Computational and Experimental Investigation of Wind Tunnel Effects on Near-Wheel Device Prediction

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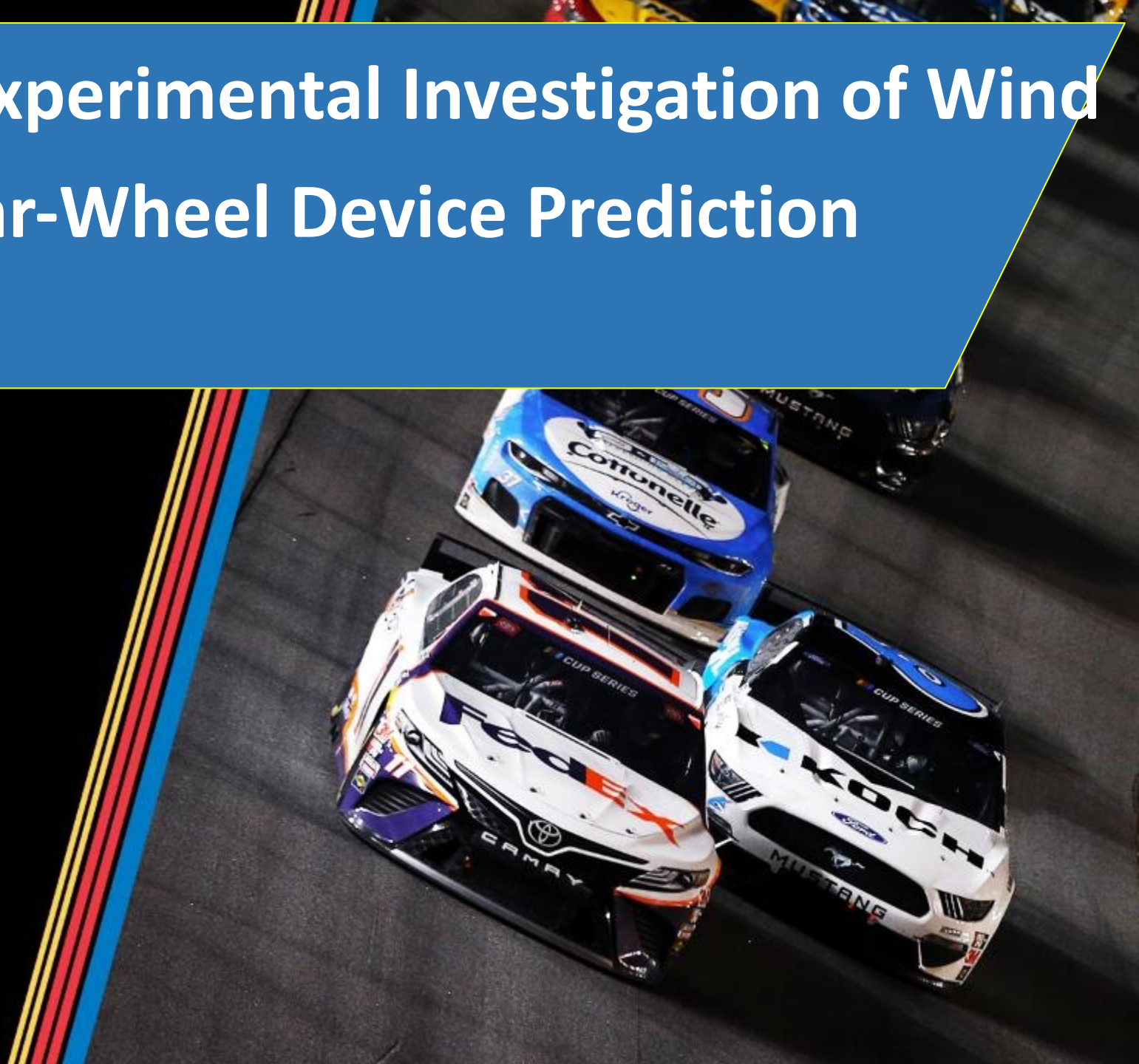
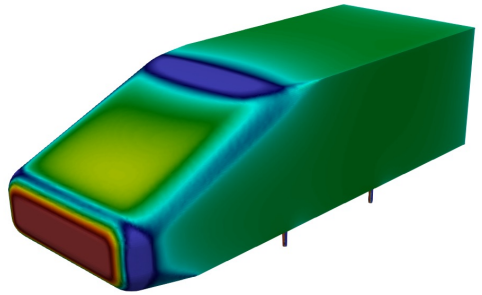


Workshop Case 1 and 2 Results (#49)

Case 1

- Steadily increasing CD from coarse to fine grids, while the moment coefficient decreased.
- CL trend inconsistent between grids.
- CS showed no change from medium to fine grids.

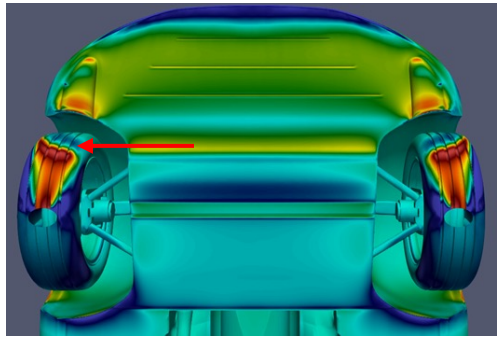
Case 1 - DDES-SA				
Description	**C_D**	**C_L**	**C_S**	**CM**
Grid 1 – Coarse Grids	0.297	-0.192	0.111	-0.108
Grid 2 – Medium (baseline) Grids	0.332	-0.186	0.139	-0.102
Grid 3 – Fine Grids	0.361	-0.202	0.139	-0.087

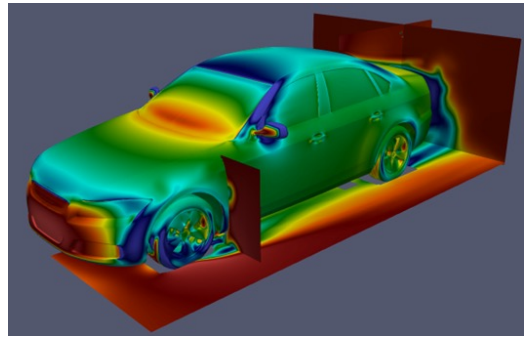


Case 2

- Decrease in drag and increase in total lift.
- ΔCD = -0.006 and ΔCL = 0.010
- Tire deflector showed CP decrease on the forward portion of the front tires.
- Surface pressure distribution and flowfield comparable to experimental results in [1].

Case 2 - DDES-SA					
Description	C_D	C_L	C_{Lf}	C_{Lr}	C_S
Case 2A - Baseline	0.283	0.045	-0.058	0.104	0.020
Case 2B - Front Wheel Deflector	0.277	0.055	-0.049	0.104	0.026
Experimental Baseline - [1]	0.255	0.087	-0.023	0.111	-





[1] Hupertz, B., Chalupa, K., Krueger, L., Howard, K. et al., "On the Aerodynamics of the Notchback Open Cooling DrivAer: A Detailed Investigation of Wind Tunnel Data for Improved Correlation and Reference," SAE Int. J. Advances & Curr. Prac. in Mobility 3(4):1726-1747, 2021

Motivation

- Interested in expanding upon the scope of the workshop.
- CFD vs. wind tunnel a constant area of interest
- Assess NASCAR/TotalSim USA CFD methodology.

- **<u>Questions:</u>**

- How important is the road simulation vs. a stationary condition?
- How do these conditions influence the deflector results?
- How important is the wind tunnel difference vs. idealized freestream?
- Can we validate the predicted surface and flow field changes in the wind tunnel?

