Spoiler

CFD를 통한 Spoiler 실험과 제어

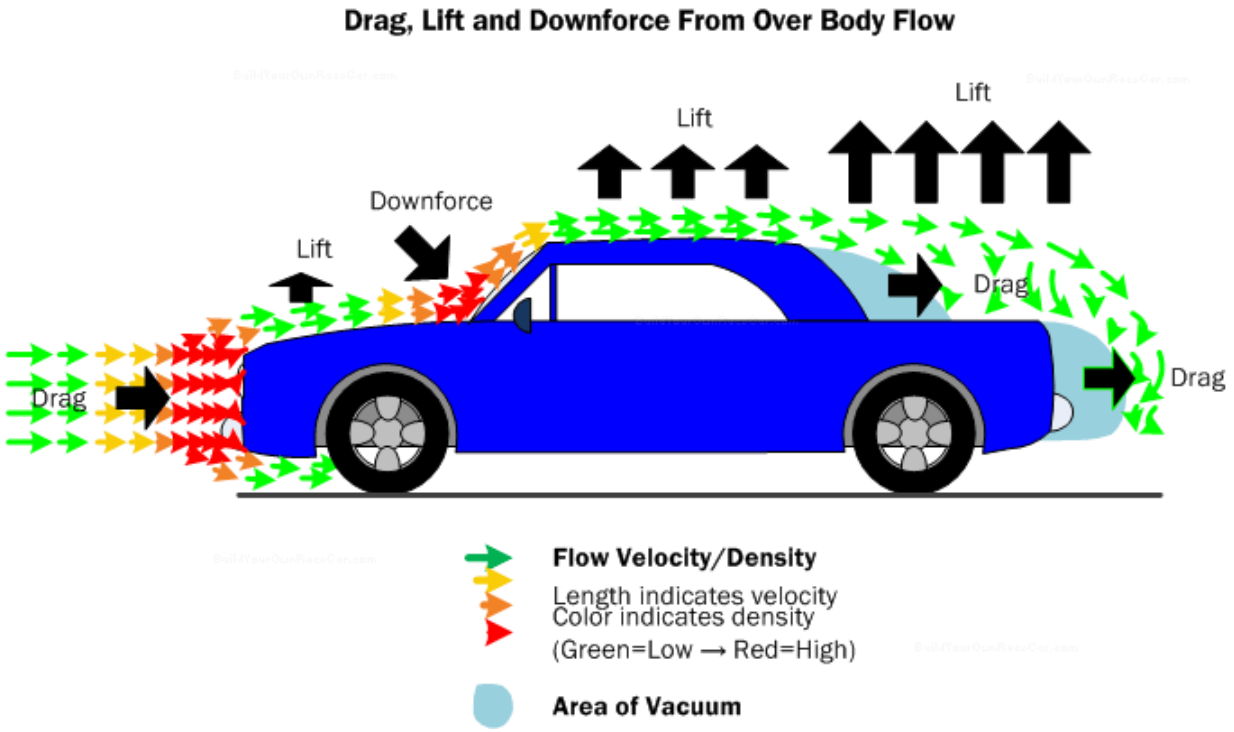
2013020518 윤성준
2014012560 송찬선
2016033654 신홍재

