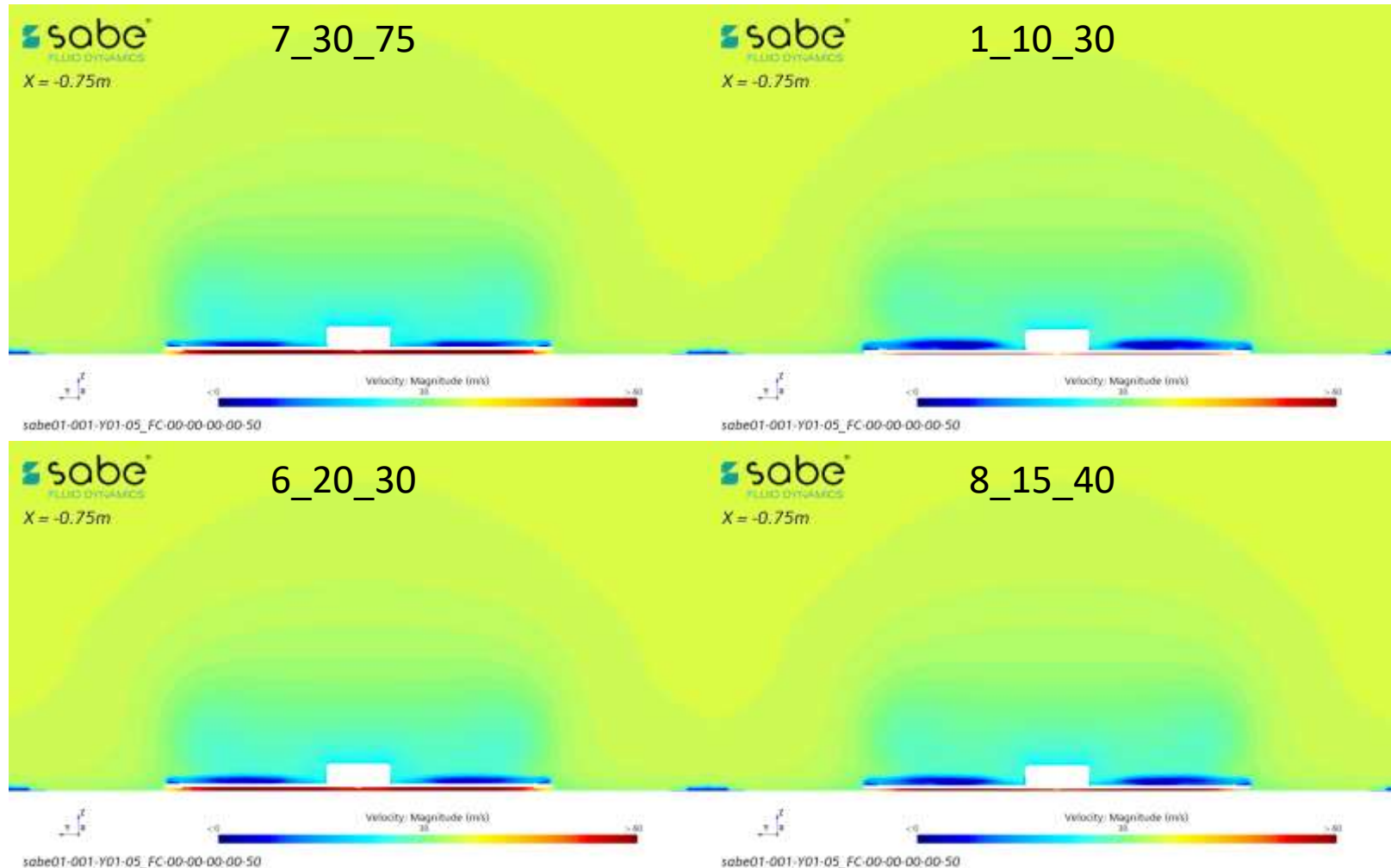
Mass Flow Rate



- Plane Location:
 - -0.75m, 0m, 0m.
 - Located within the contraction (throat) section.
- Plane Dimensions:
 - Y = 0.85m, -0.85m.
 - Z = Geometry dependant.



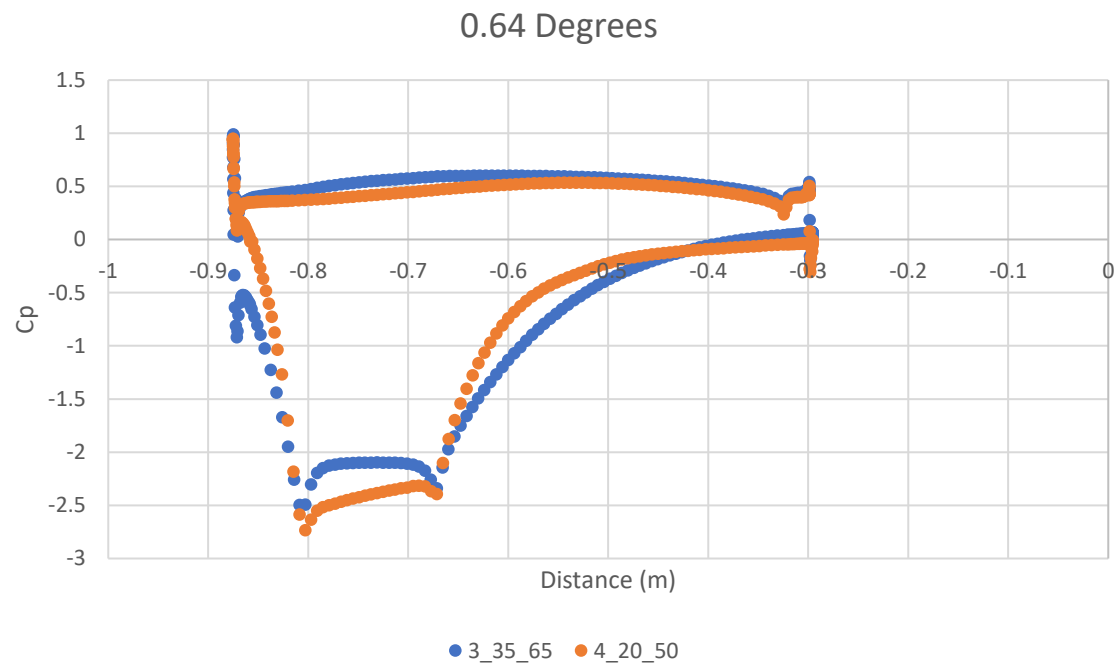
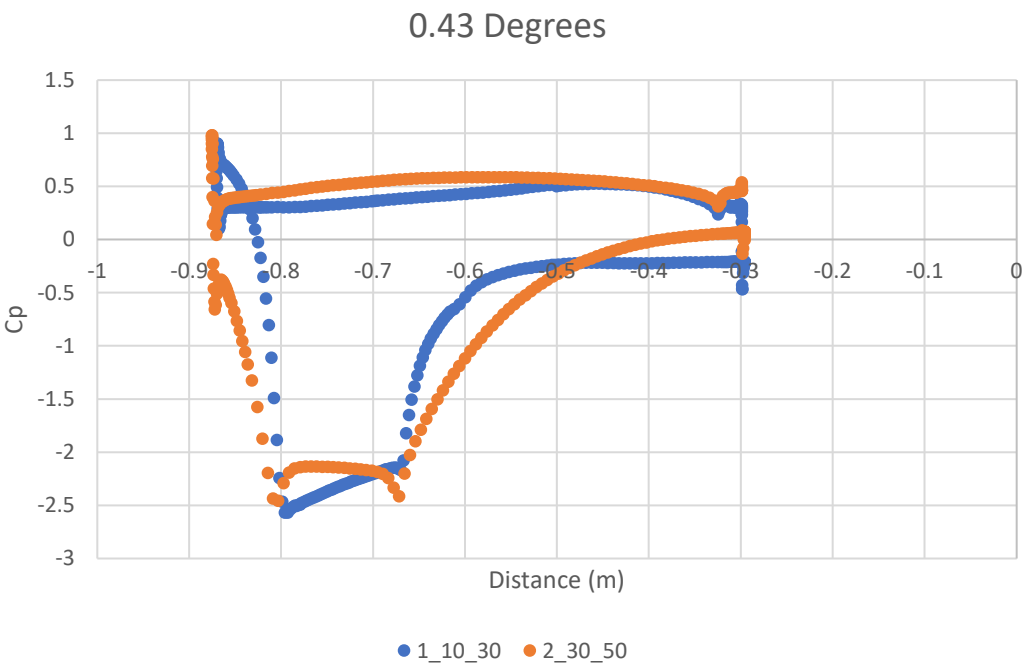
Velocity Contours -0.75m



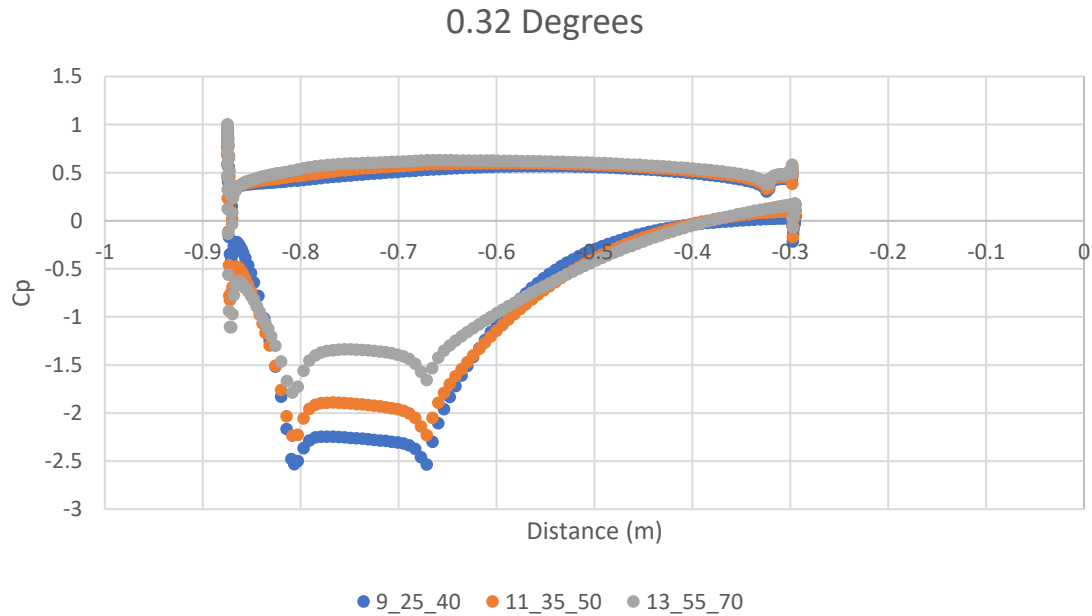
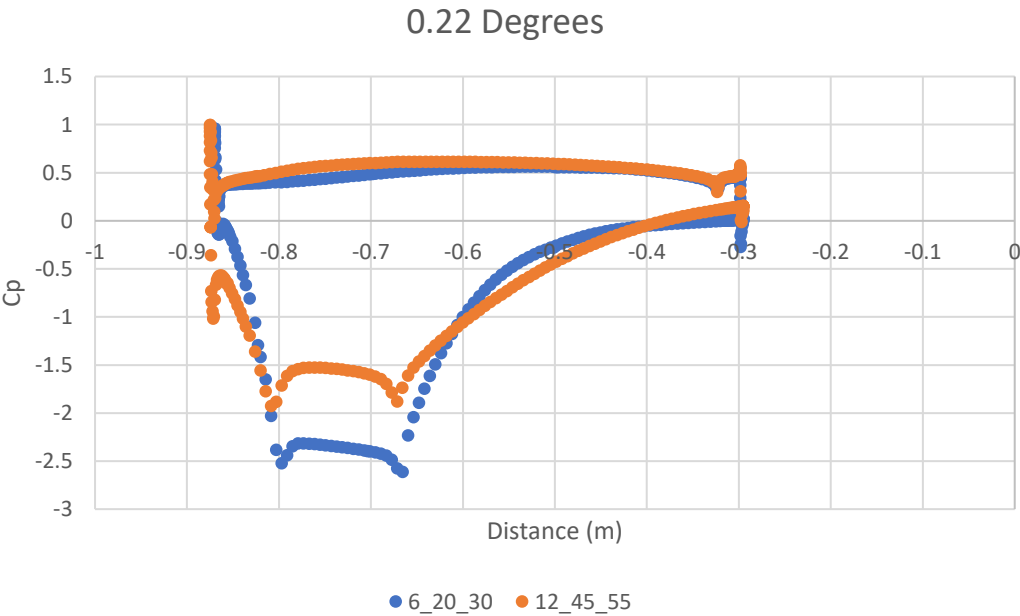
Cpt Contours -0.75m