Computational & Experimental Setup

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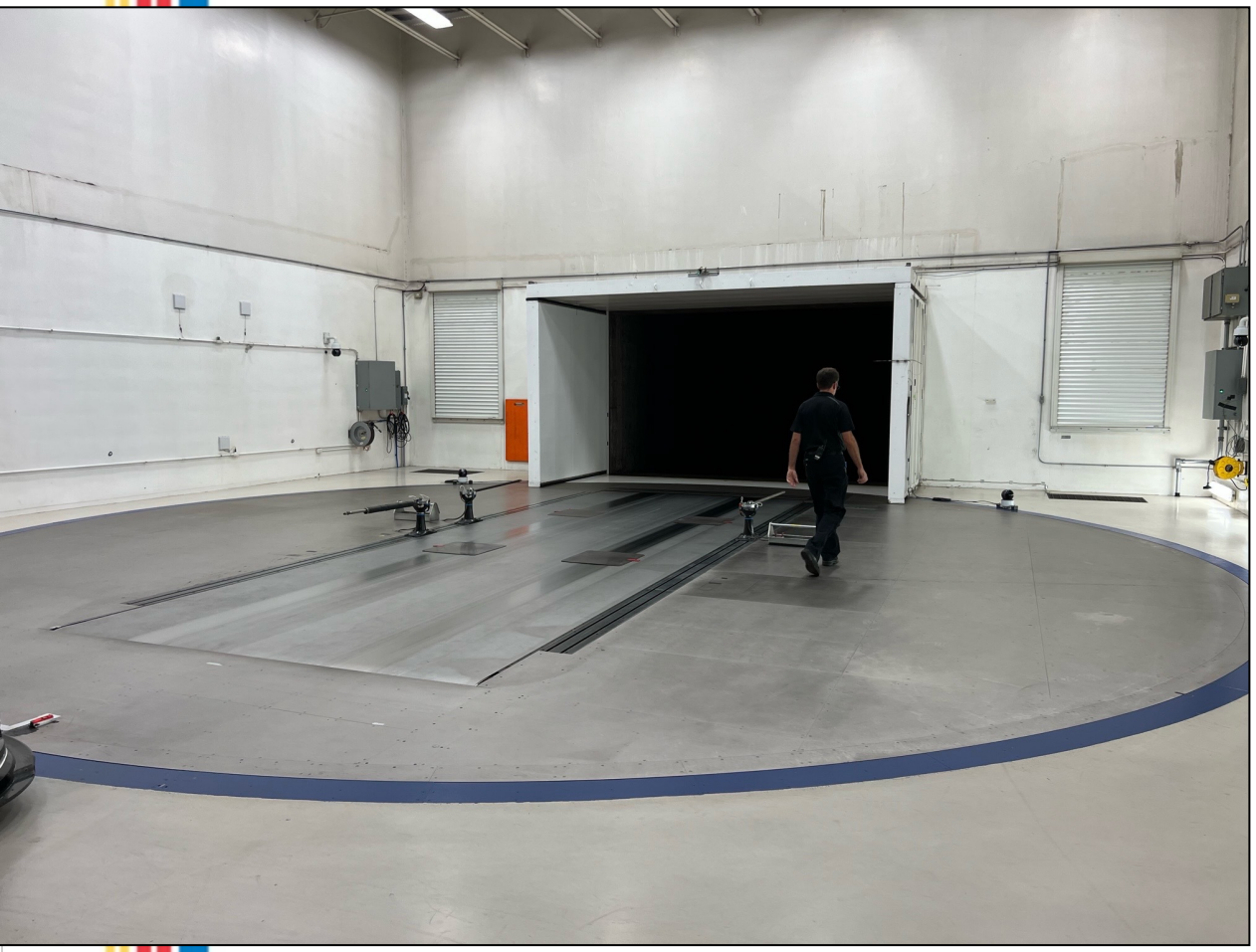
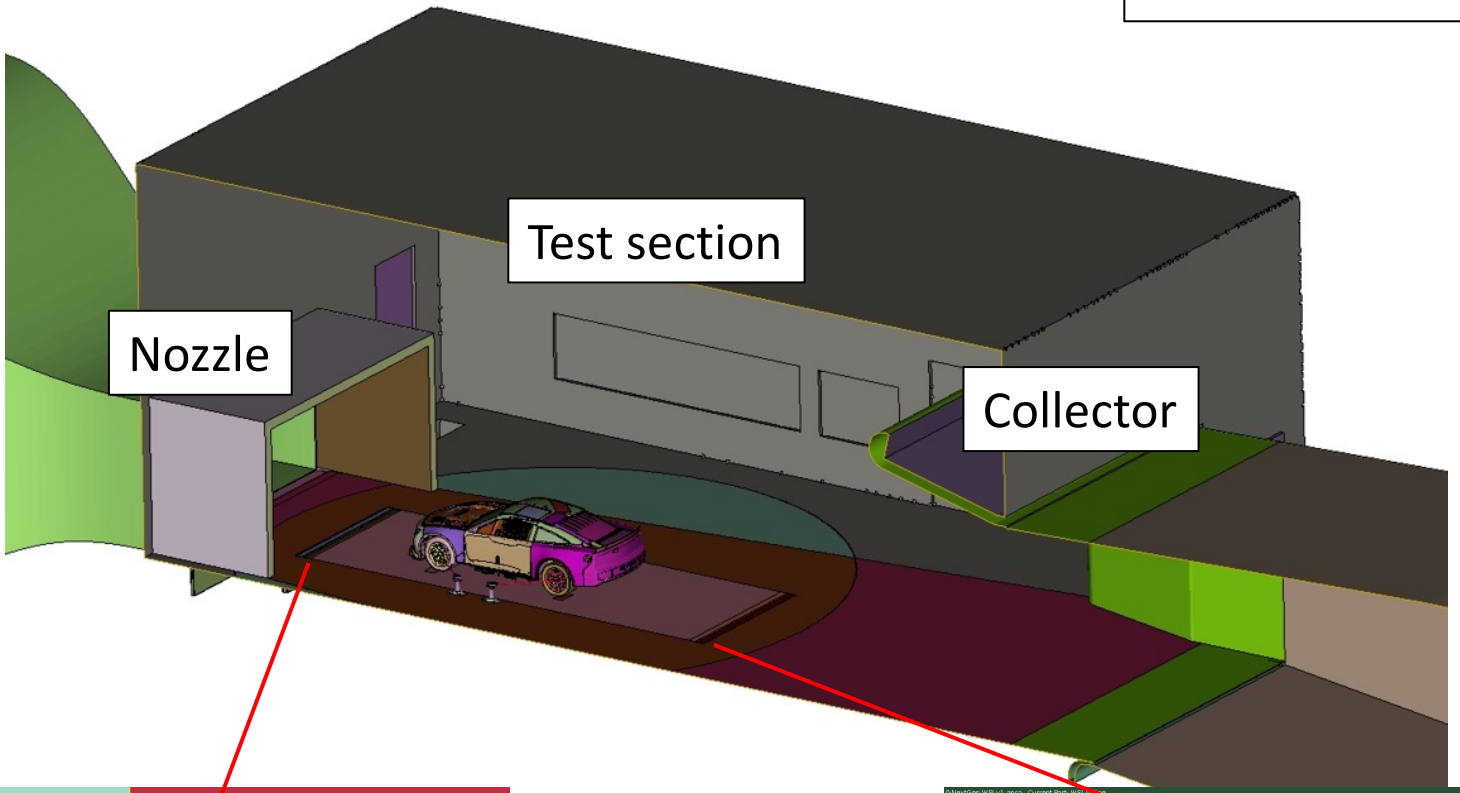
- Windshear, Inc. (WSI) – purpose built automotive/motorsport wind tunnel.
- 180 mph open jet, single belt rolling road automotive wind tunnel in Concord, North Carolina USA.
- Lift/drag externally measured, side force measured using transducer wheels.

