CFRP Monocoque Body를 이용한 경량화 설계

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* Part Design
  · Suspension
  · Brake

* Additional Supplement
  · Aerodynamics

CFRP Monocoque Body

CFRP Monocoque Body

Difference between
Monocoque Body and Steel Frame Body

Low cost
Limited performance

High cost
High performance

Frame Body(30kg)

Advantage	Disadvantage
저렴한 제작비용	무거운 차체
높은 정비성	동적성능 제한
높은 제작의 편의성	-

Monocoque Body(16kg)

Advantage	Disadvantage
차체가 가볍다	높은 제작비용
우수한 동적성능	제작 후 수정불가
프레임과 같은 강성	-

CFRP Monocoque Body

Monocoque Body 선택 이유

Optimize Rigidity

High Performance

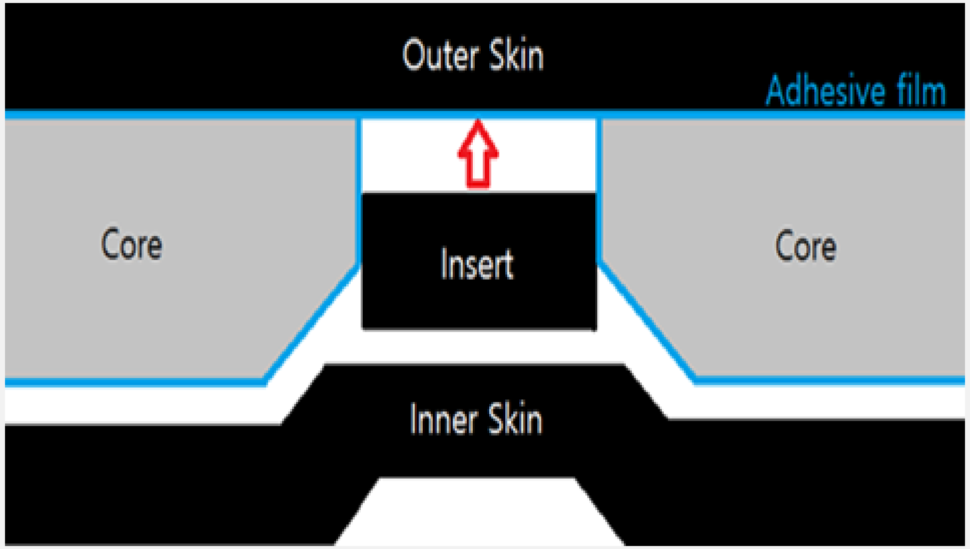
Minimize Weight

CFRP Monocoque Body

Structure of Monocoque

Core

Skin



Sandwich Structure

CFRP Monocoque Body

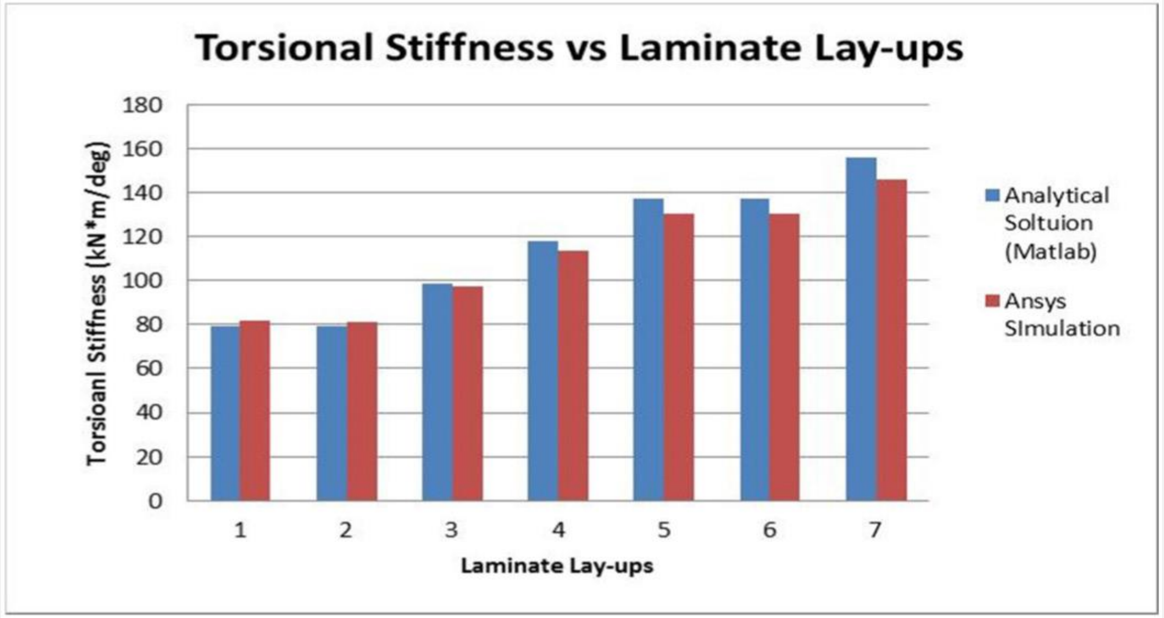
물성표 분석을 통한 Core 선정

Density (lb/ft3)	Cell Size (inch)	Plate Shear					
		L Direction			W Direction		
		Strength (psi)		Modulus (ksi)	Strength (psi)		Modulus (ksi)
		Typ	Min	Typ	Typ	Min	Typ
2	3/16	90	68	4.3	50	38	2.4
2	3/16	65	48	23.2	65	38	3.7
2.5	3/16	90	59	2.7	95	55	5
3	1/8	195	133	6.4	95	70	3.3
3	3/16	175	133	5.8	105	64	3.9
3	1/4	170	133	5.4	105	64	4.8