Cp Plot (Ride Height Comparison)



Cp Plot (Ride Height Comparison)

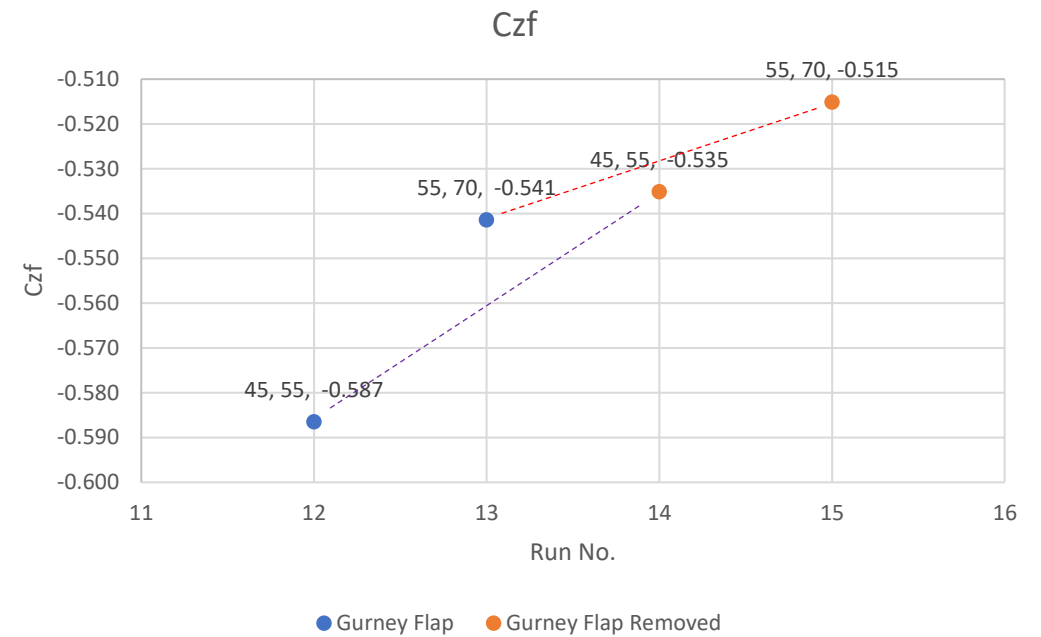
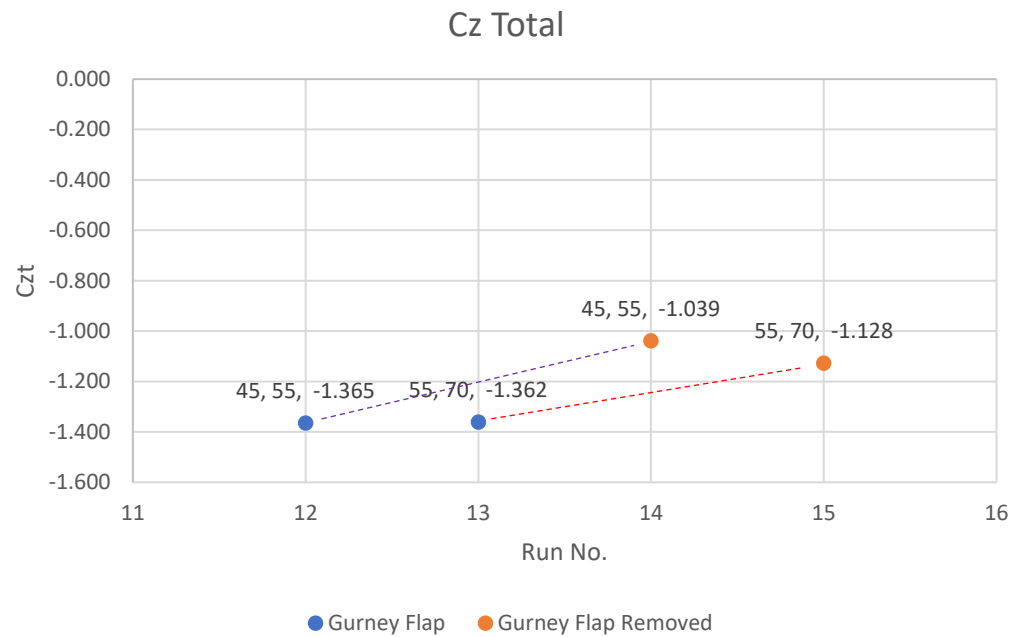


Conclusion – Front Splitter

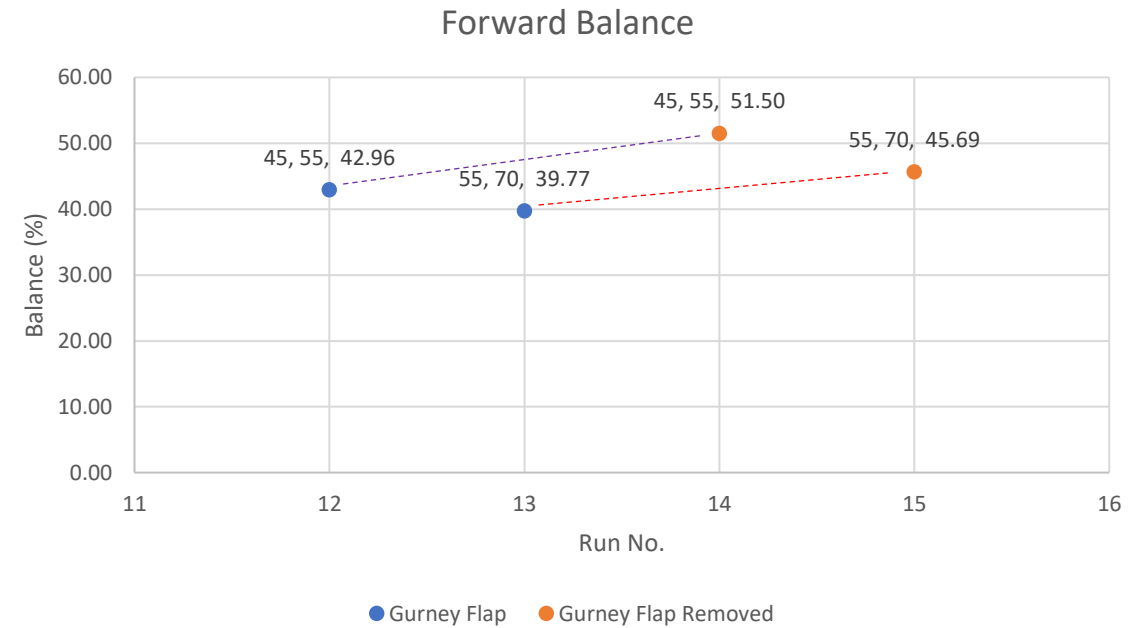
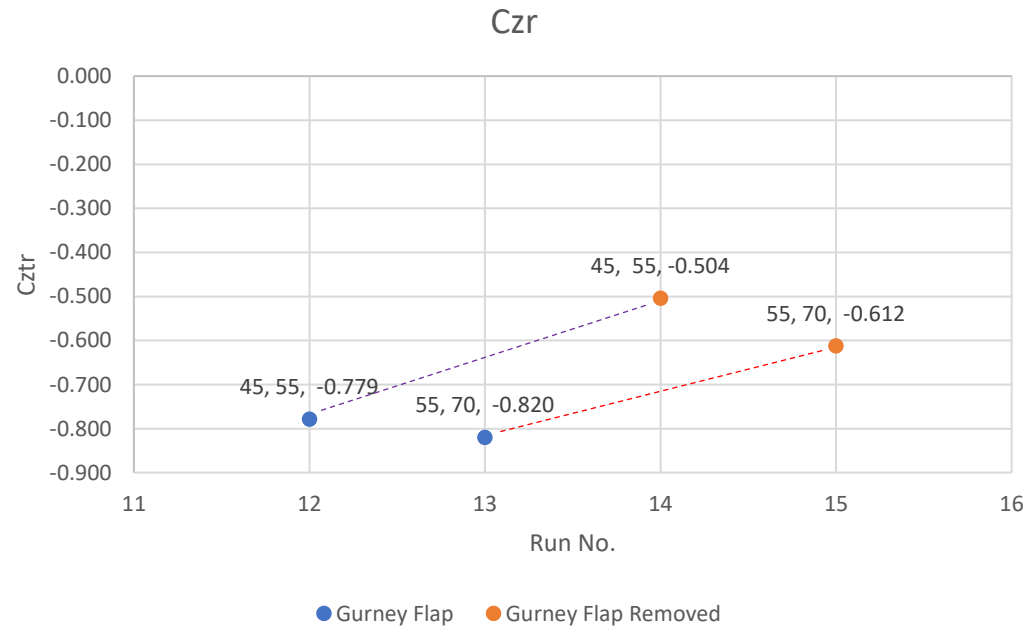
- Results display that forward balance begins to reduce when:
 - $Fr_h < 20\text{mm}$.
 - $Rr_h < 40\text{mm}$.
- This was highlighted and investigated.
- Investigations show that as fr_h is reduced below 20mm, the splitter is susceptible to choking, therefore suffers a reduction in performance. It also shows increased separation from the upper leading edge, therefore a reduction in pressure differential is developed.
- As rr_h is reduced, rake angle is lessened. This lowers the expansion zone from the front diffuser, thus a reduction in performance.
- Once the splitter has choked, the expansion section suffers earlier onset separation due to the increased pressure gradient.