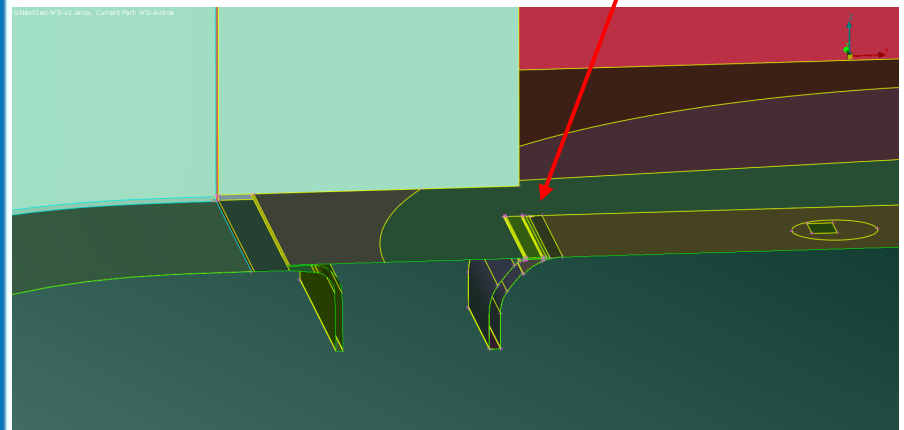
Windshear, Inc. (WSI)

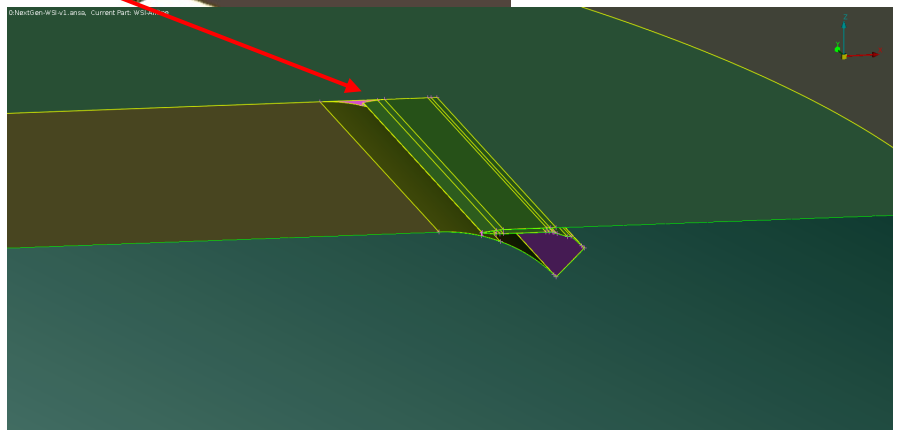


Windshear Simulation

Boundary layer suction modeled and tuned to empty tunnel section.

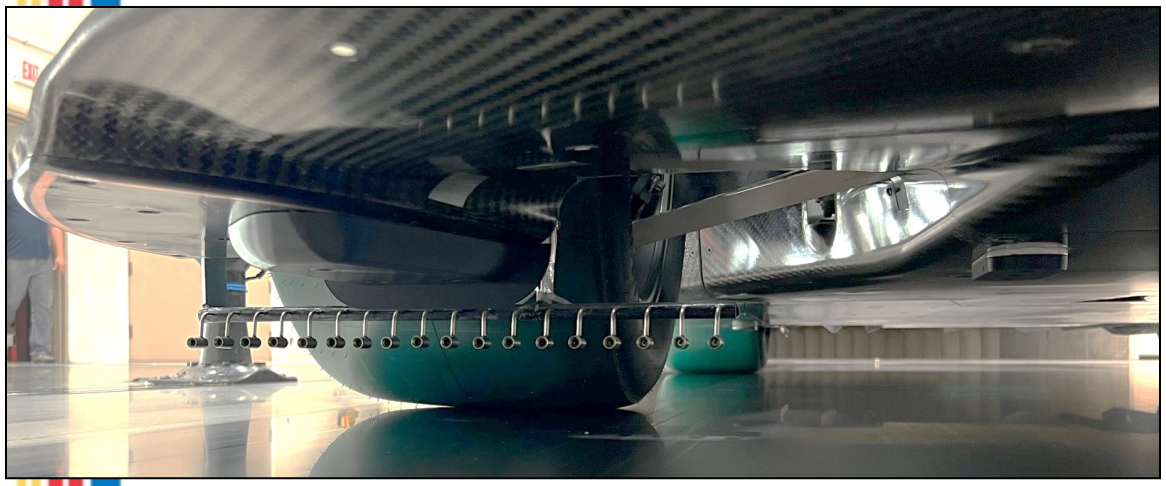


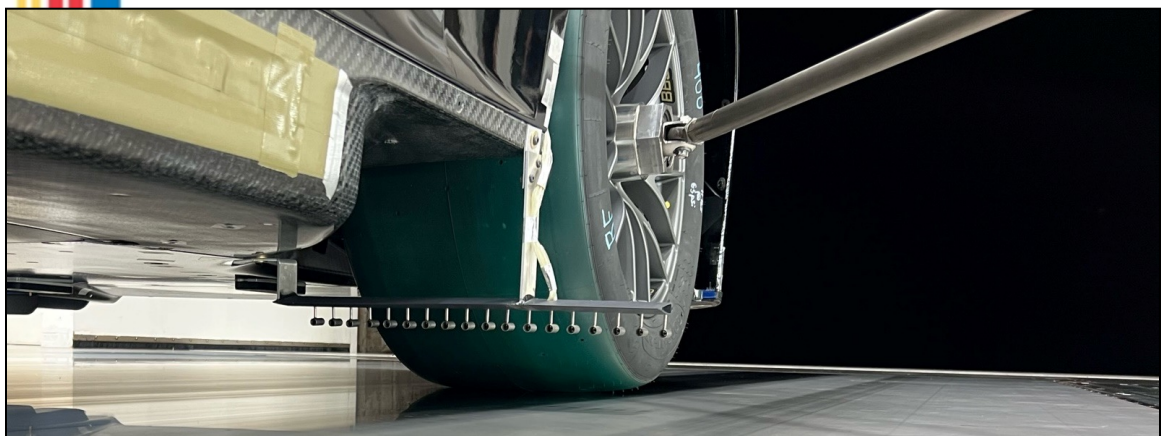


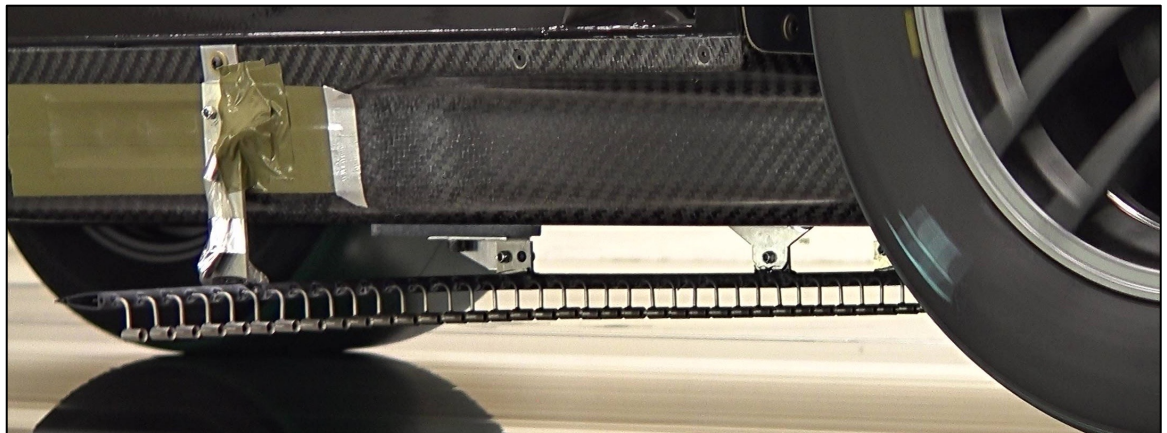


Flow Survey

- Kiel probes were used to survey flow conditions based on CFD observations.
- Rakes were fixed to the vehicle in appropriate positions using as non-intrusive of mounts as possible.