주제 및 팀명 선정

이론

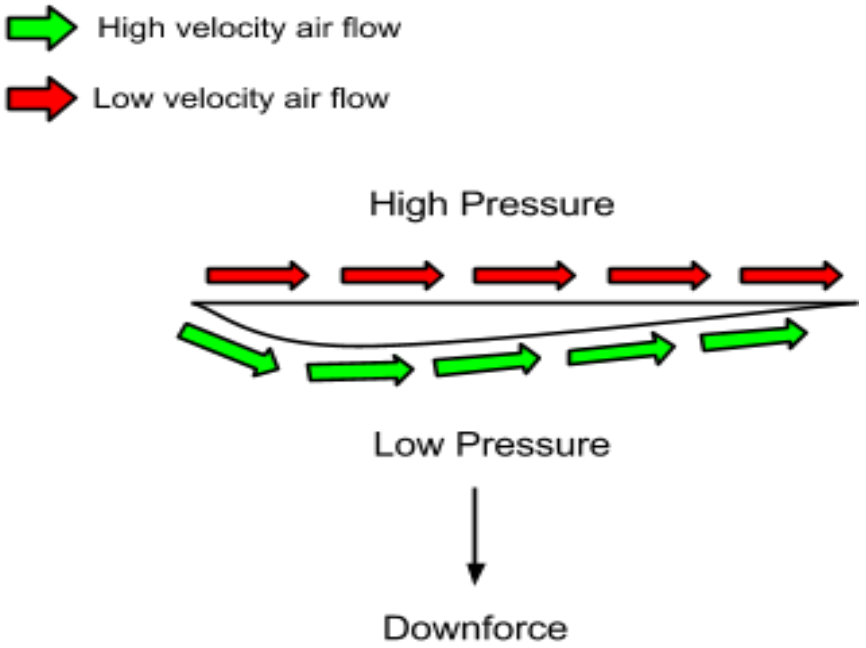
자동차에 작용하는 힘

자동차에 작용하는 유체에 의한 힘



이론

Spoiler의 이해



$$\frac{1}{2}\rho v^2 + \rho g z + p = \text{constant}$$

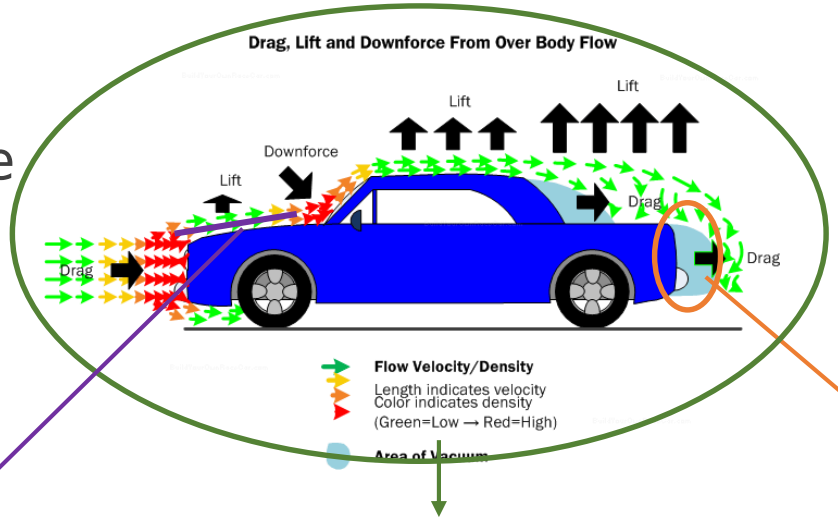
kinetic energy — work done by weight — work done by pressure