3	1/8	160	95	4.8	110	76	3.8
3	3/16	110	71	3.2	130	71	6.3
4	1/8	265	204	8.2	145	130	4.5
4	3/16	220	204	7.8	160	106	5.2
4	1/4	225	204	6.8	150	106	6.4
4	1/8	225	150	6.7	185	125	6.8
4	3/16	150	95	3.9	185	114	8.9
5	1/8	310	252	10.3	205	124	5.8
6	1/8	340	304	12.3	235	143	7.1
6	3/16	285	275	9.8	245	143	6.7

CFRP Monocoque Body

Ply Table 최적화 : 45′, -45′

1	2	3	4	5	6	7
Original	Shuffle	One Set 0 to 45	Two Set 0 to 45	Three Set 0 to 45 (Outer)	Three Set 0 to 45 (Inner)	All 45s
0	0	0	0	45	0	45
45	0	0	0	0	45	45
0	0	0	45	45	45	45
45	0	45	45	45	45	45
0	45	45	45	45	45	45
45	45	45	45	45	45	45
0	45	45	45	45	45	45
Core	Core	Core	Core	Core	Core	Core



출처 : **Design, Analysis, and Simulation of an Automotive Carbon Fiber Monocoque Chassis**
Jingsi Wu, Owusu Agyeman Badu, Yonchen Tai, and Albert R. George, Cornell Univ.

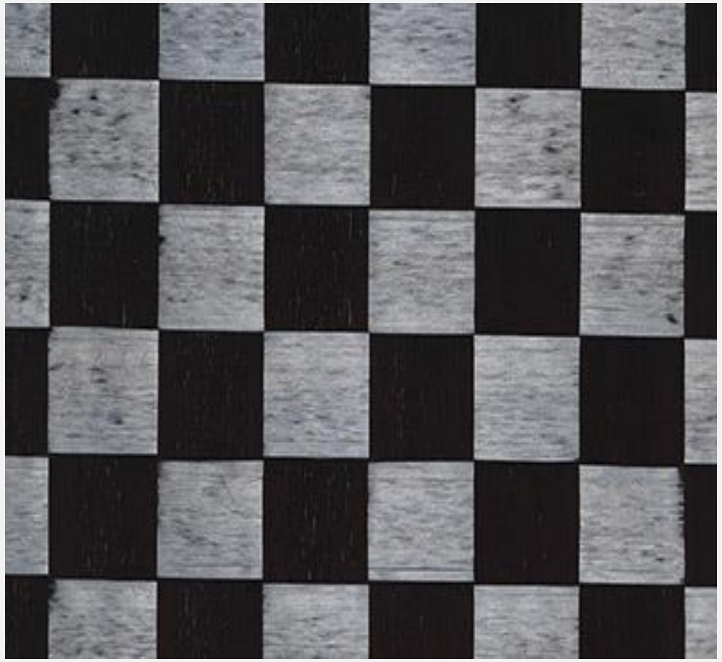
CFRP Monocoque Body

Carbon 적층

1		All		Tow		0
2		Bolting		UD		90
3		Bolting		UD		0
4		All		UD		45
5		All		UD		-45
6		All		UD		0
7		All		UD		90
8		All		UD		0
9		All		UD		90
10		All		UD		0
11		All		UD		45
12		All		UD		-45
13		Bolting		UD		0
14		Bolting		UD		90
15		All		Tow		0