Rear Deck Gurney Flap Investigation

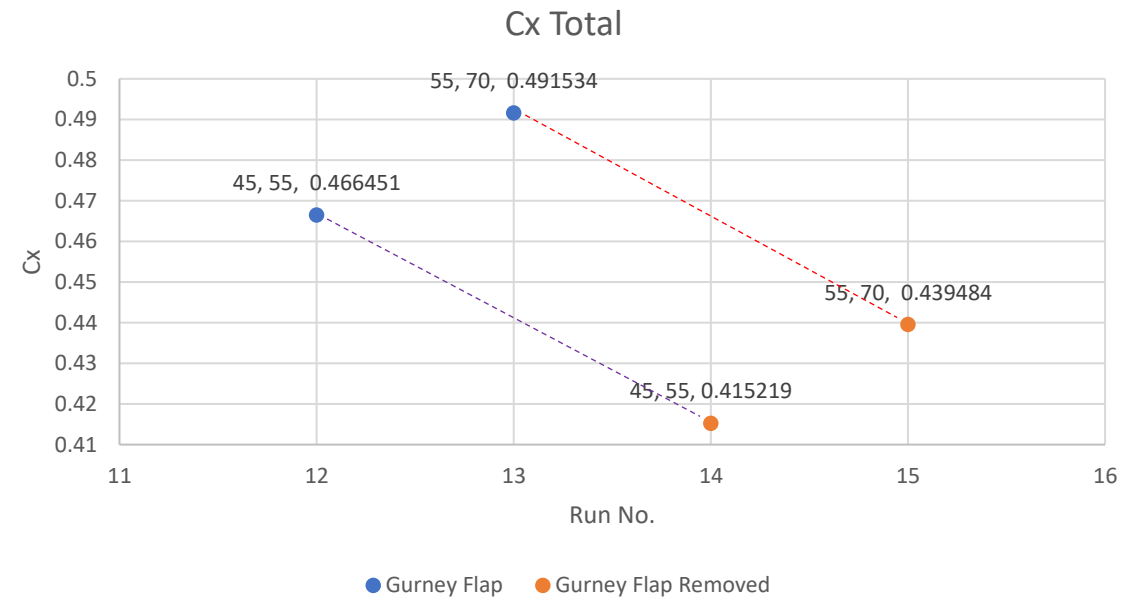
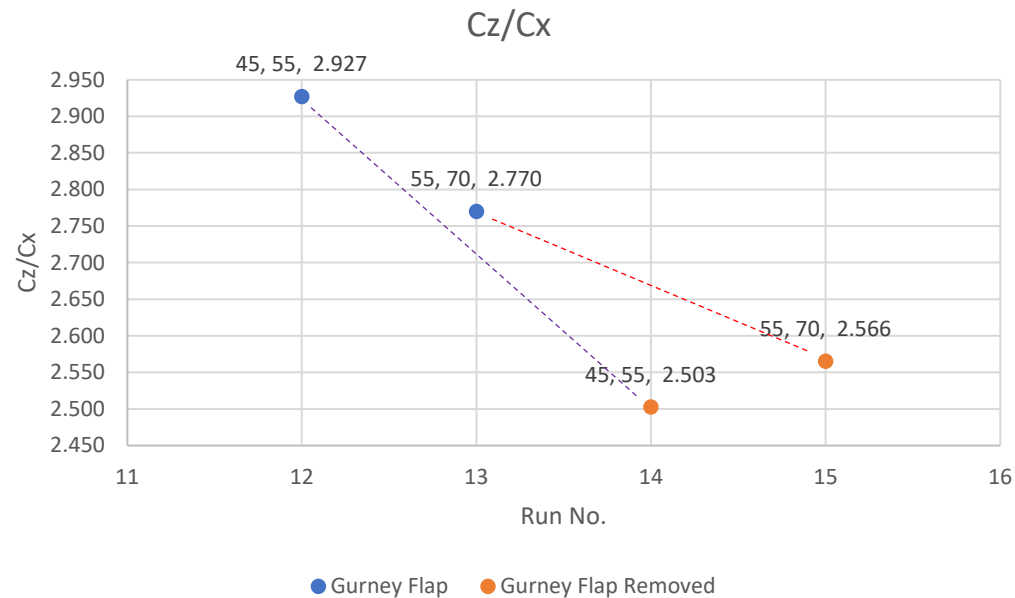
Results – Gurney Flap