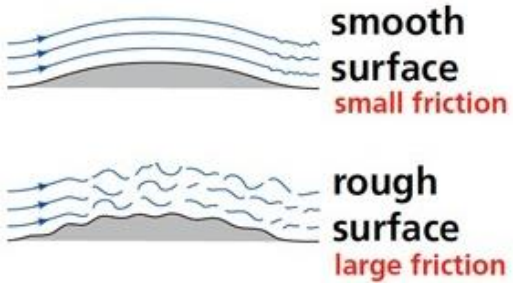
Bernoulli Equation

이론

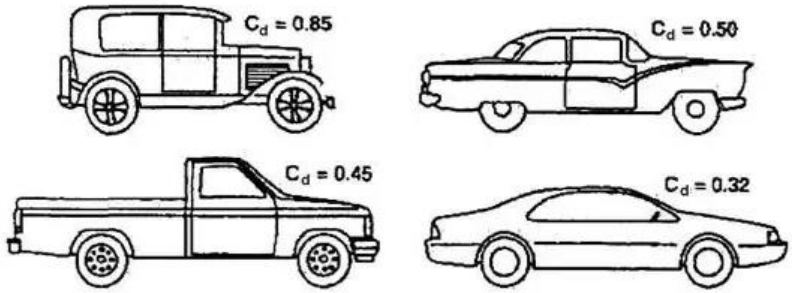
Spoiler의 이해

Drag Force

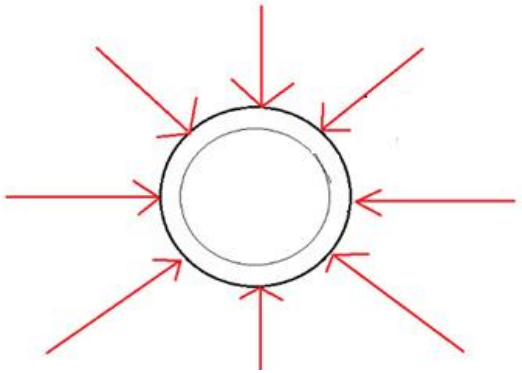




friction



shape

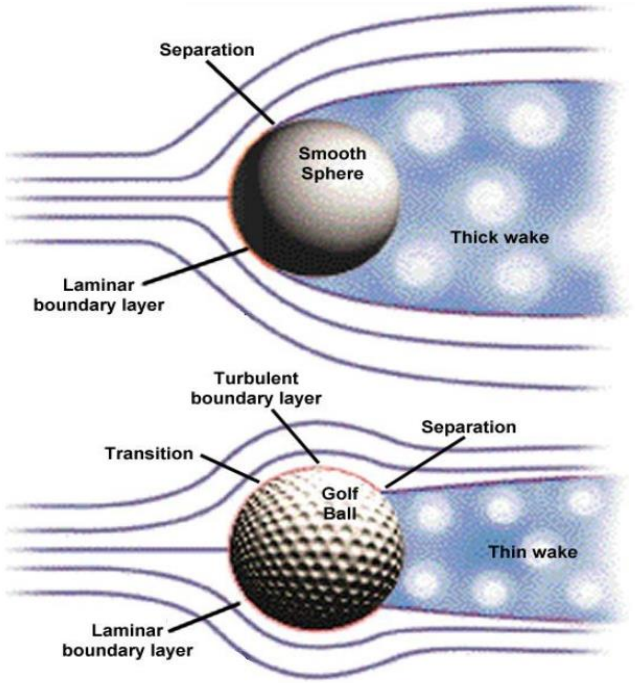


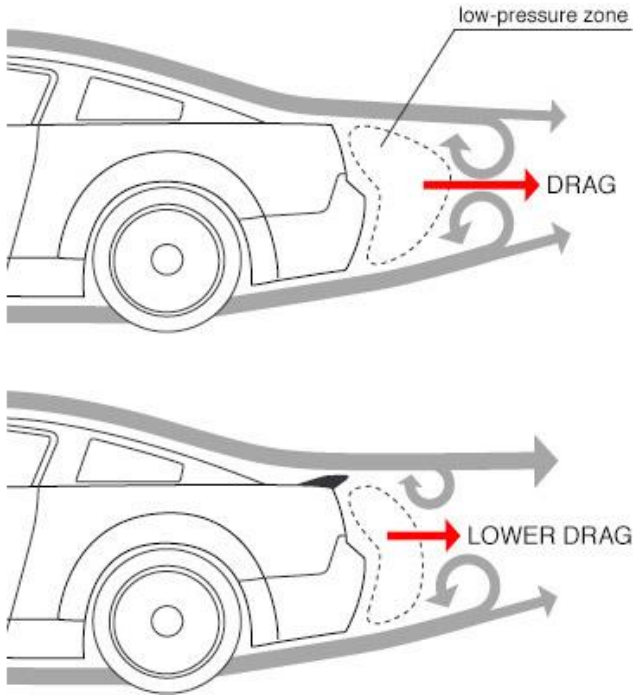
vacuum

이론

Spoiler의 이해

$F = \rho * A * v^2 * \frac{c_d}{2}$ (F=drag force, Cd: drag coeffiency)