Ply Table

UD



Tow

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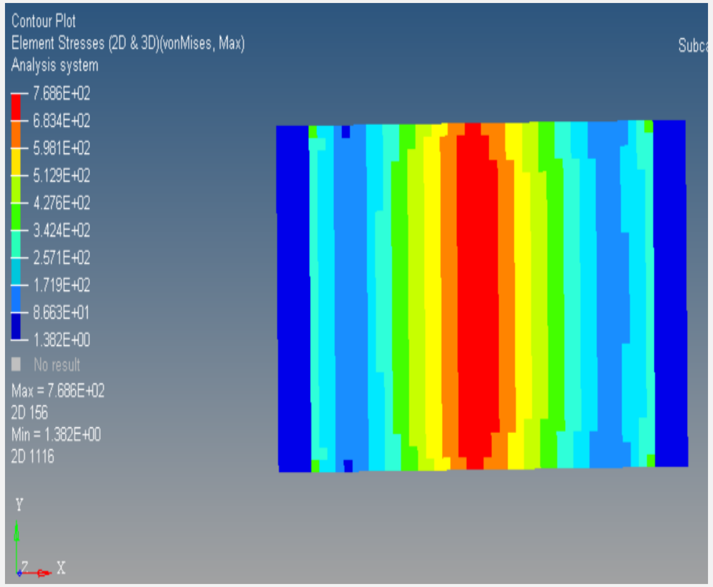
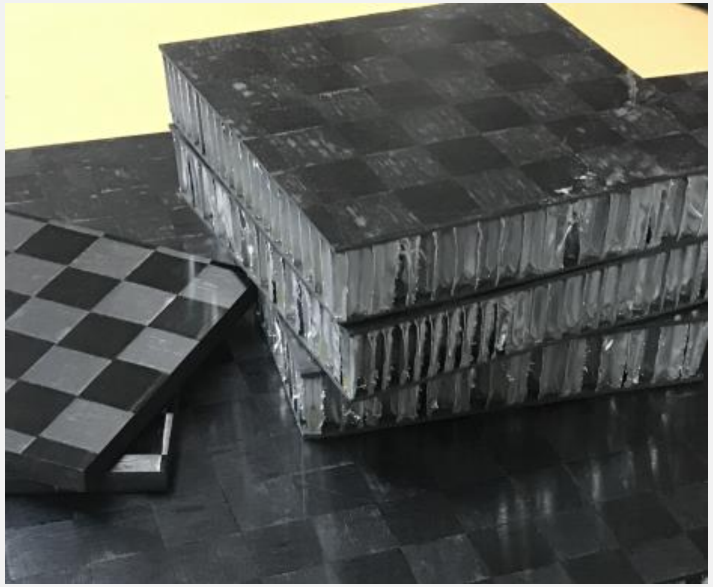
Specimen Test Process