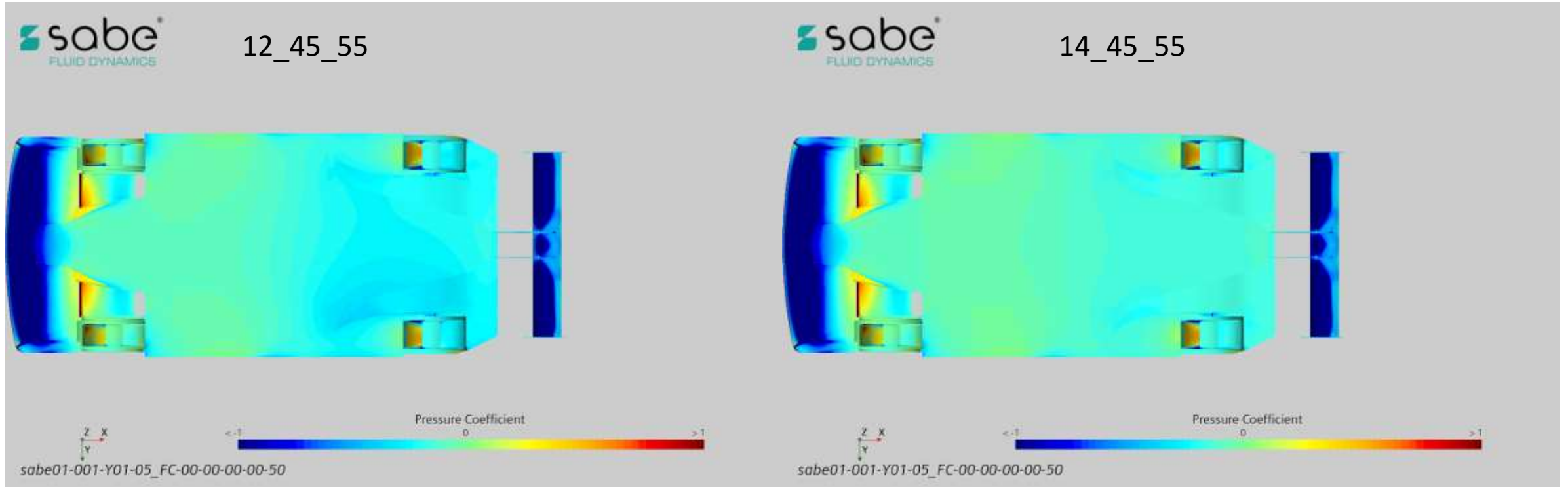
Results – Gurney Flap



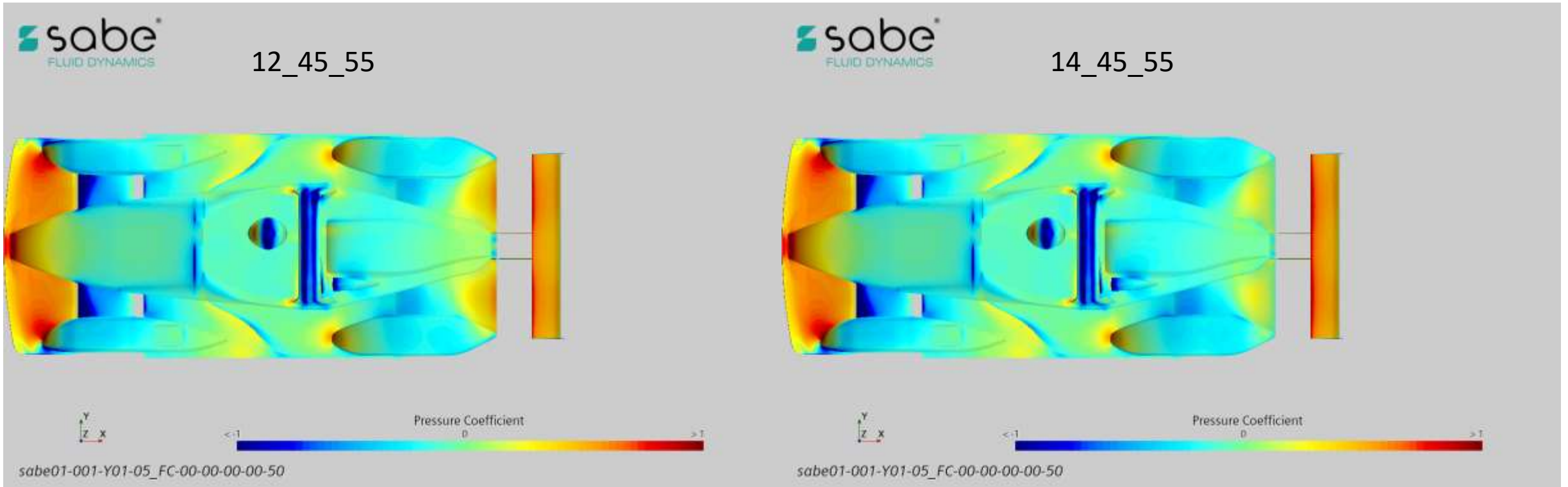
Results – Gurney Flap



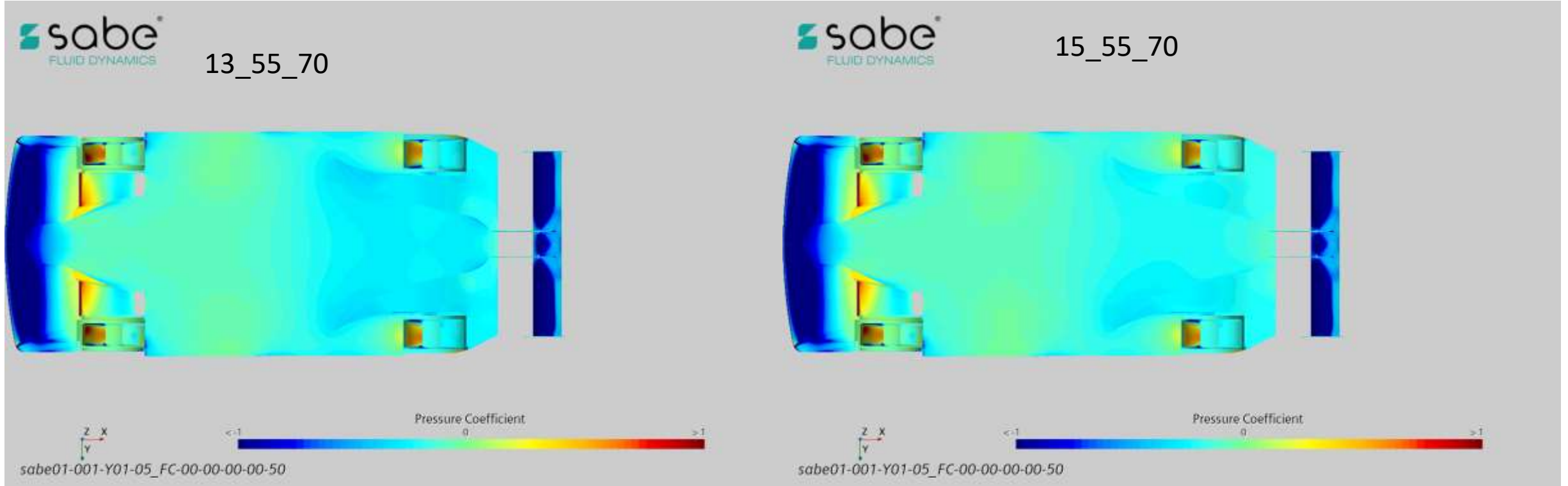
Surface Plots – Pressure Coefficient



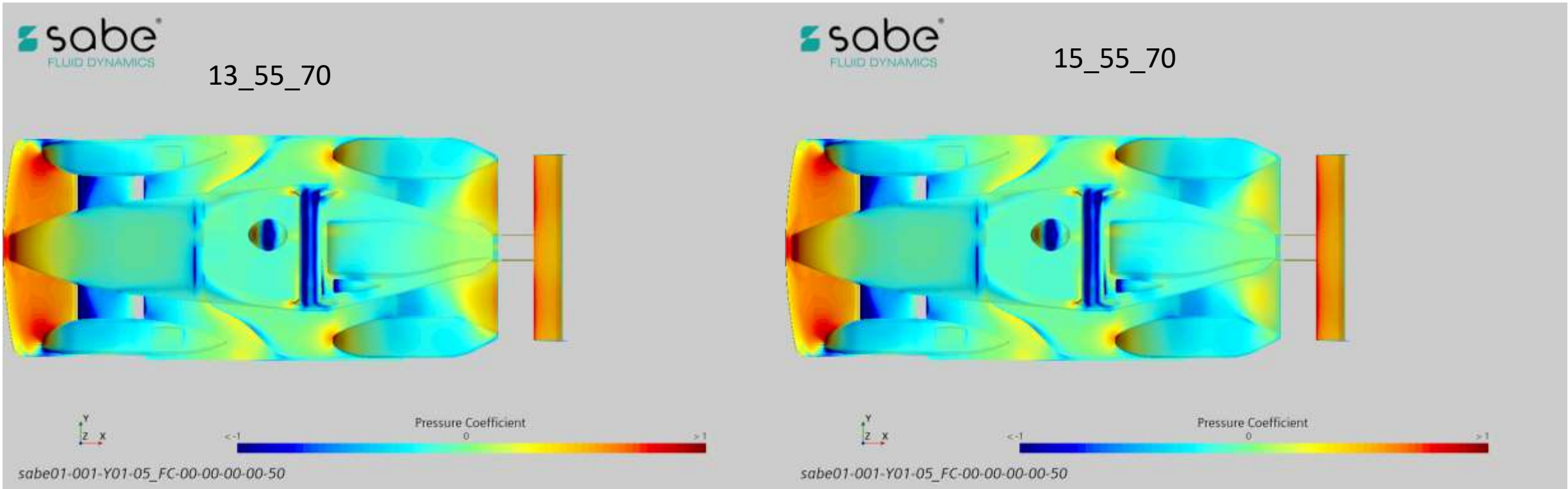
Surface Plots – Pressure Coefficient



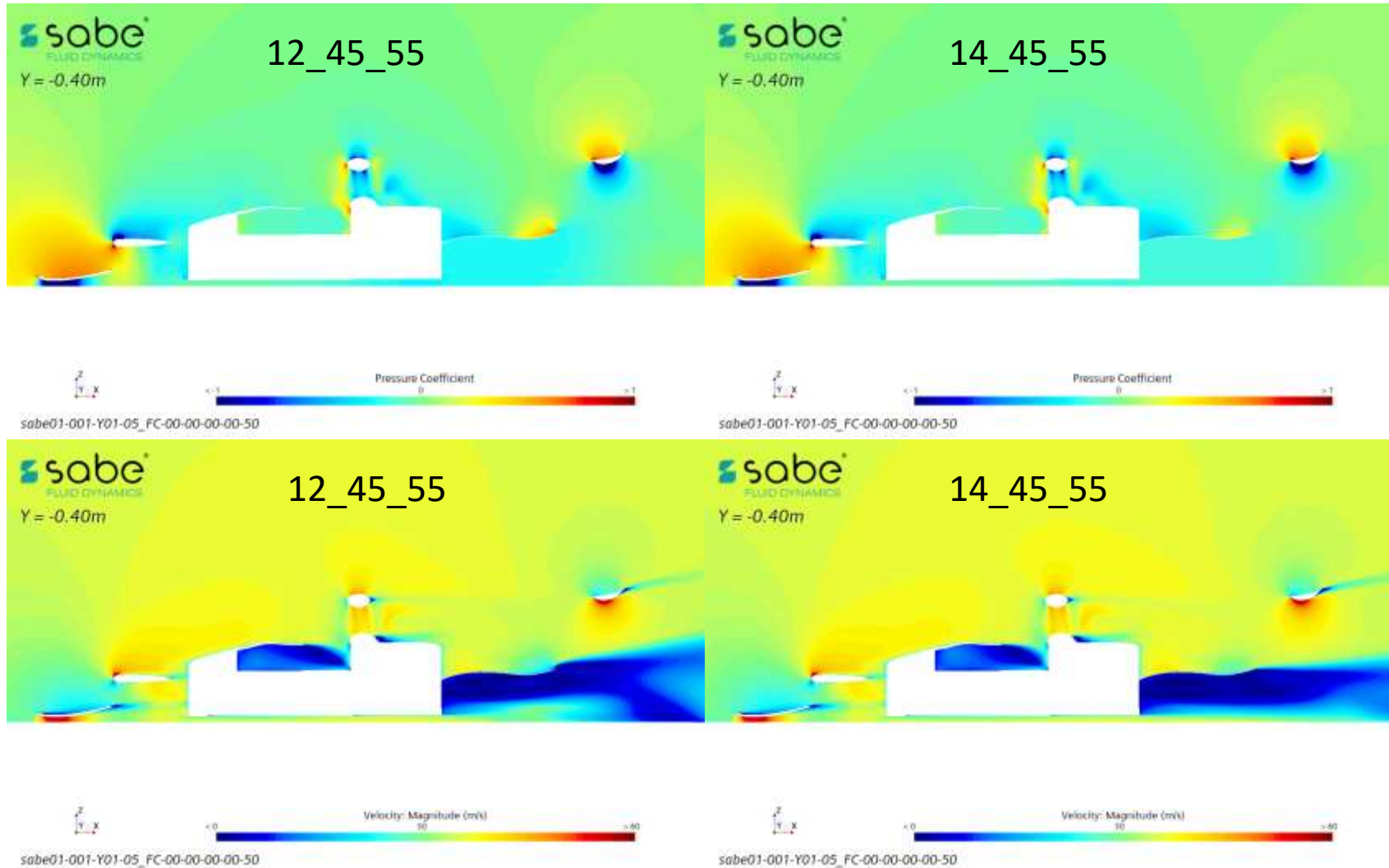
Surface Plots – Pressure Coefficient



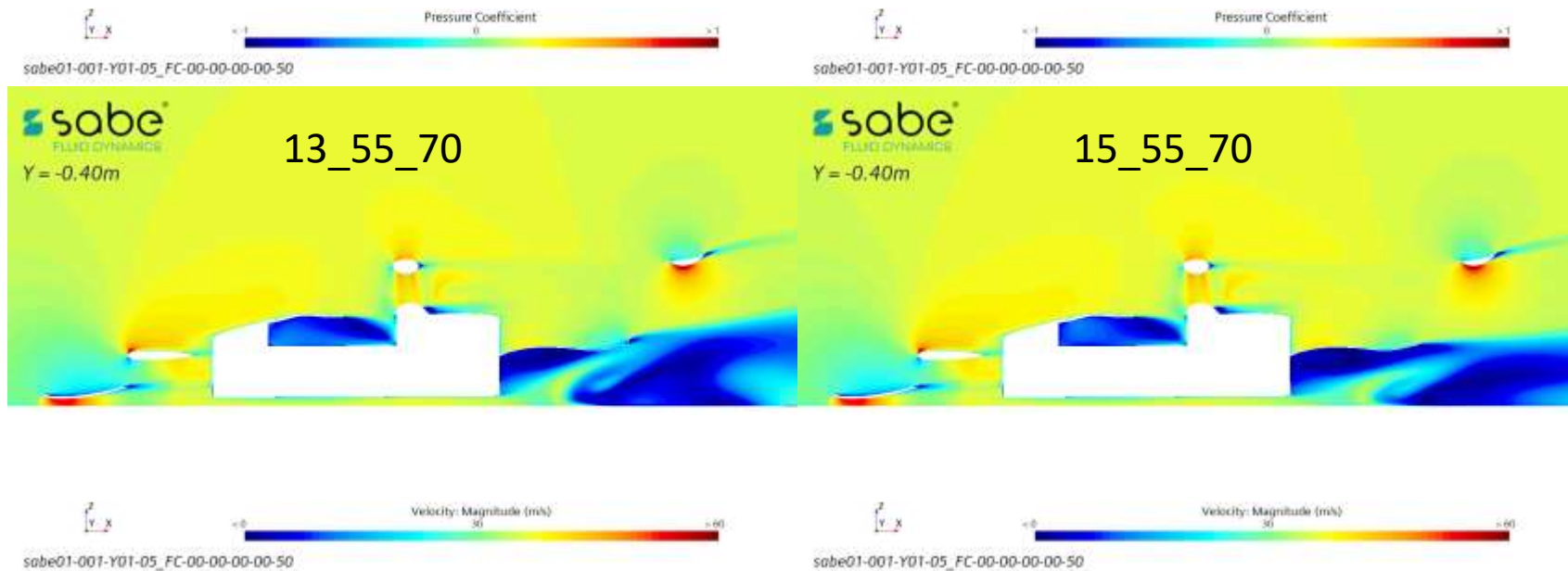
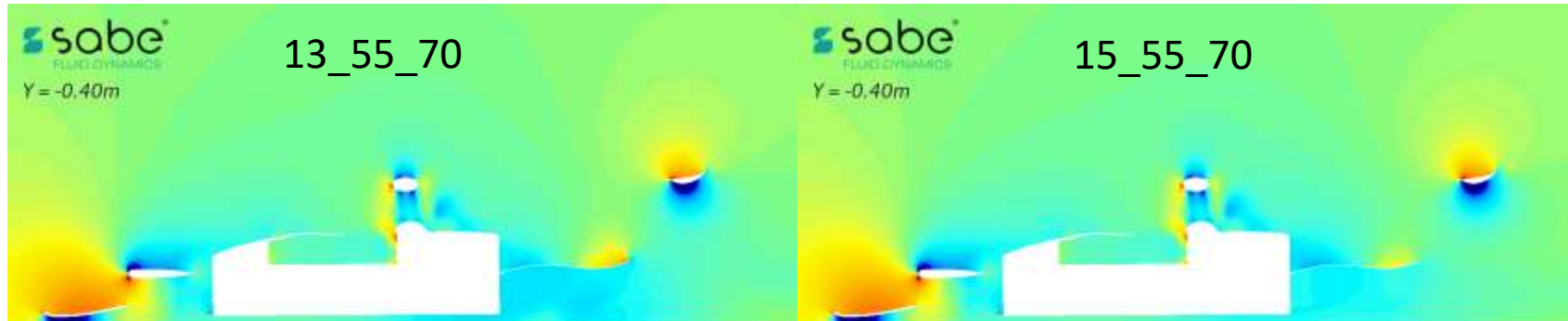
Surface Plots – Pressure Coefficient