Stationary vs. Moving Road

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CFD vs. WSI: Stationary vs. Moving Road

CFD Results

Description	Point	YAW	CD	CL	CLF	CLR	L\D	Lift Balance
RANS Freestream	1	0.0	0.495	-0.471	-0.052	-0.419	-0.95	10.96%
	2	0.0	0.484	-0.316	-0.010	-0.306	-0.65	3.25%
	Delta - Stationary Road		**-0.011**	**0.155**	**0.042**	**0.113**	**0.30**	**-7.71%**
DES Freestream	1	0.0	0.534	-0.552	-0.097	-0.456	-1.04	17.50%
	2	0.0	0.531	-0.400	-0.049	-0.351	-0.75	12.28%
	Delta - Stationary Road		**-0.003**	**0.152**	**0.048**	**0.105**	**0.28**	**-5.22%**
RANS WSI	1	0.0	0.535	-0.491	0.028	-0.519	-0.92	-5.74%
	2	0.0	0.523	-0.377	0.057	-0.434	-0.72	-5.70%
	Delta - Stationary Road		**-0.012**	**0.114**	**0.029**	**0.085**	**0.020**	**0.04%**

WSI Tunnel Results

Description	Point	YAW	CD	CL	CLF	CLR	L\D	Lift Balance
Wind Tunnel	1	0.0	0.524	-0.463	-0.075	-0.388	-0.883	16.23%
	2	0.0	0.511	-0.369	-0.046	-0.323	-0.758	12.47%
	Delta - Stationary Road		**-0.013**	**0.094**	**0.029**	**0.069**	**0.125**	**-3.76%**

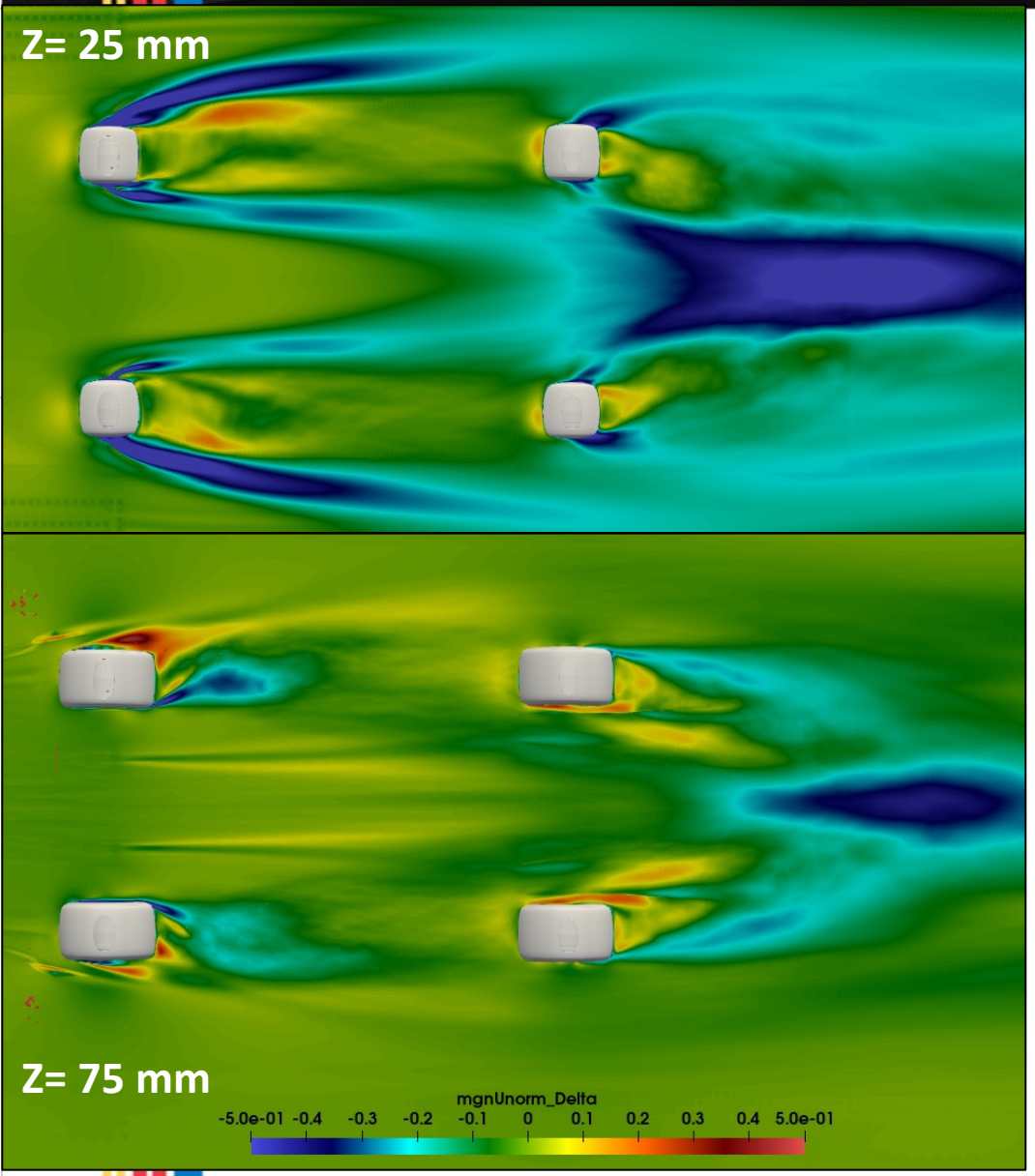
Notes

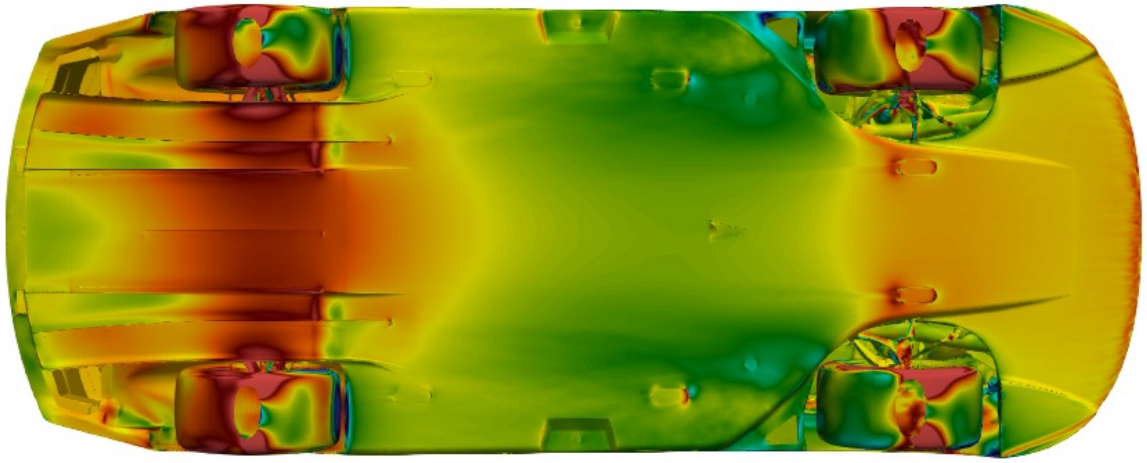
- Point 1 = moving wheels and road
- Point 2 = stationary wheels and road
- All runs at 140 kph windspeed, 165 mm ride height.
- WSI minimum road speed 4.8 kph

Results Discussion

- All simulations predict a drag decrease and lift increase with approximately 2/3 occurring on rear.
- WSI RANS most accurate vs. experimental.
- Delta lift magnitude is over-predicted.