이론

Spoiler의 이해

Newtonian Fluid Reynolds Number (Re) Formula

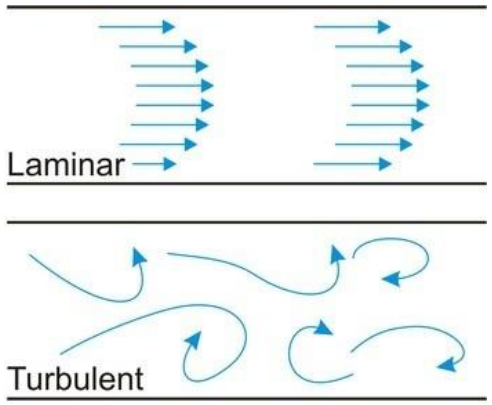
$$Re = \frac{\rho V D}{\mu}$$

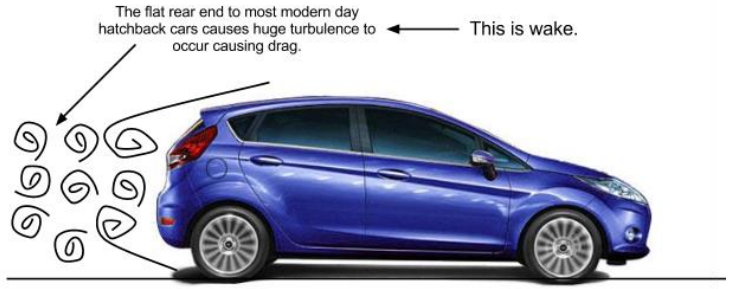
$\mu - fluid\ dynamic\ viscosity\ in\ kg/(m.s)$