Vmag & Cp



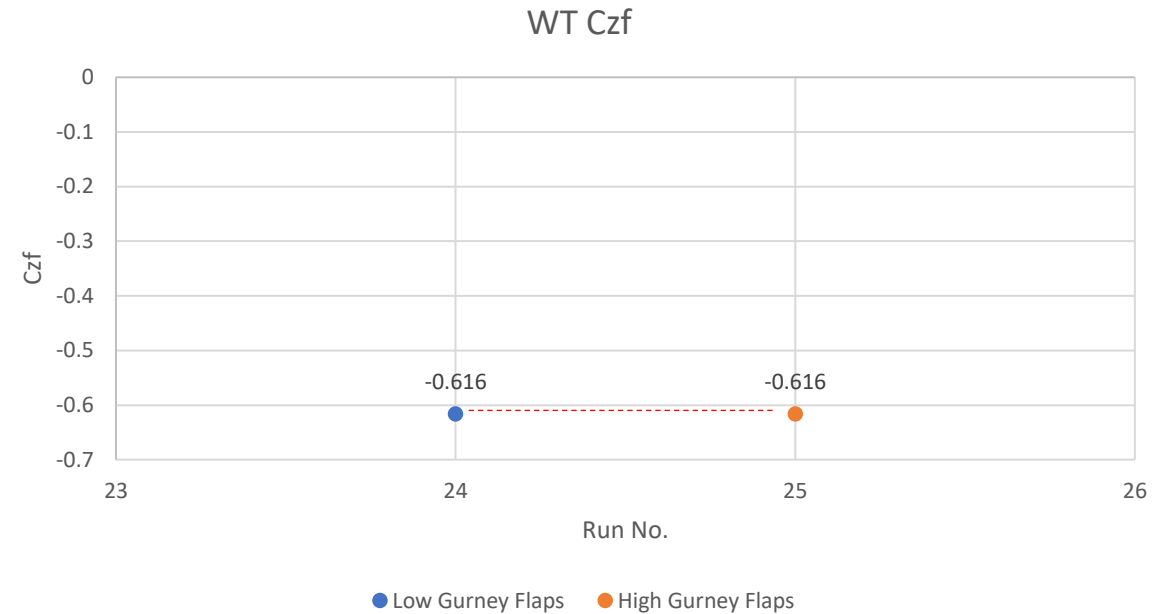
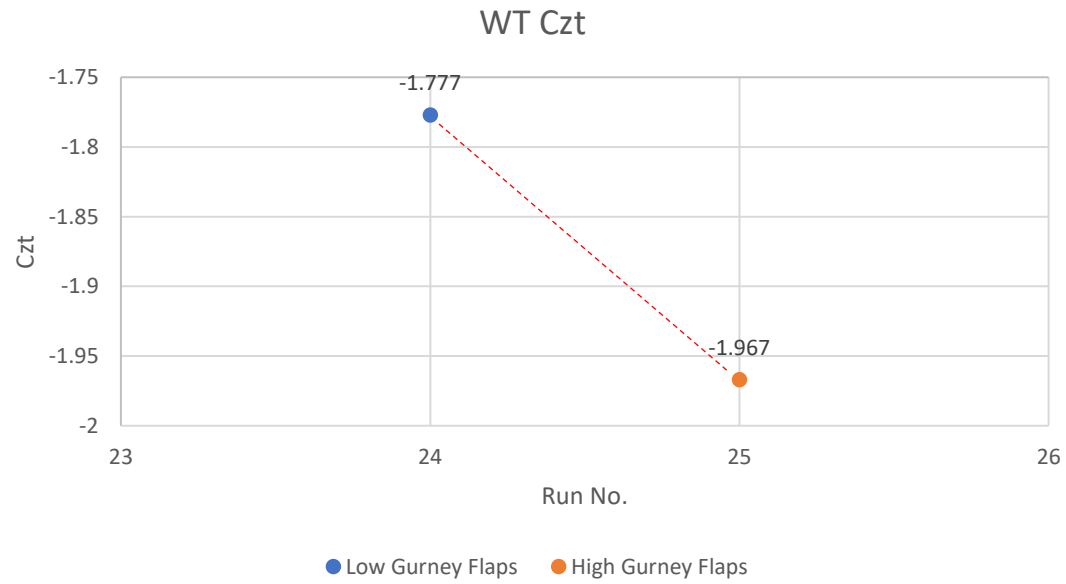
Vmag & Cp



Wind Tunnel Data

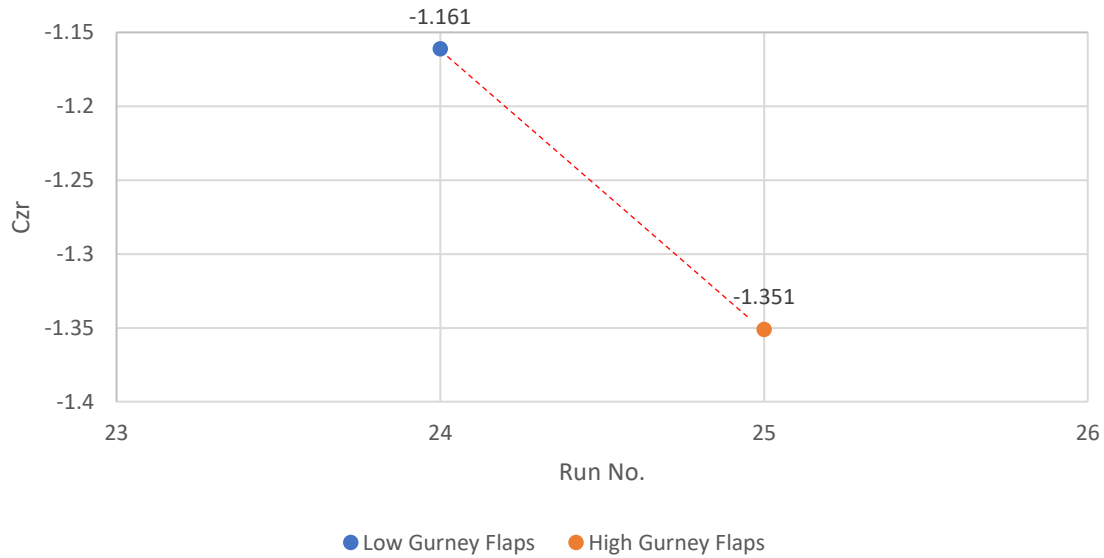
- The following slides contain data taken from a wind tunnel session.
- The was the same as that used in the CFD investigations, however the CAD used does have some simplifications (wheels, suspension etc).
- HORIBA MIRA wind tunnel does not have a moving ground, therefore there is no relative wheel rotation.
- Free stream velocity used was 35m/s.
- The ride heights used for the following data:
 - Frh = 42mm
 - Rrh = 75mm