CFD: Flowfield Effects – Stationary Road vs. Moving

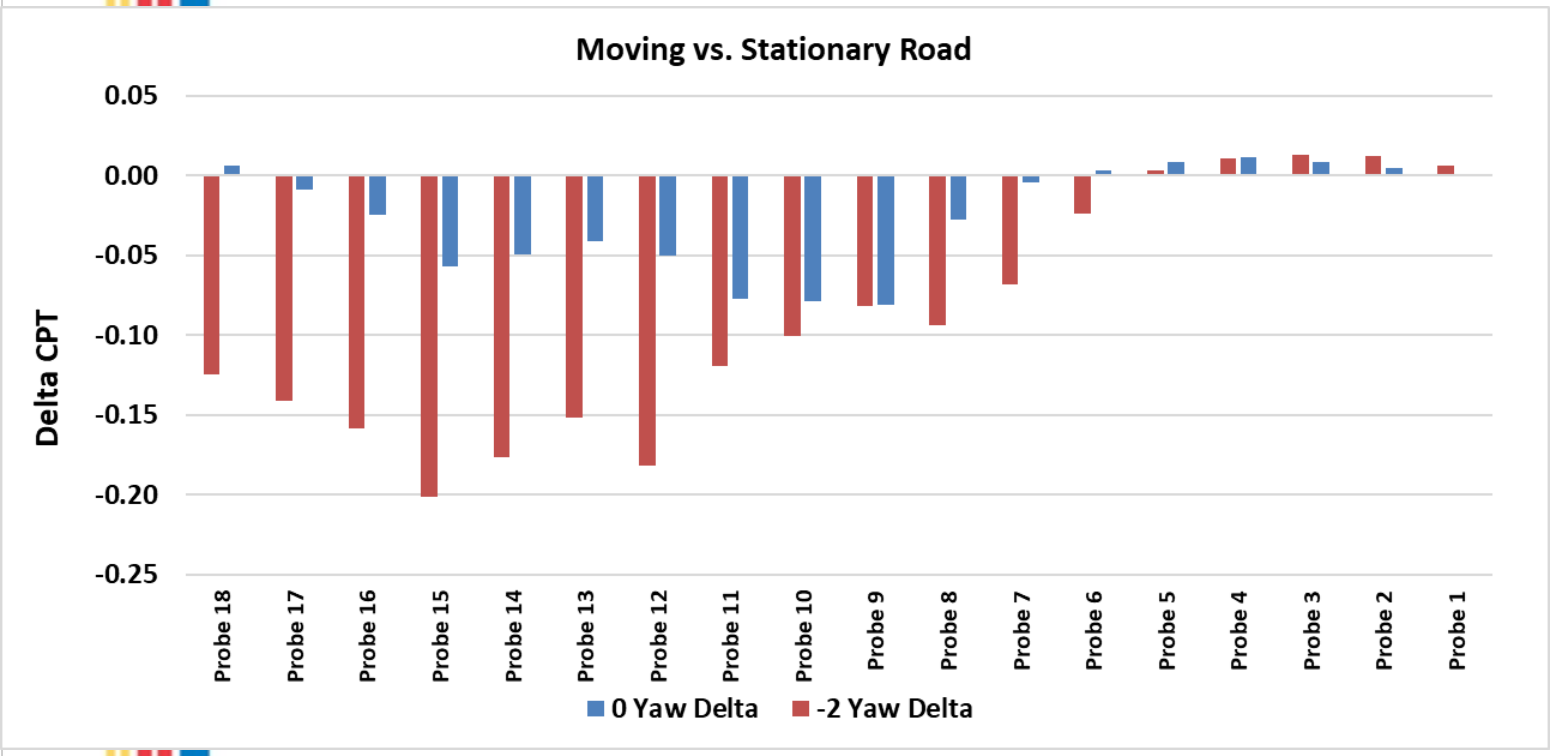


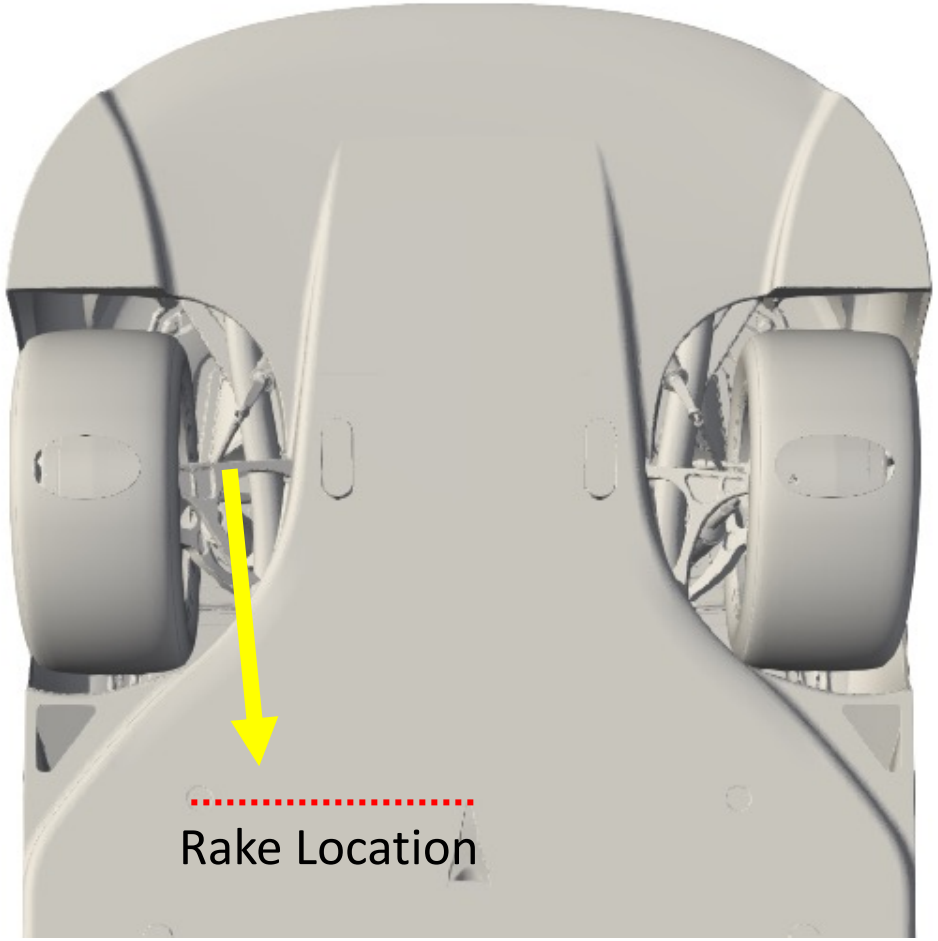


- Non-rotating wheel lacks tire ‘squirt’ which is a critical issue for ground effect cars.
- Reduced energy due to missing inboard tire squirt and stationary road results in decreased diffuser velocity.
- CP decrease at front of car and particularly dramatic in the diffuser section.

Tire Squirt – Kiel Probe Measurements

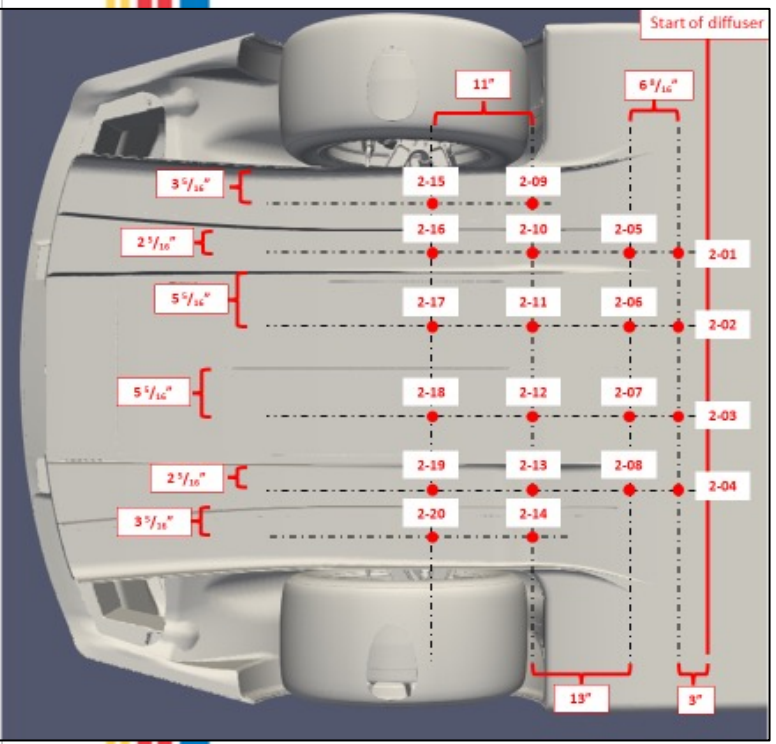
- Predicted loss of tire squirt was measured between moving and stationary road conditions.
- Delta CP Total was observed to be lower in the rake area shown and was more pronounced for yawed case - possibly due to upstream body effects.