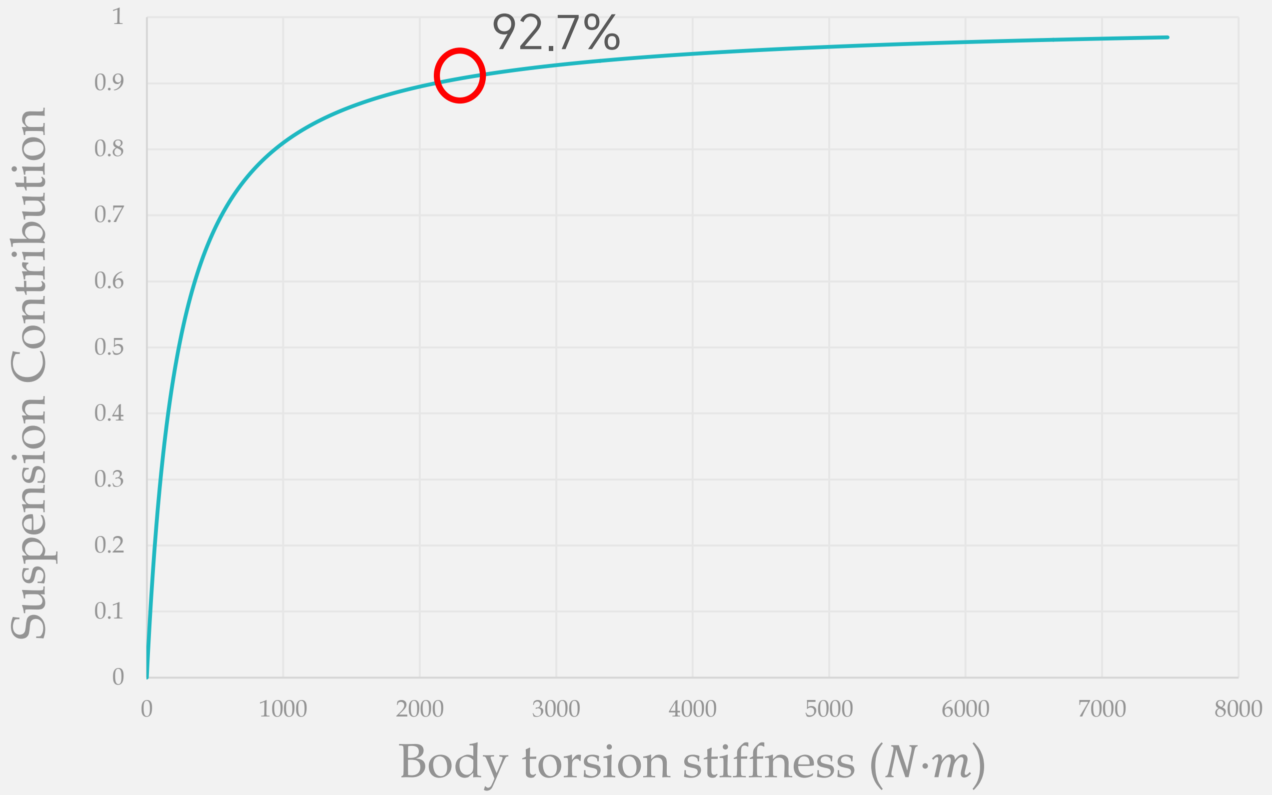




시편 설계 → 시편 제작 → 시편 시험

CFRP Monocoque Body

최적설계를 위한 Target Torsional Stiffness

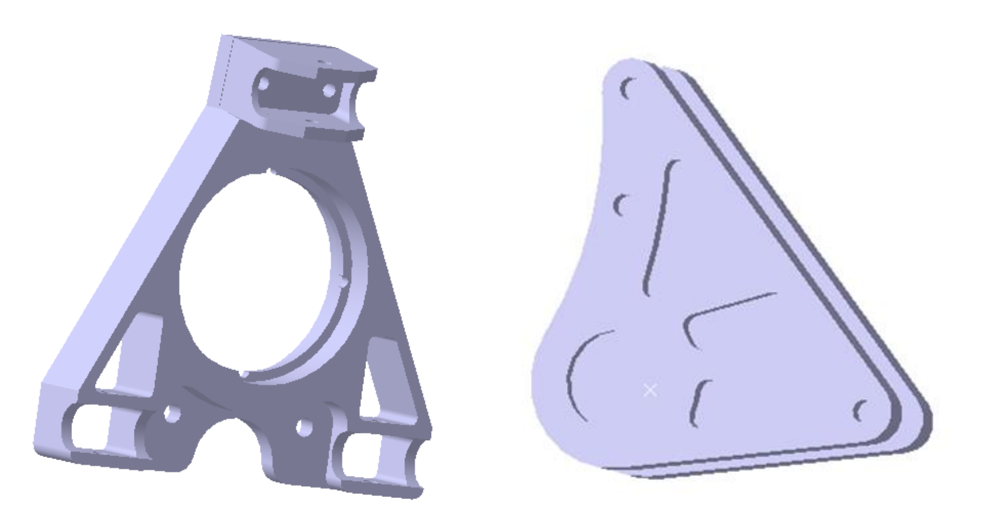


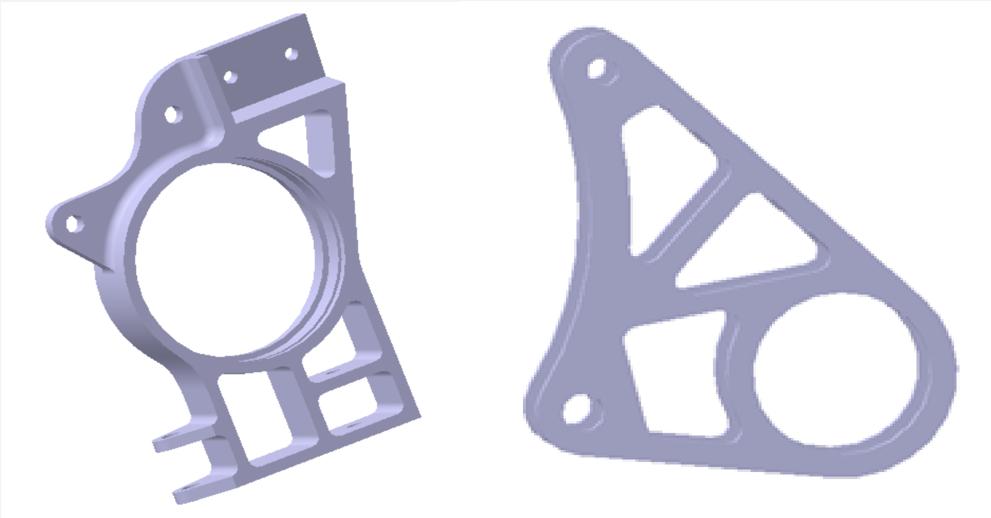
데이터분석을 통한 바디 해석

Suspension

Suspension Design

Component에서의 경량화

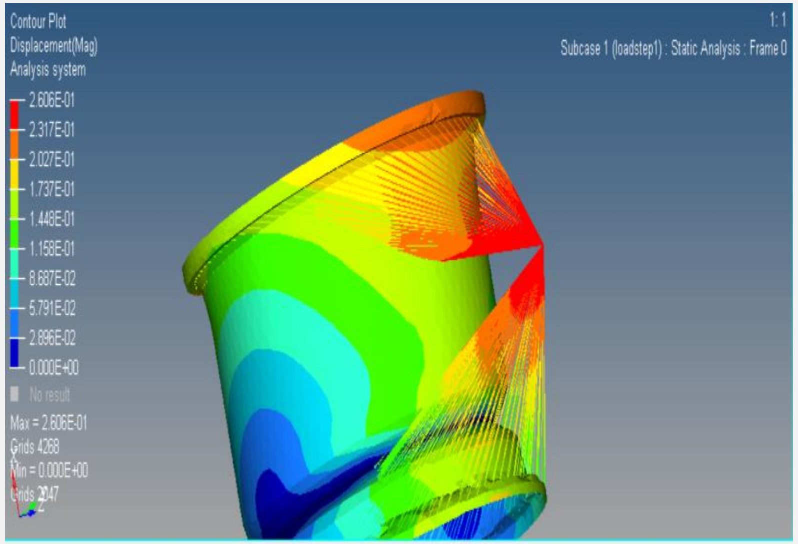




KF-15 **기존 대비 10% 경량화 실현** KF-17

Suspension Design

Component에서의 경량화



Main ply 수에 따른 응력 해석

Ply 수 감소로 인한 8.5% 경량화

Brake

Brake

페달박스 경량화

디스크 경량화

Brake Design

차량의 경량화로 인한 필요 제동력 감소