$\rho - fluid\ density\ in\ kg/m^3$

$V - fluid\ velocity\ in\ m/s$

$D - pipe\ diameter\ in\ m$





평판에서의 Re

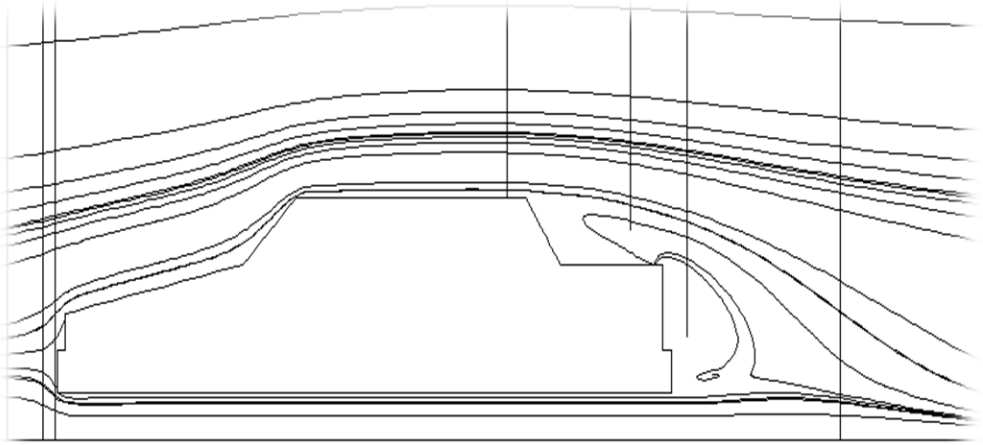
Re<$5 * 10^5$ Laminar

Re>$5 * 10^5$ Turbulent

Spoiler Aerodynamic Properties – 1

Reality

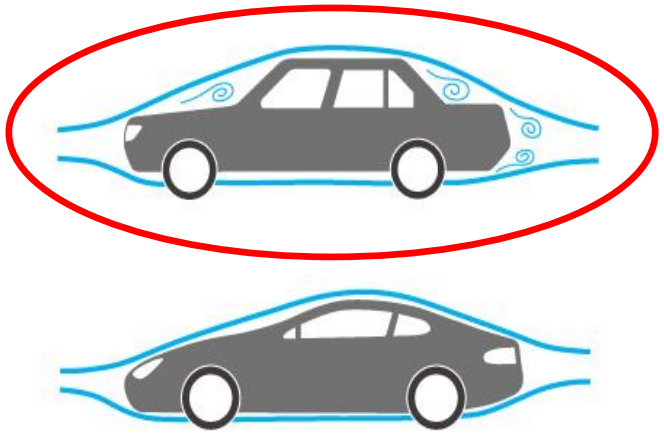
Comsol



1. Fluid model

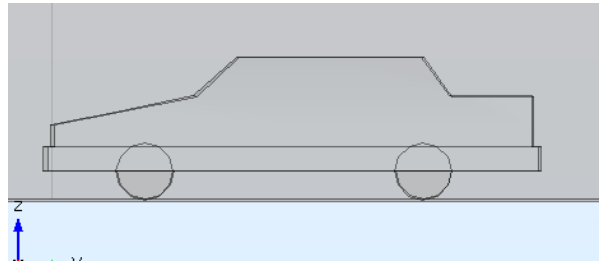
$$Re = \frac{\rho * V * L}{\mu} = \frac{1.2 * 40 * 1.35}{1.515 * 10^{-5}} = 2.14 * 10^{6} \ (5 * 10^{5}) \rightarrow \ Turbulent$$