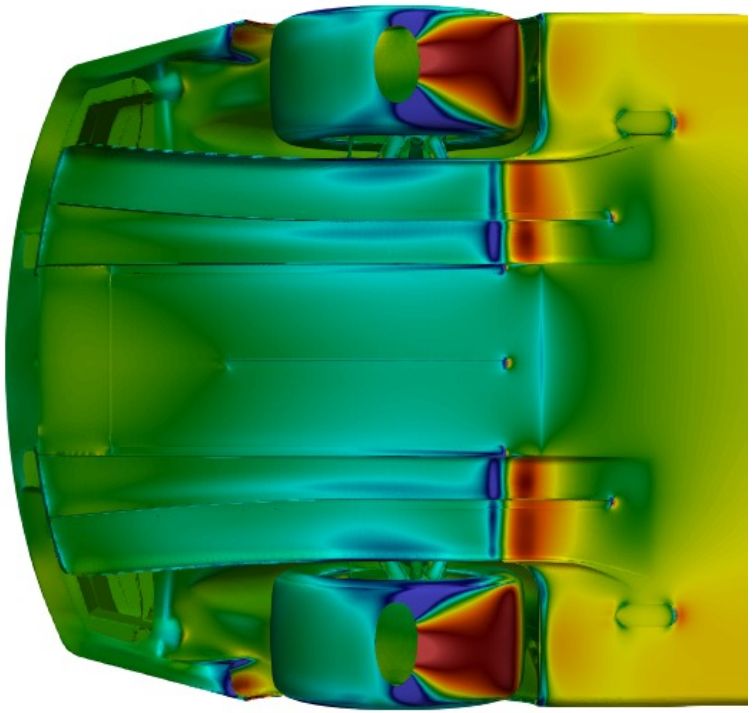


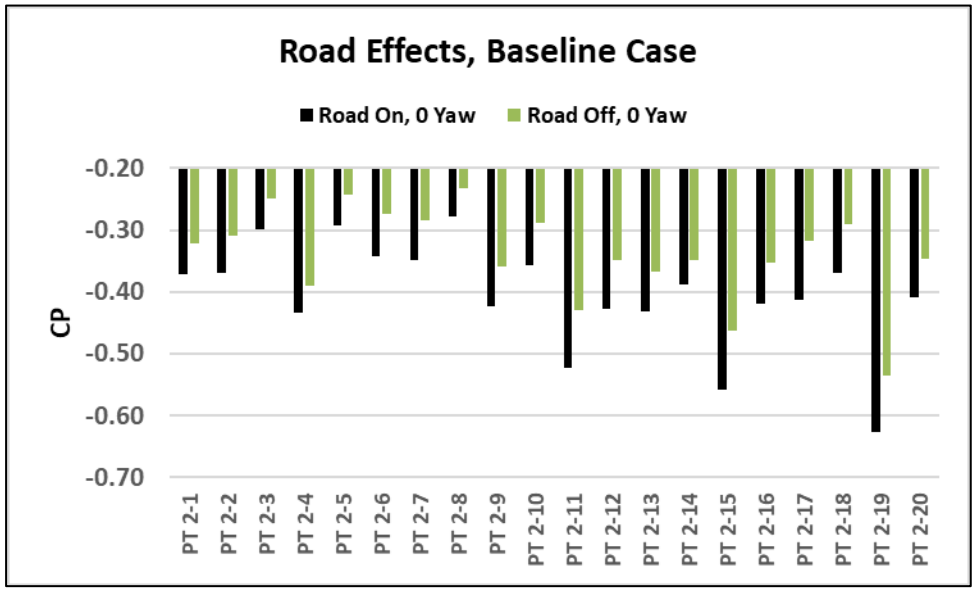


Diffuser Pressure Taps – Road Effects

- Diffuser pressure taps show decrease in negative CP with stationary road as anticipated.
- Corresponding downforce loss is accounted for.







Tire Deflector Prediction

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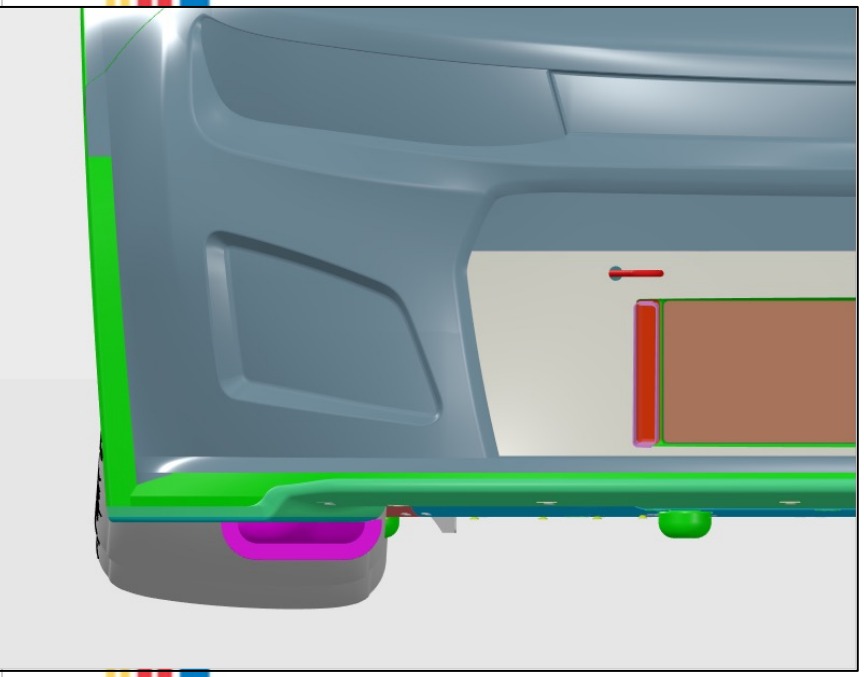
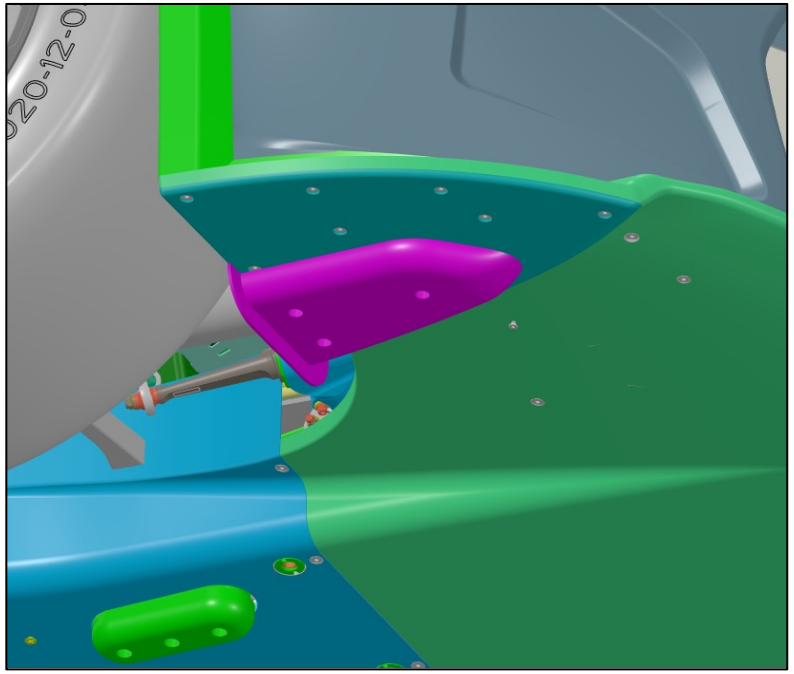
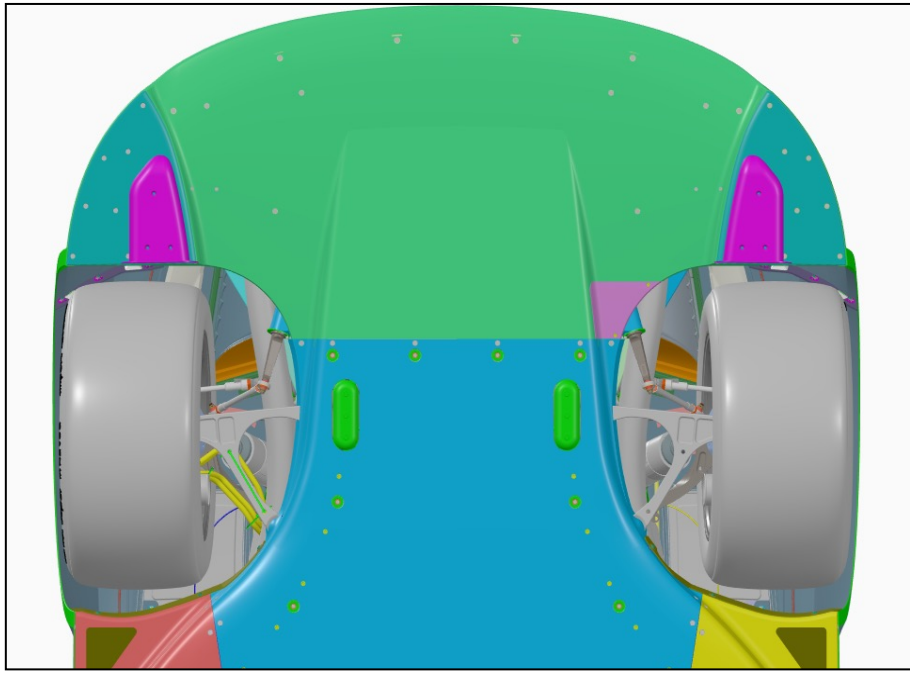
Front Wheel Air Deflector Geometry