$$B_f = \frac{a}{g}\left(W_f + W\frac{a}{g}\frac{h}{l}\right)$$

Weight		Front	Rear
245	Kg	117.6	127.4
2403.45	N	1153.66	1249.79

Deceleration G	Ideal Braking Force(N)	
1.4g	Front	Rear
	2517.5	847.32

Weight		Front	Rear
230	Kg	110.4	119.6
2256.3	N	1083.02	1173.28

Deceleration G	Ideal Braking Force(N)	
1.4g	Front	Rear
	2363.37	795.44

Weight : 245kg → 230kg

무게 6.1% 감소

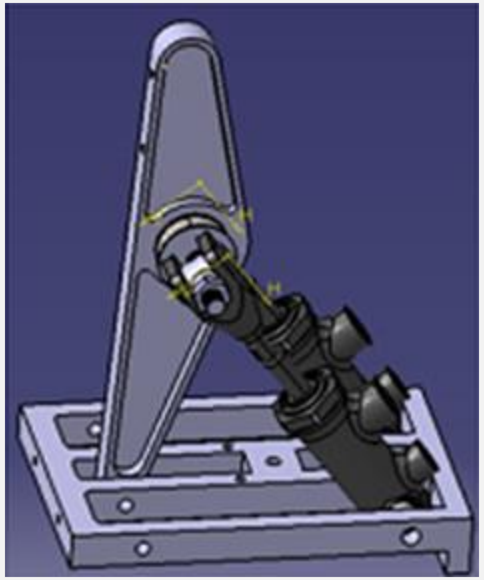
Front Braking Force :
2517N → 2363N (제동력 6.1% 감소)

Rear Braking Force :
847N → 795N (제동력 6.1% 감소)