Results – WT Gurney Flap

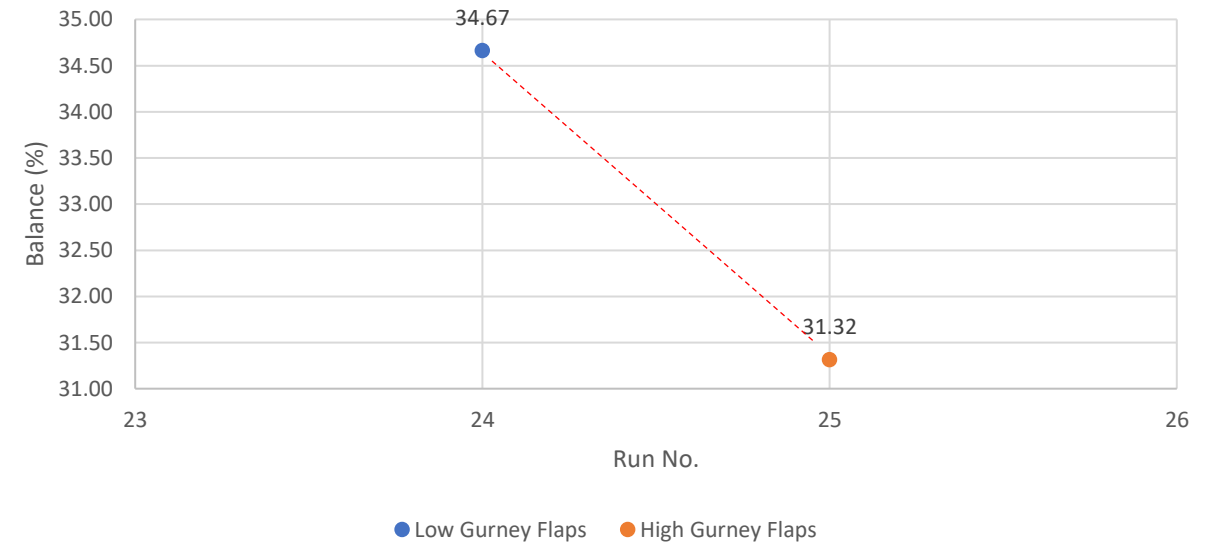


Results – WT Gurney Flap

WT Czr

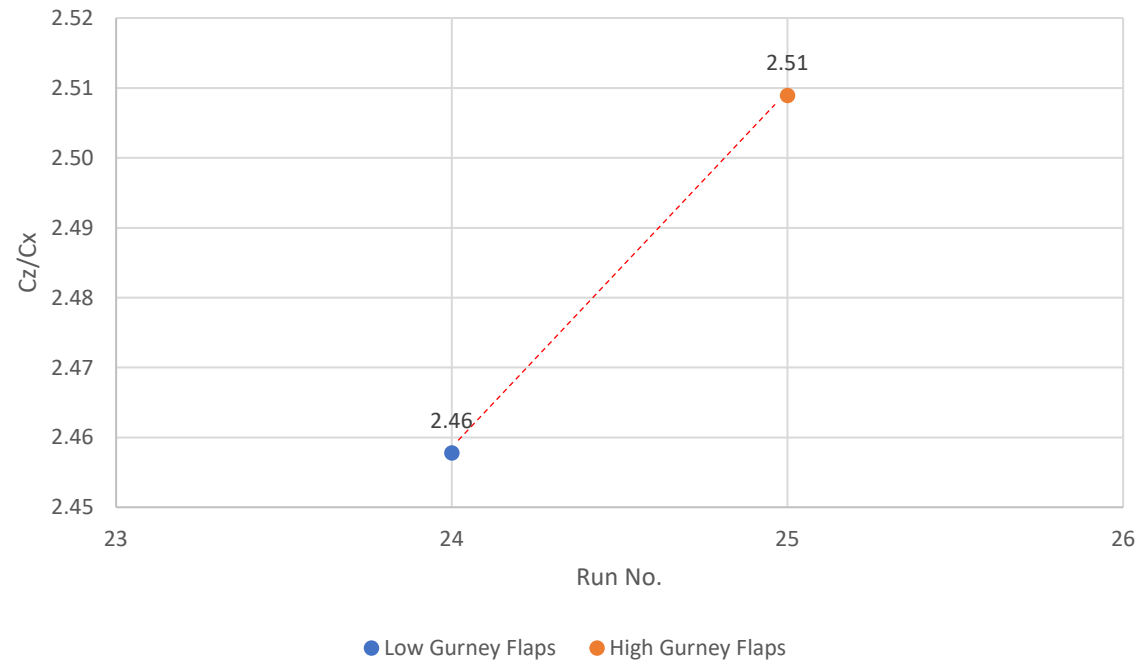


WT Forward Balance

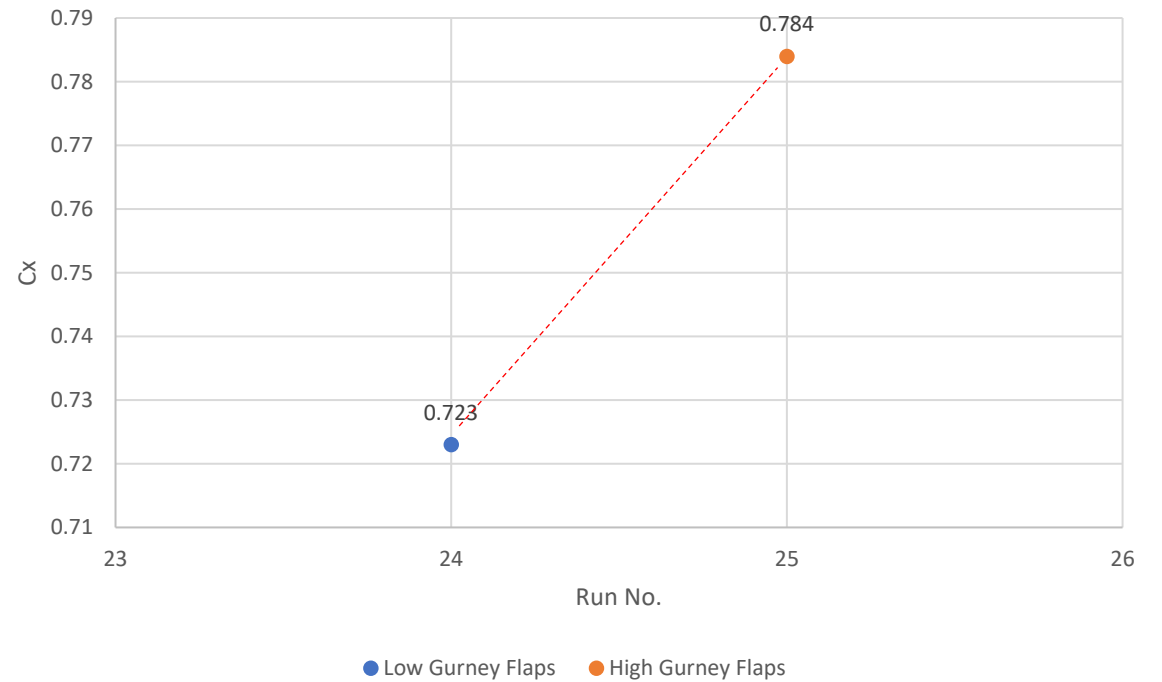


Results – WT Gurney Flap

C_z/C_x



C_x



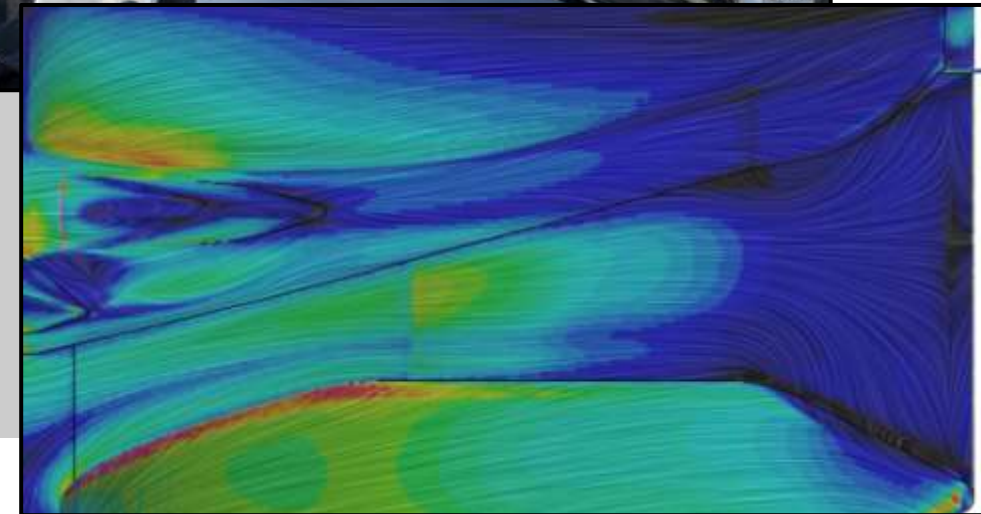
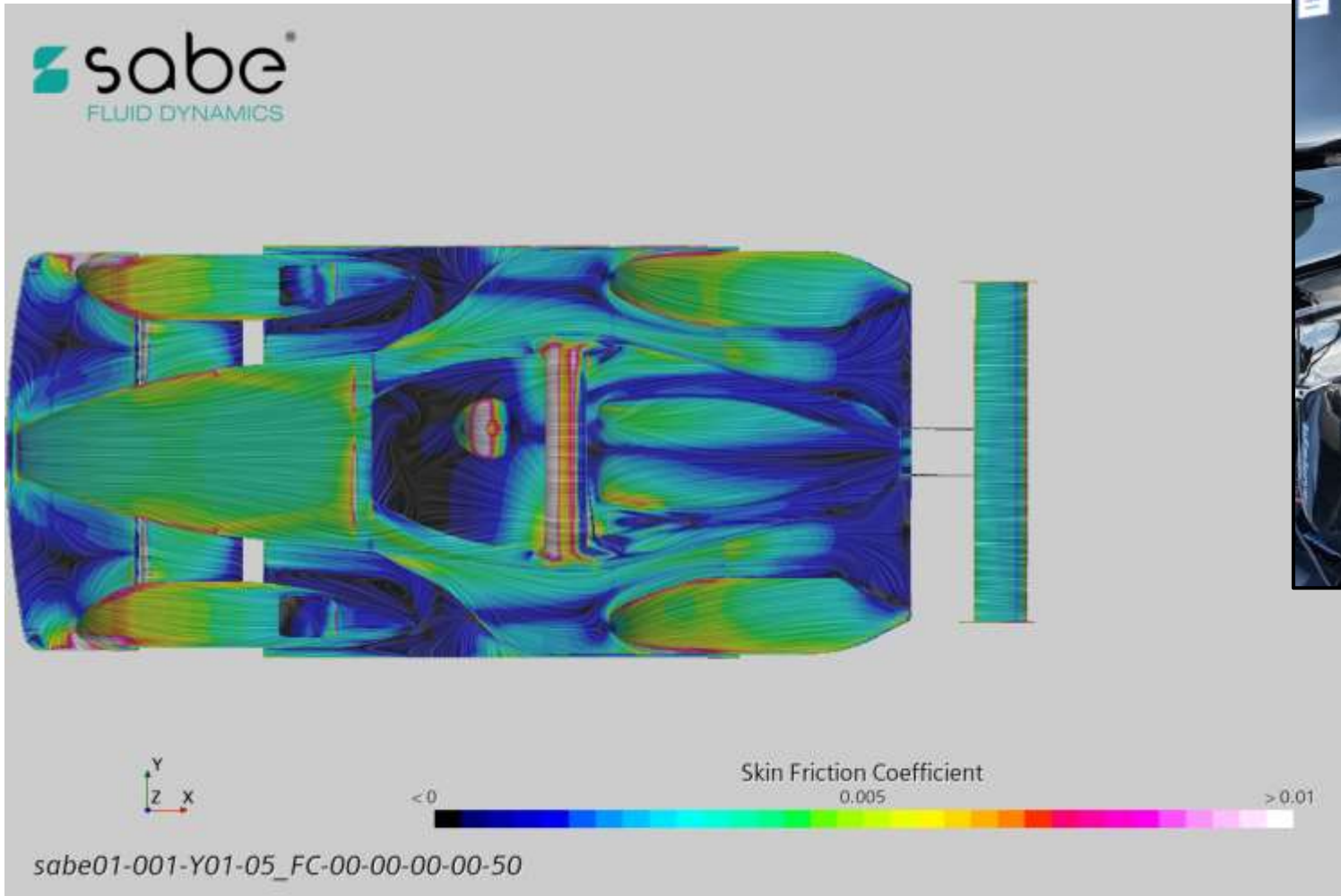
Conclusion – Gurney Flap

- The Rear Deck Gurney Flap displays powerful characteristics when implemented.
- Gurney flap installed introduces a much larger pressure differential on the rear deck.
- Rear upwash is increased and creates much more expansion.
- Flow velocity is increased on the floor section, which decreases C_p .
- The better upwash then has a positive interaction onto the suction side of the rear wing.
- Rear wing trailing edge separation is delayed, therefore improving rear wing efficiency.
- CFD shows similar trends to WT data, however the WT data shows neutrality on C_{zf} , whereas the CFD displayed an increase in C_{zf} when the Gurney Flap was introduced.

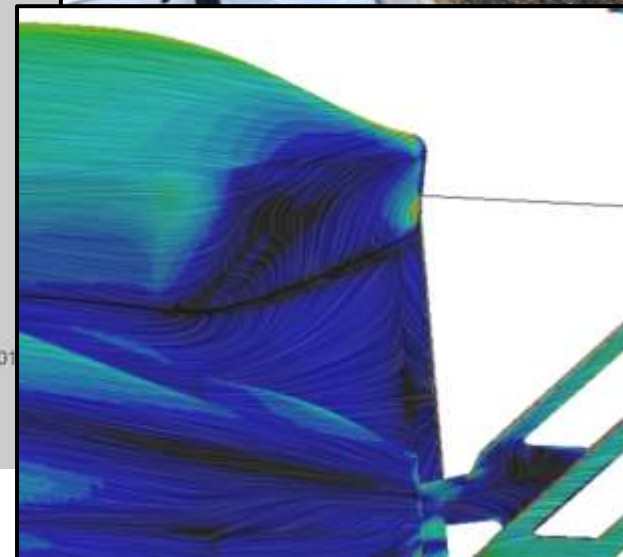
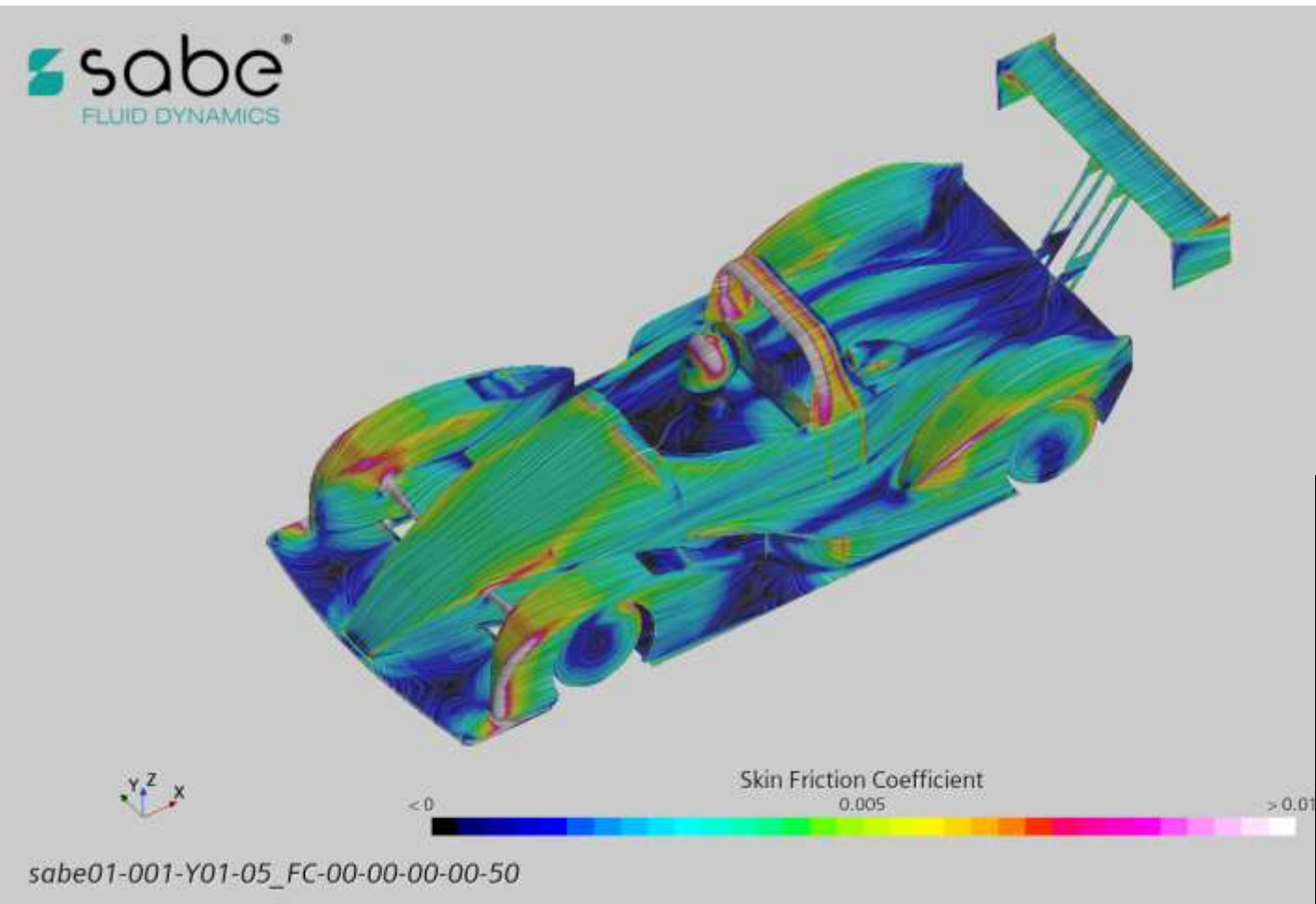
Flow Visualisation Testing