2. Car Model

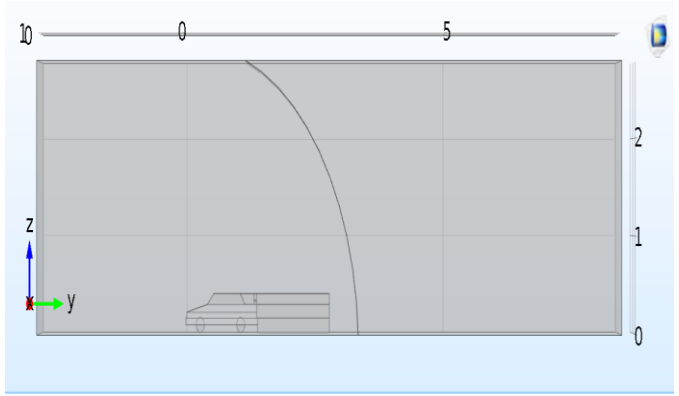


Volvo
740

1/10 model



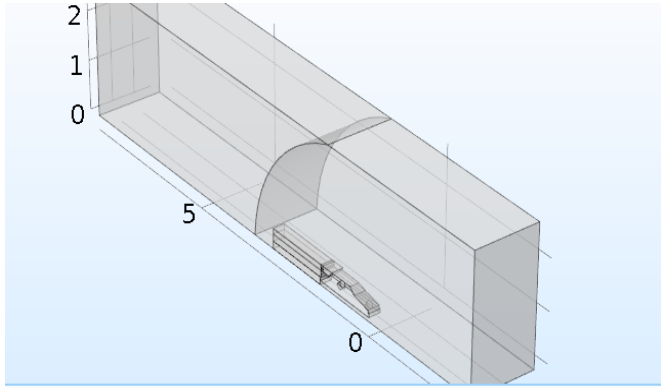
3. Comsol Modeling



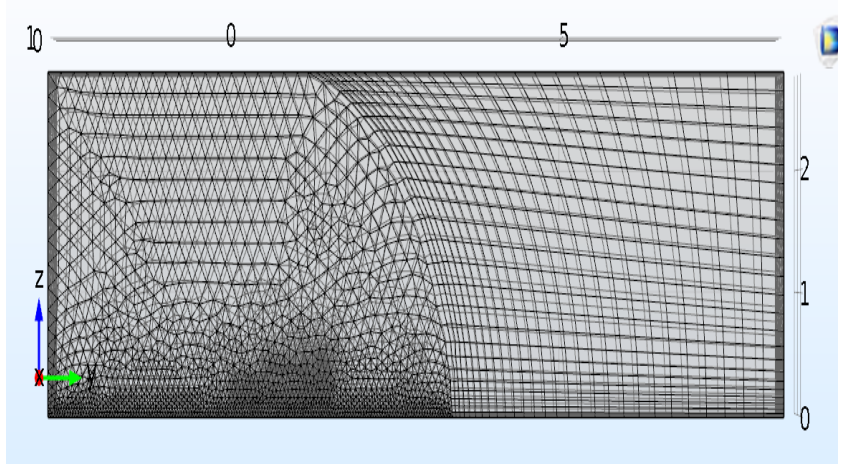
Mesh 크기의 차별화

빠른 계산작업 & 높은 정확도

+



Symmetry 이용



4. 결과 분석

◎현실값 : 0.42

◎

Total stress, y component (N)	Total stress, z component (N)
-37.962	-17.844

Drag Force :