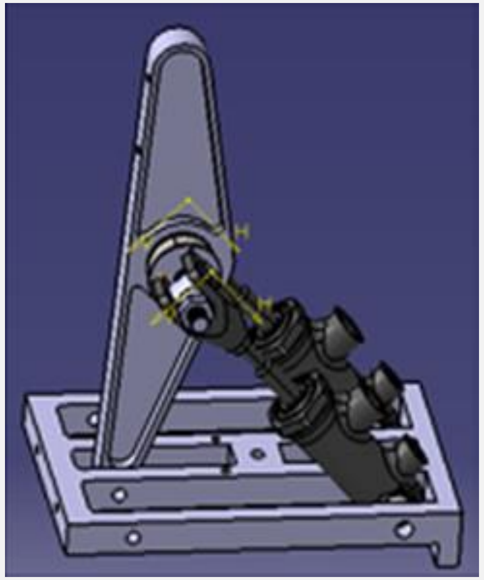
Brake Design

필요 제동력 감소로 인한 페달 박스 경량화

페달비	1.89	1.74
페달	135g	133g
플레이트	419g	404g
실린더	300g	300g
총합	854g	837g



페달비 : 1.89



페달비 : 1.74

Brake Design

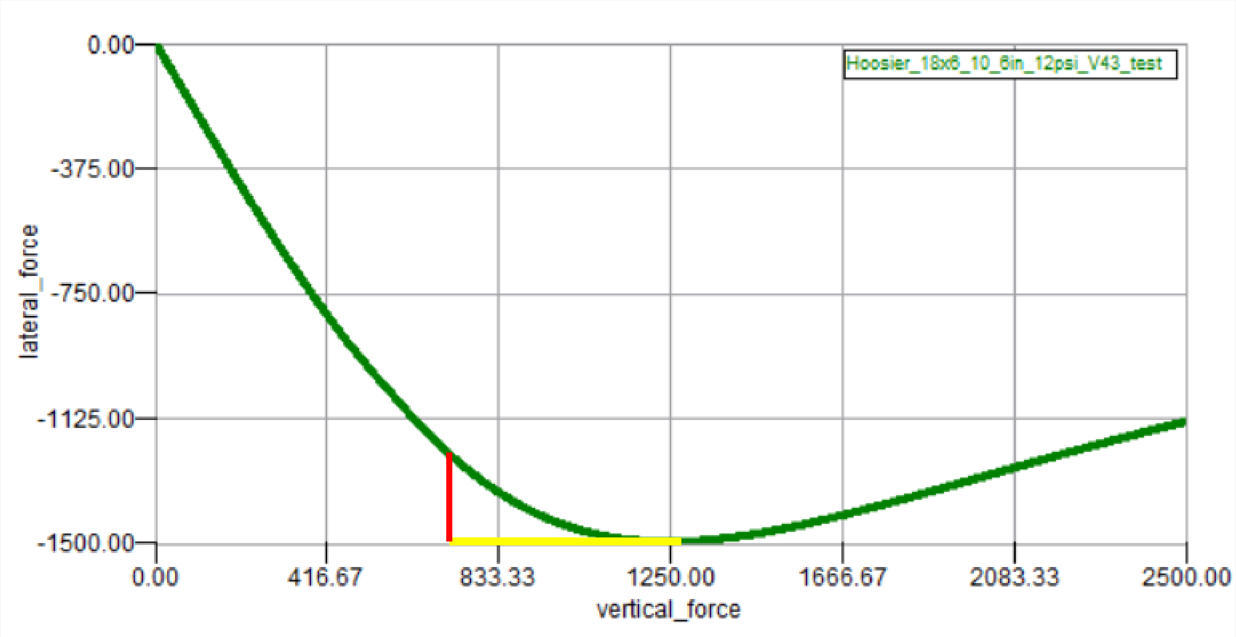
바디 경량화로 인한 브레이크 디스크 경량화

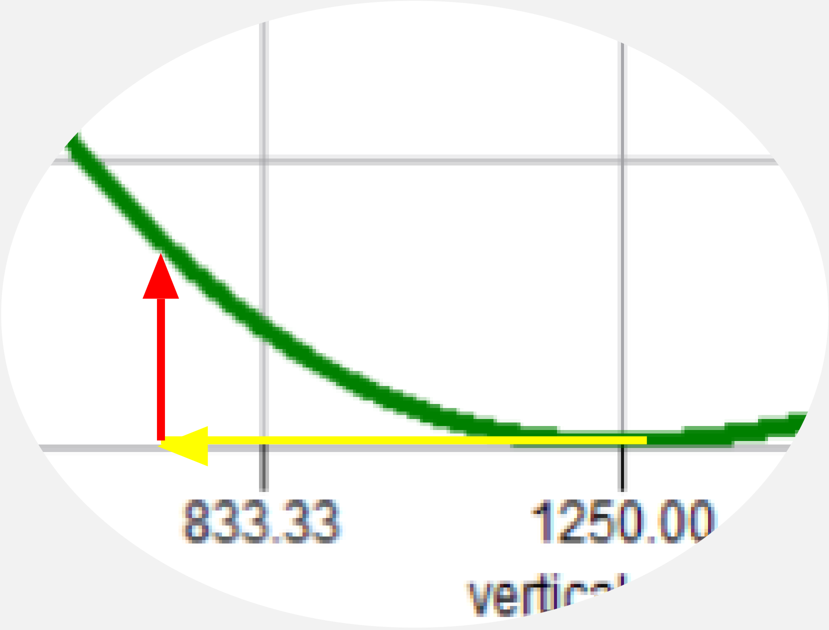
중량 5% 감량

Aerodynamics

Aerodynamics