- Vehicle parameters were scaled in reference to the DrivAer model:
  - Ride Height (6.5”/165 mm)
  - Deflector Dimensions (50% tire coverage)







Front Tire Air Deflector Effects

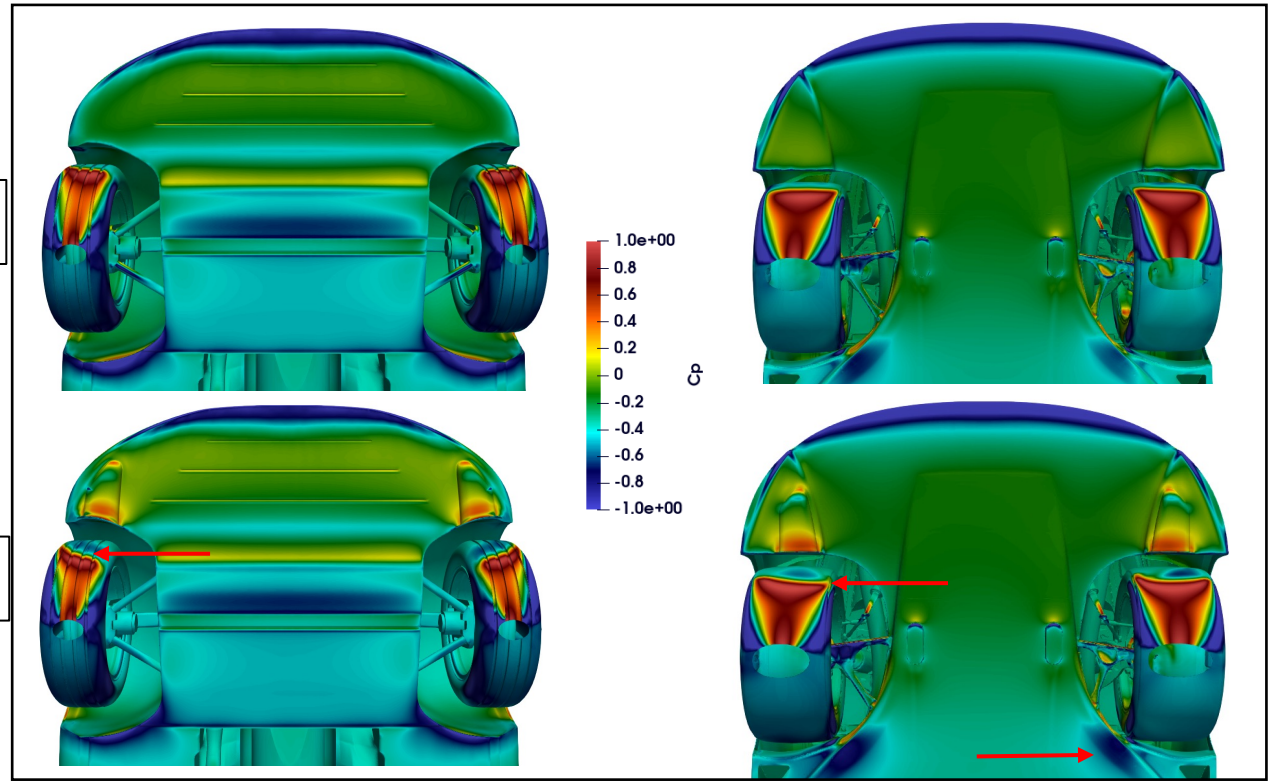
- Both the DrivAer and Next Gen model show a CP decrease at the front tire when using the front wheel air deflector.
- Both stationary and moving wheels/floor show similar CP results in the Next Gen model.
- For the Next Gen, note the CP decrease inboard of the front tires with deflector.

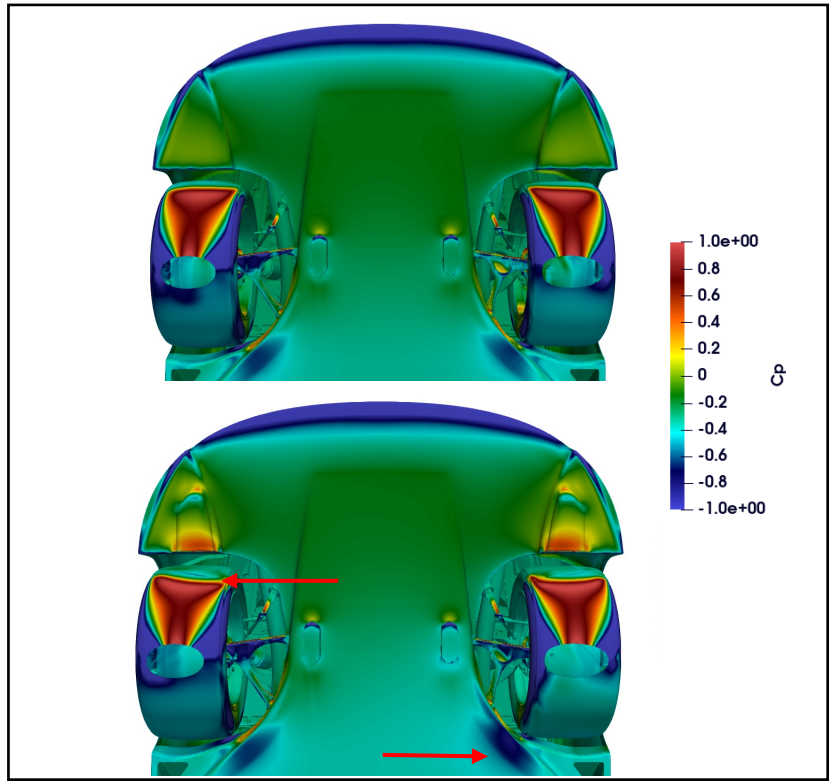
Stationary Wheels/Floor

Moving Wheels/Floor

Deflector Off

Deflector On





CFD Results

Description	Point	YAW	CD	CL	CLF	CLR	L\D	Lift Balance
Baseline (RANS) (Freestream)	1	0.0	0.495	-0.471	-0.052	-0.419	-0.95	10.96%
	2	0.0	0.484	-0.316	-0.010	-0.306	-0.65	3.25%
Deflector (RANS) (Freestream)	1	0.0	0.486	-0.492	-0.067	-0.424	-1.01	13.70%
	2	0.0	0.494	-0.311	0.000	-0.310	-0.63	0.14%
Delta - Deflector, Moving Road			**-0.009**	**-0.021**	**-0.015**	**-0.005**	**-0.060**	**2.73%**
Delta - Deflector, Stationary Road			**0.010**	**0.005**	**0.010**	**-0.004**	**0.024**	**-3.11%**

Description	Point	YAW	CD	CL	CLF	CLR	L\D	Lift Balance
Baseline (DES) (Freestream)	1	0.0	0.534	-0.552	-0.097	-0.456	-1.04	17.50%
	2	0.0	0.531	-0.400	-0.049	-0.351	-0.75	12.28%
Deflector (DES) (Freestream)	1	0.0	0.528	-0.543	-0.075	-0.467	-1.03	13.89%
	2	0.0	0.536	-0.384	-0.031	-0.353	-0.72	8.07%
Delta - Deflector, Moving Road			**-0.006**	**0.009**	**0.022**	**-0.011**	**0.006**	**-3.62%**
Delta - Deflector, Stationary Road			**0.005**	**0.016**	**0.018**	**-0.002**	**0.038**	**-4.22%**

Description	Point	YAW	CD	CL	CLF	CLR	L\D	Lift Balance
Baseline (RANS) (WSI)	1	0.0	0.535	-0.491	0.028	-0.519	-0.92	-5.74%
	2	0.0	0.523	-0.377	0.057	-0.434	-0.72	-5.70%
Deflector (RANS) (WSI)	1	0.0	0.525	-0.516	0.014	-0.530	-0.98	-2.66%
	2	0.0	0.539	-0.356	0.063	-0.419	-0.66	-17.55%
Delta - Deflector, Moving Road			**-0.010**	**-0.025**	**-0.015**	**-0.010**	**-0.07**	**3.08%**
Delta - Deflector, Stationary Road			**0.016**	**0.021**	**0.006**	**0.015**	**0.06**	**-11.85%**

Notes

- Point 1 = moving wheels and road
- Point 2 = stationary wheels and road

Results Discussion

RANS and DES freestream with deflector:

- Drag reduction with moving road
- Lift result divergent between RANS/DES
- Lift difference focused on CLF
- Drag and lift increase with stationary road

WSI RANS simulation:

- Nearly the same for the freestream RANS case.
- Higher lift increase in the stationary road condition when using the tire deflector.
- Drag in either configuration closer to wind tunnel.