$$F = \rho * A * v^2 * c_d/2$$

$$c_d = \frac{2*F}{\rho*A*v^2} = \frac{2*37{,}962}{1.22*0.081*40^2} = 0.48$$

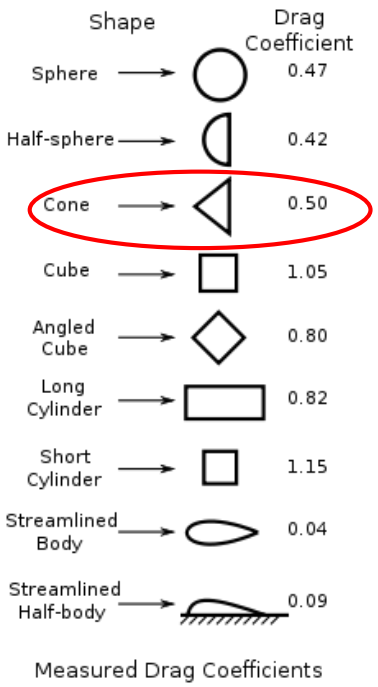
◎ 차체 모델링

◎ 풍동 실험의 k,ε 값의 차이

◎ Mesh의 한계성

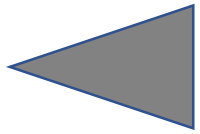
Spoiler Aerodynamic Properties – 2

스포일러 Modeling

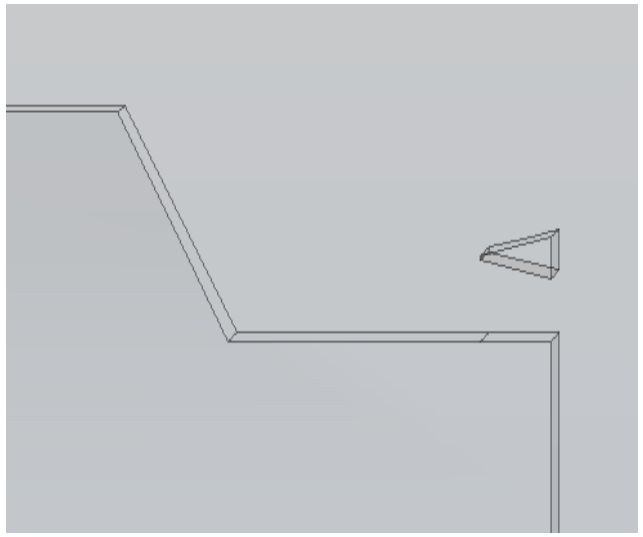


Measured Drag Coefficients

Cone

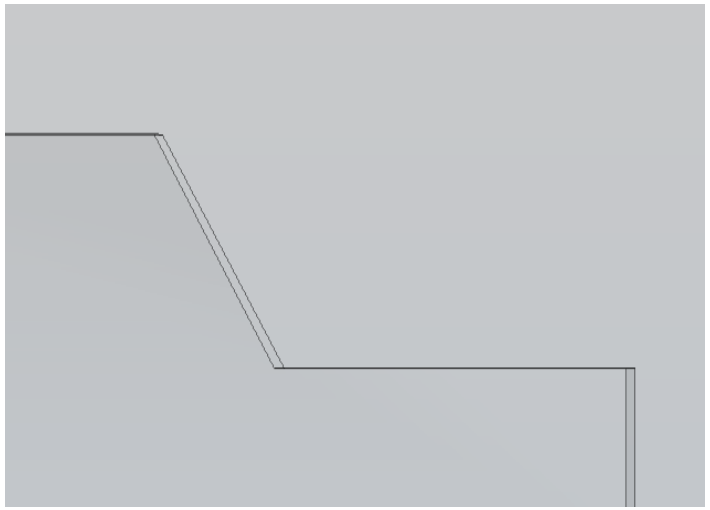


Comsol



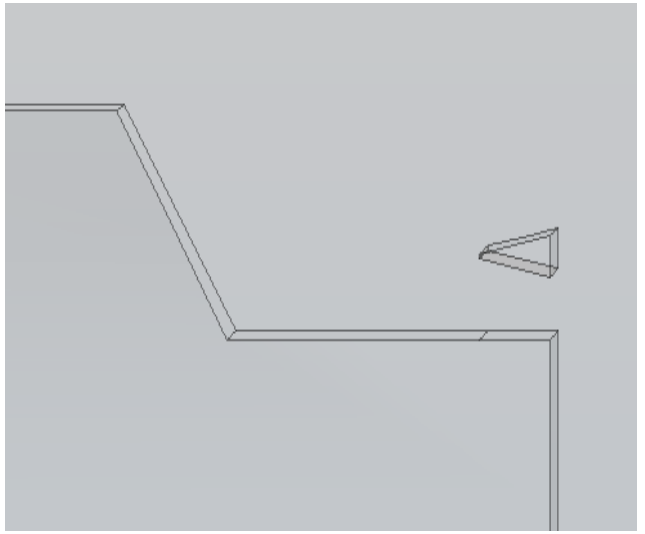
Spoiler Aerodynamic Properties – 2

No Spoiler



Cd : 0.48

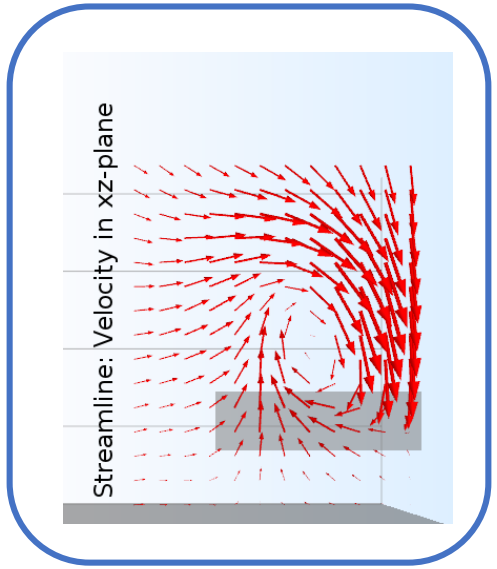
Spoiler



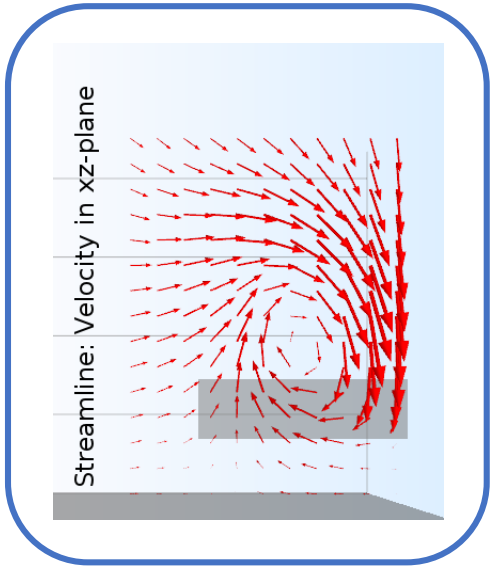
Cd : 0.46

Cd 분석-no Spoiler(Blue), Spoiler(0도)(Red)