바디 경량화로 인해 추가적인 Down Force



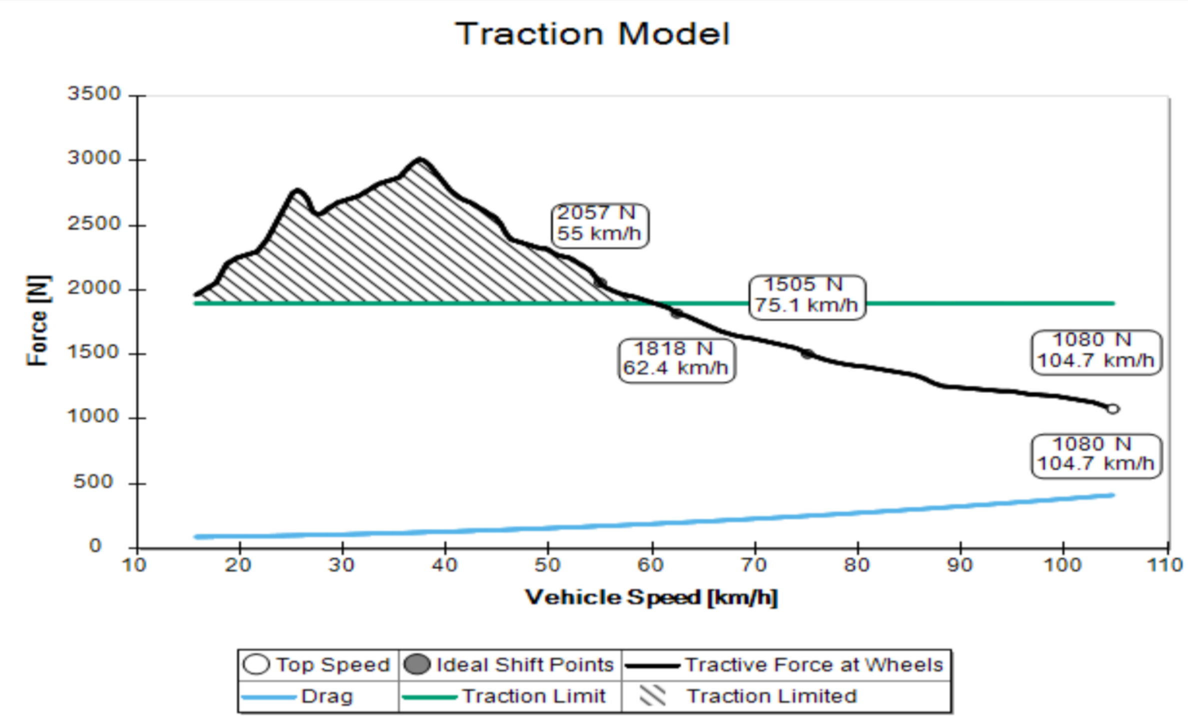


타이어를 한계치까지 사용

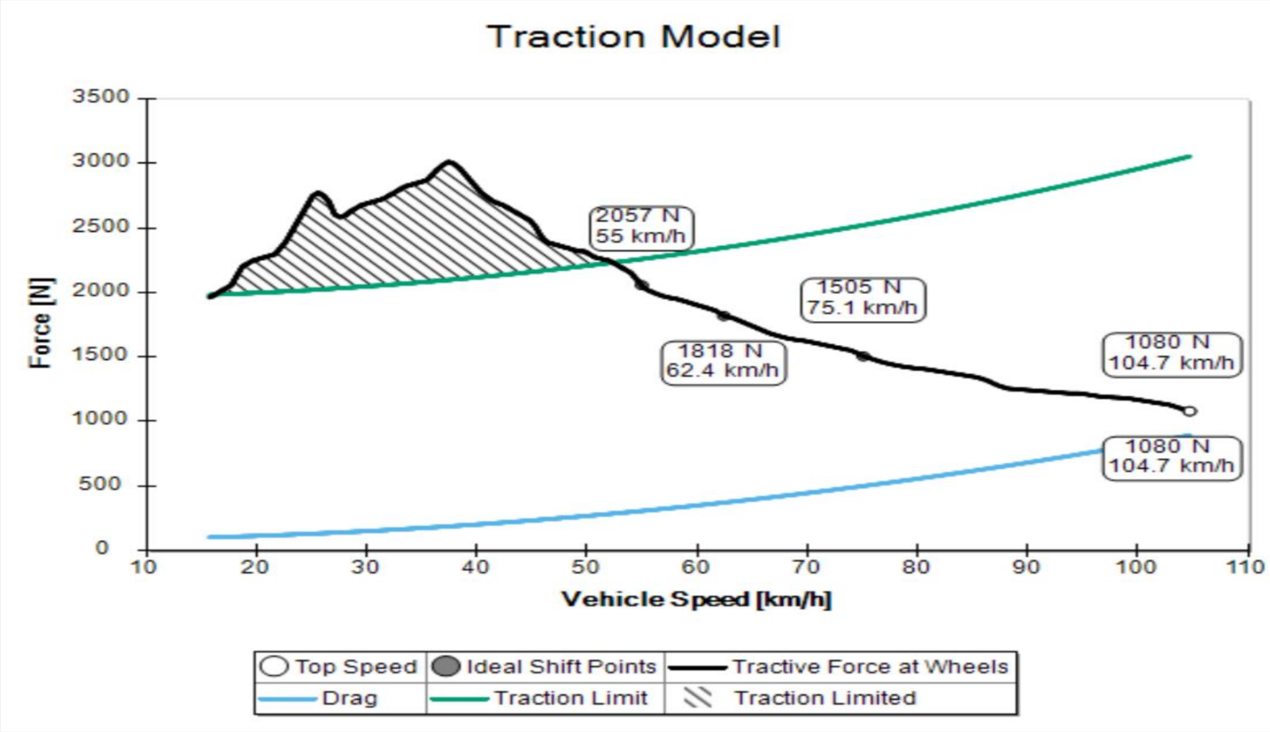
Aerodynamics

Wing 통한 선회속도 증가

Non-Winged

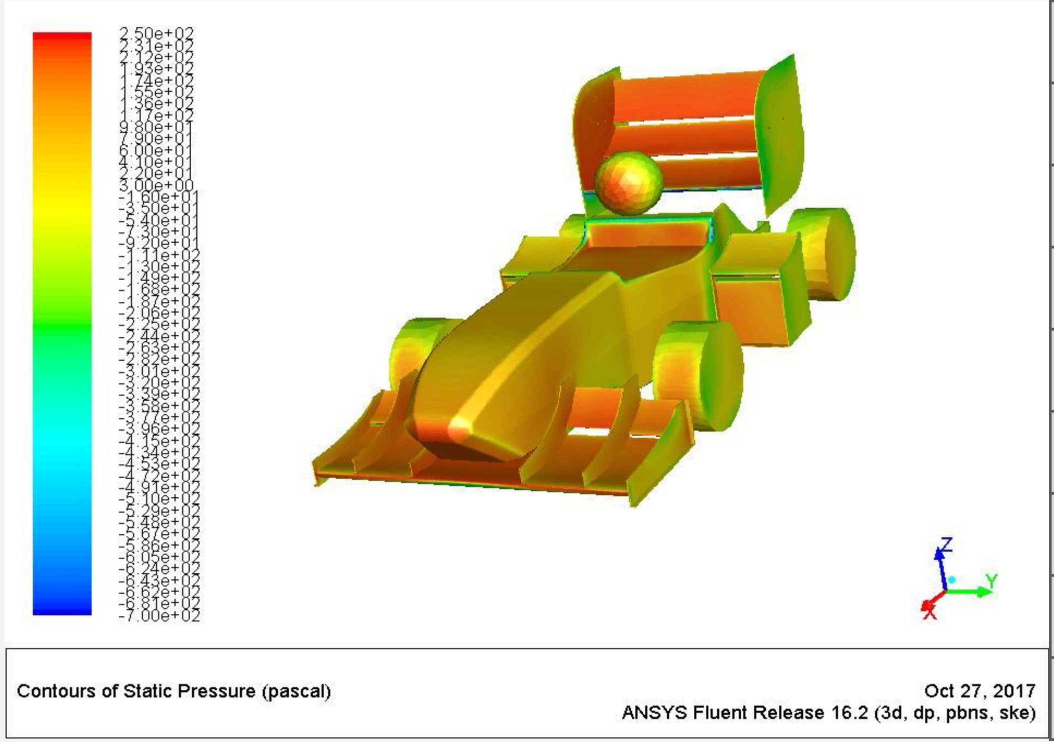


Winged



Aerodynamics Design

Wing 해석을 통한 Angle, Overlap, Gap 선정



Overlap	0	1	2	3	4	10
Drag	117.12	117.78	119	119.33	119.79	123.42
Cd	0.75	0.75	0.75	0.76	0.76	0.78
Down Force	236.33	237.04	239	238.34	238.44	241.47
Overlap	13	14	15	16	17	20
Drag	124.12	124.57	125	125.14	125.35	123.63
Cd	0.79	0.79	1	0.8	0.8	0.8
Down Force	241.66	241.78	$\boxed{242}$	241.57	241.64	241.38

Advantage by CFRP Monocoque Body

Body
무게감소

Parts 별
무게감소

High
Performance

Q & A