Donnington Park Circuit – September 2023

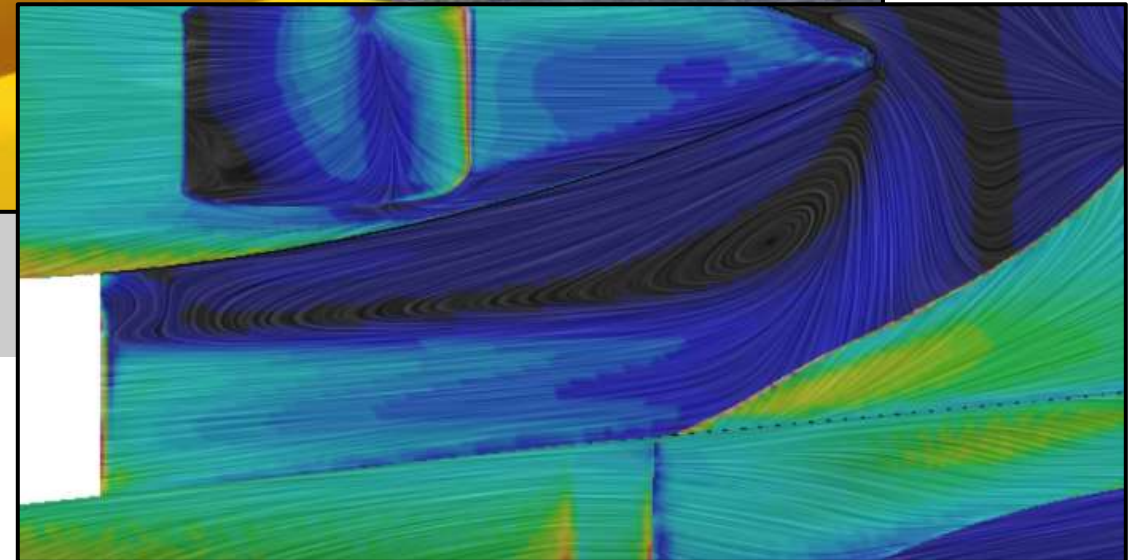
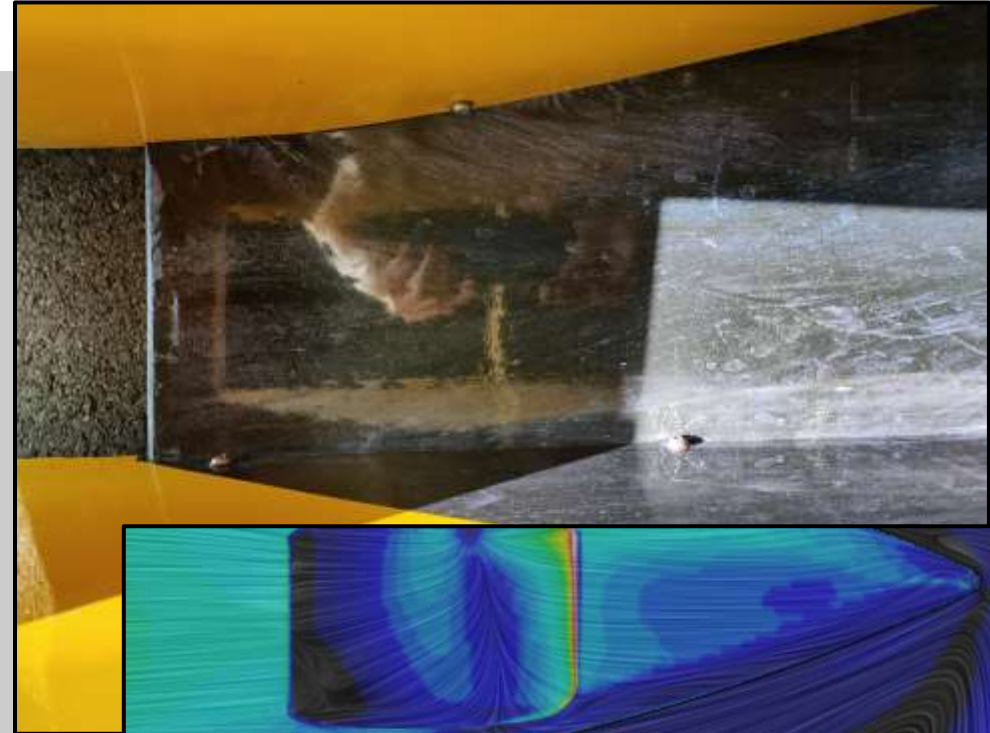
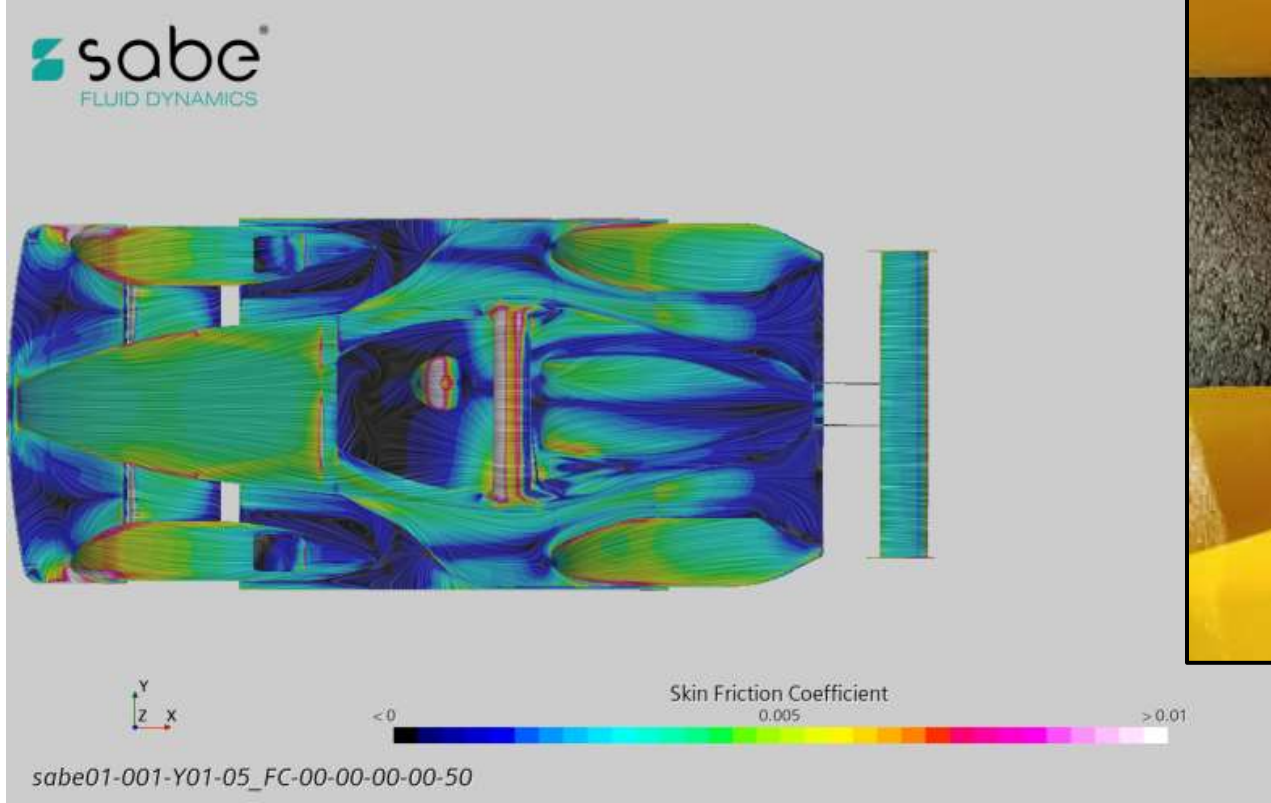
Rear Deck