Wind Tunnel Results

Description	Point	YAW	CD	CL	CLF	CLR	L\D	Lift Balance
Baseline	1	0.0	0.524	-0.463	-0.075	-0.388	-0.883	16.23%
	2	0.0	0.511	-0.369	-0.046	-0.323	-0.758	12.47%
Deflector On	1	0	0.521	-0.469	-0.071	-0.399	-0.9	15.10%
	2	0	0.515	-0.36	-0.038	-0.322	-0.734	10.57%
Delta - Deflector, Moving Road			**-0.003**	**-0.006**	**0.004**	**-0.011**	**-0.017**	**-1.13%**
Delta - Deflector, Stationary Road			**0.004**	**0.009**	**0.008**	**0.001**	**0.024**	**-1.90%**

- WSI reported decrease in drag/lift with moving road for deflector, increase in drag/lift with stationary road.
- Comparing to CFD, magnitudes are smaller.
- Freestream DES incorrectly predicted moving road CL.

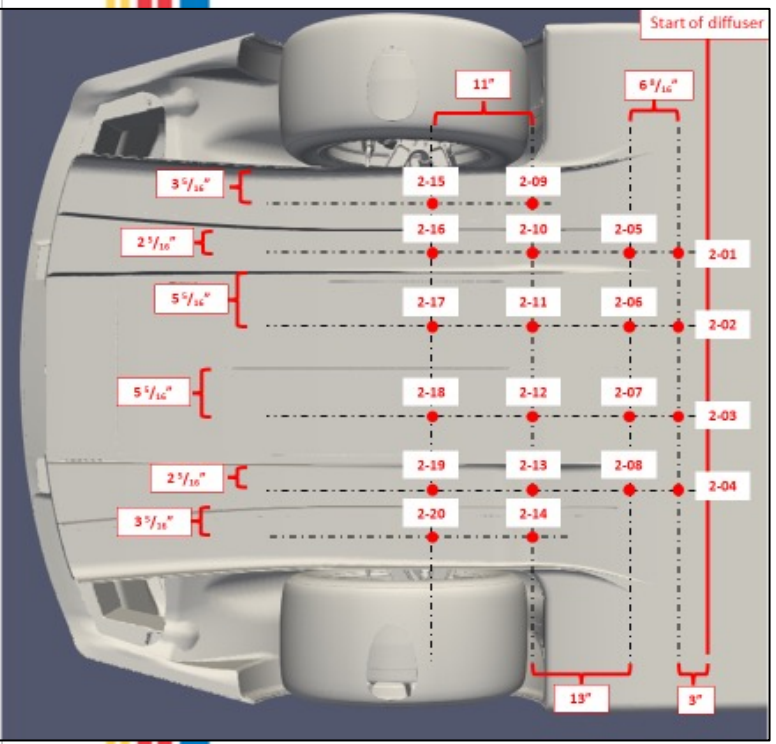
CFD Summary

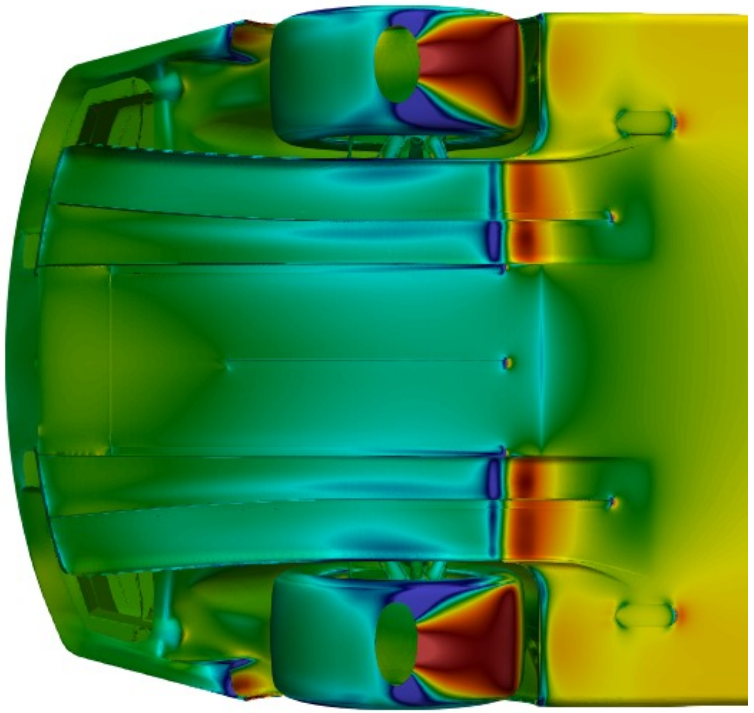
Deflector On, Moving Road		
Description	CD	CL
Freestream - RANS	-0.009	-0.021
Freestream - DES	-0.006	0.009
Windshear - RANS	-0.010	-0.025
Windshear - Experimental	-0.003	-0.006

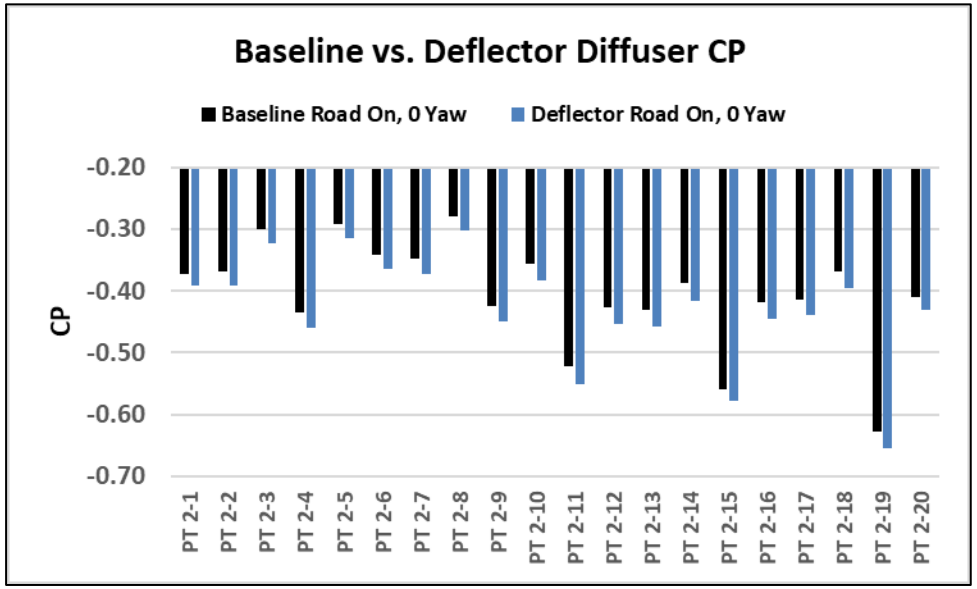
Deflector On, Stationary Road		
Description	CD	CL
Freestream - RANS	0.010	0.005
Freestream - DES	0.005	0.016
Windshear - RANS	0.016	0.021
Windshear - Experimental	0.004	0.009

Diffuser Pressure Taps – Deflector Effects

- Deflector with moving road shows an increase in negative CP in the diffuser when compared to baseline.
- Results in a corresponding rear downforce increase due to higher energy flow directed inboard.







Conclusions

- NASCAR investigated the effect of freestream, wind tunnel, and rotating vs. non-rotating road/wheels between CFD and experimental results.
- Stationary road/wheels eliminates tire squirt, increases drag, and increases lift.
- ***Stationary road/wheels gives contradictory results for the deflector as compared to a moving road/freestream simulation or experiment.***
- WSI RANS simulations closely resemble predictions from freestream RANS simulations and experiment.
- WSI modeling for stationary floor increased accuracy; moving floor decreased accuracy.

à bientôt en France !