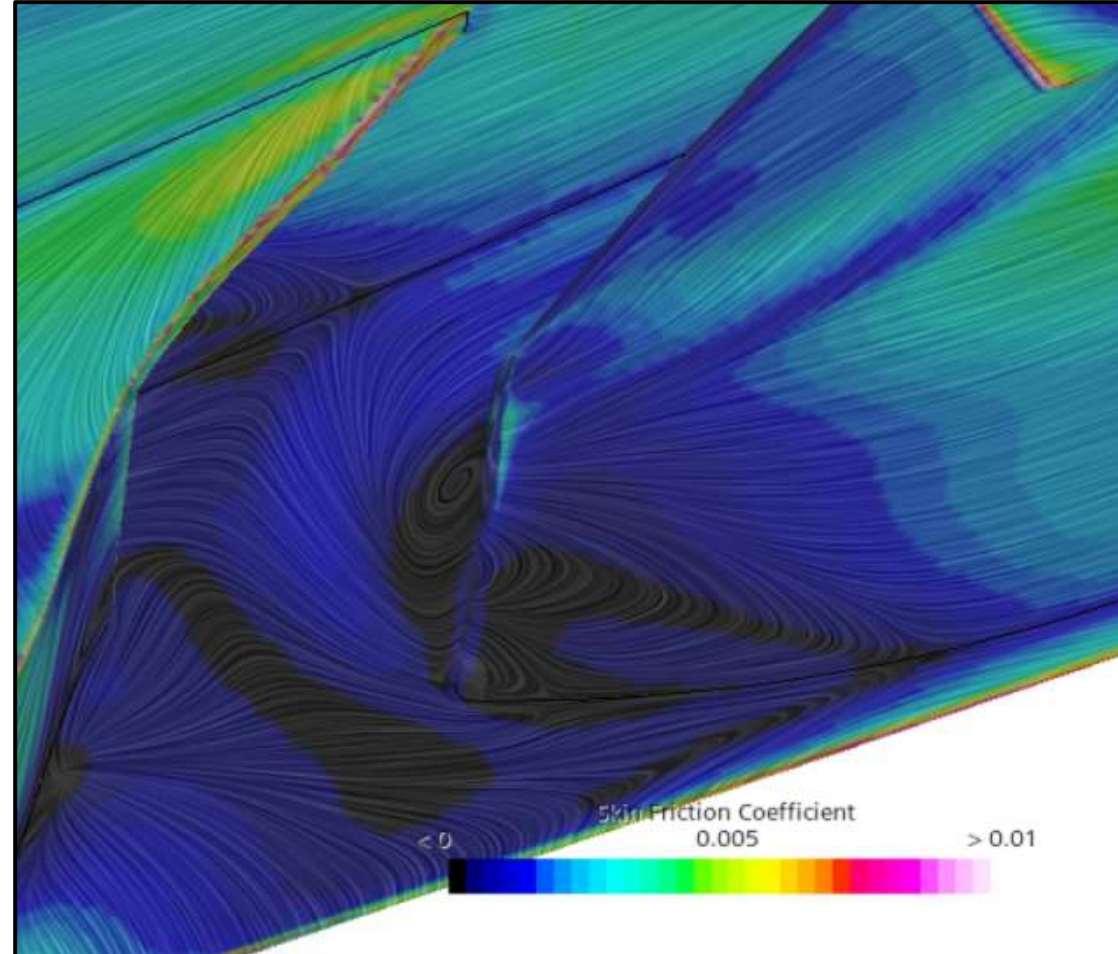
Gurney Flap



Front Floor

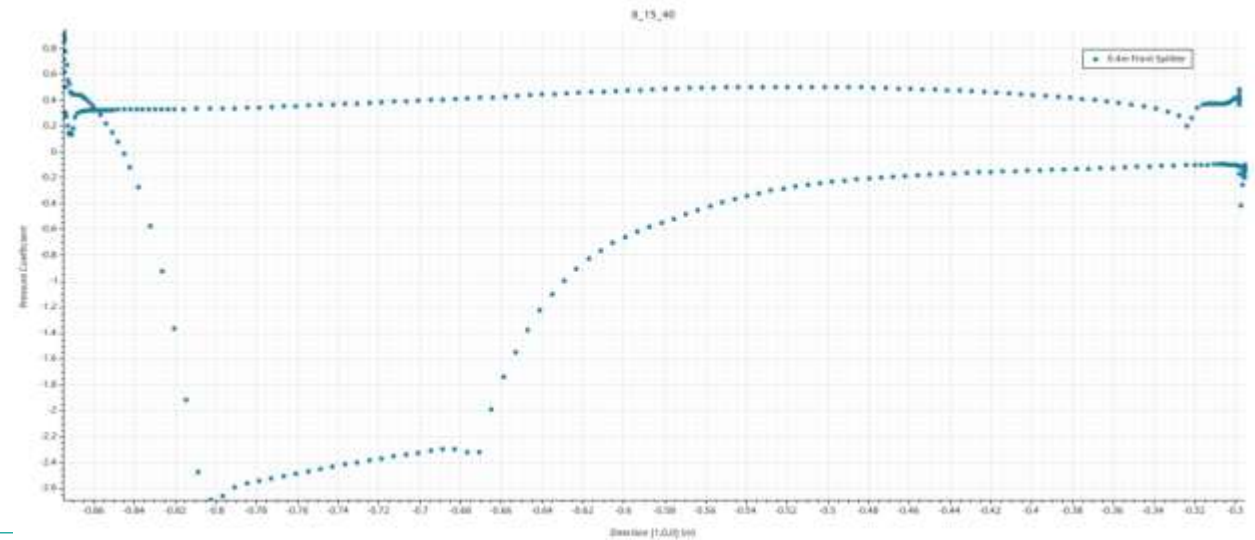
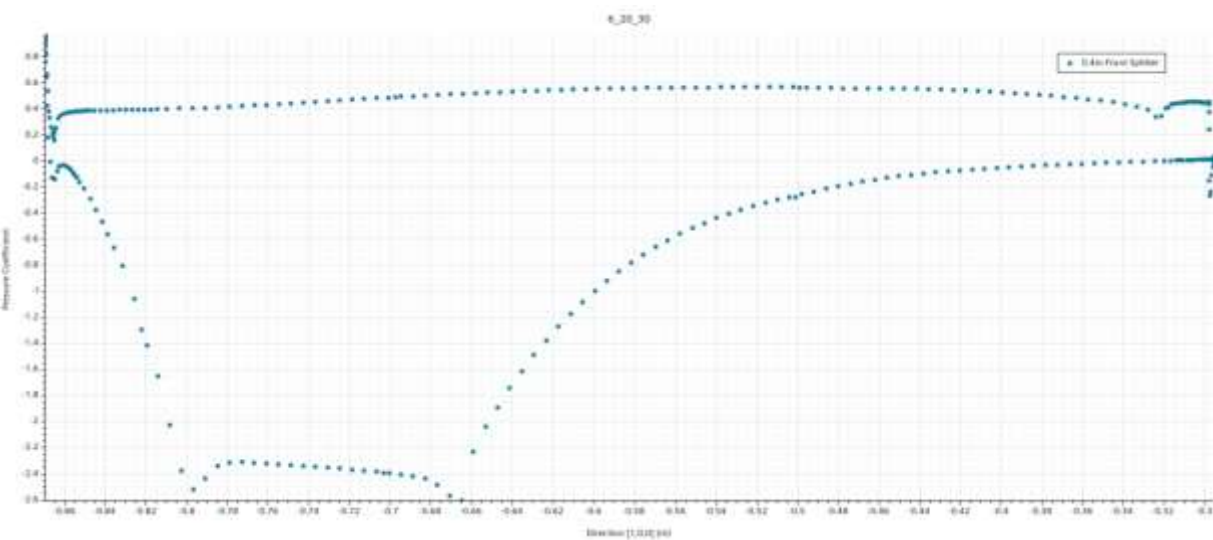
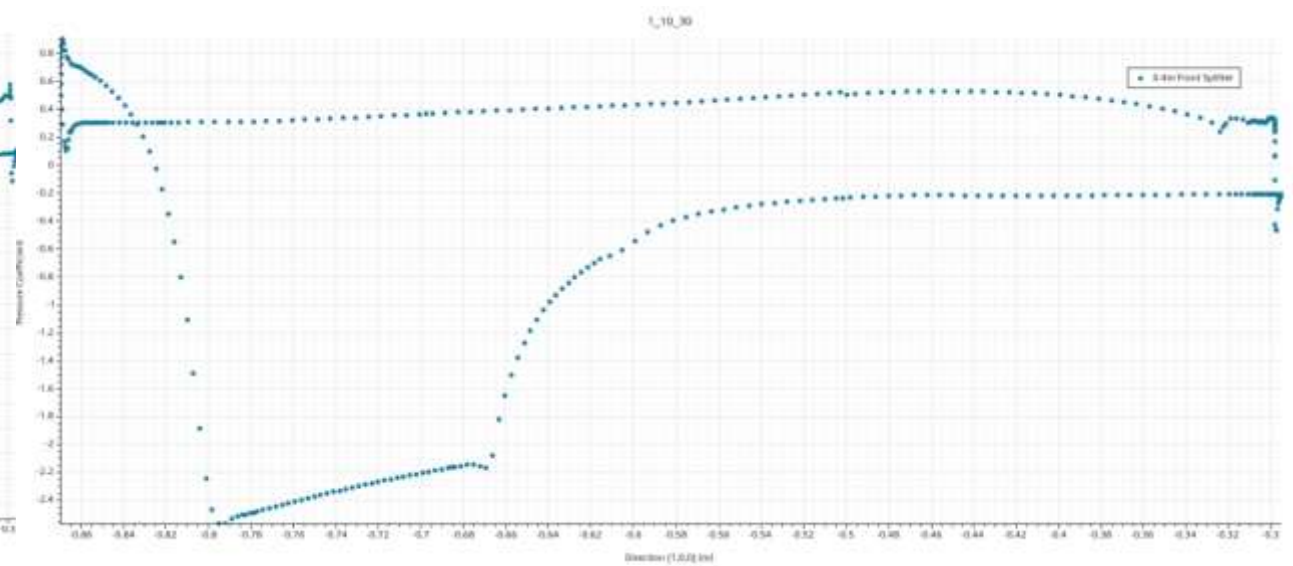
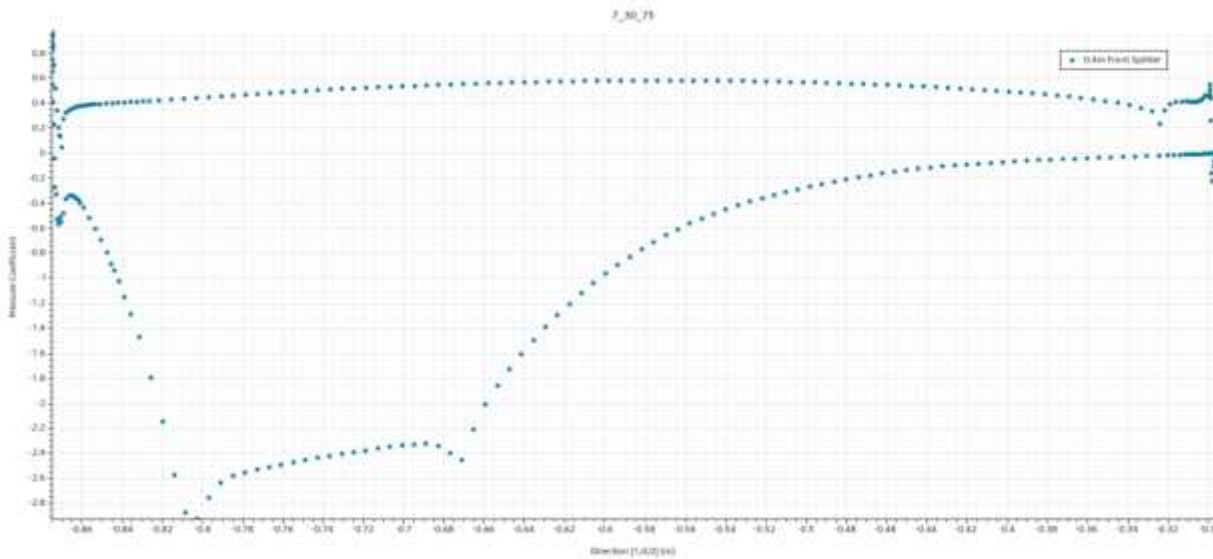


Front Floor



Appendix

Splitter Cp – Y = 0.4m



Floor – Surface Plots