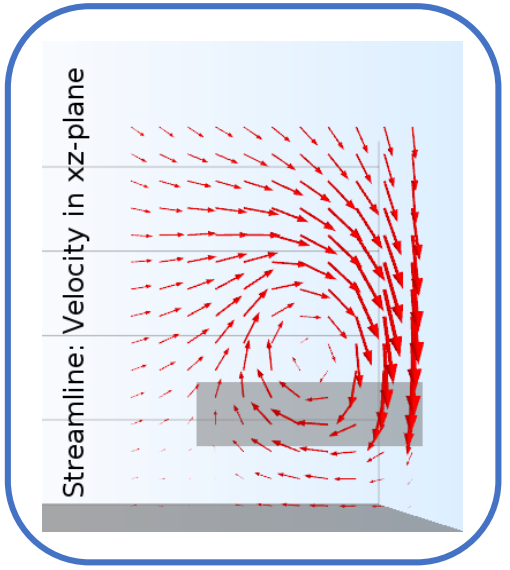
D: 자동차 뒷면으로 부터 떨어진 거리



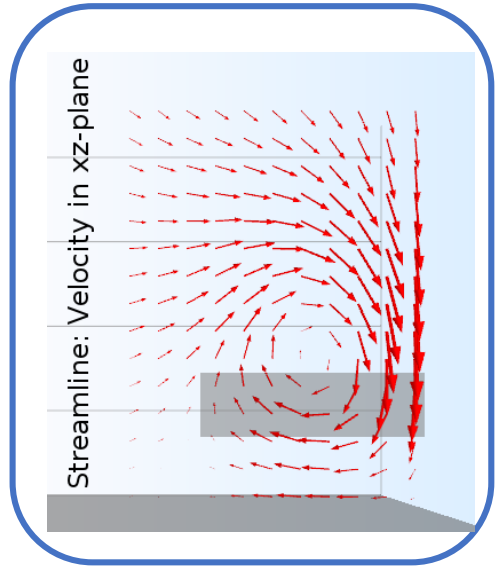
D=0.2



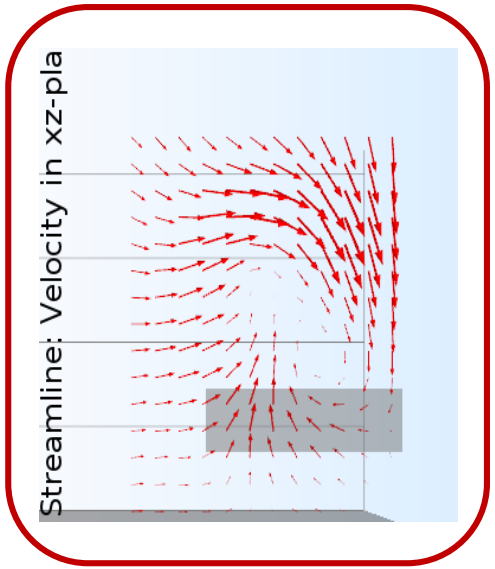
D=0.3

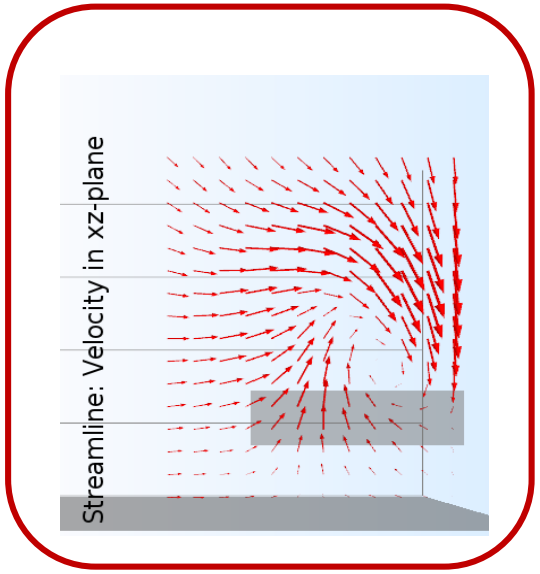


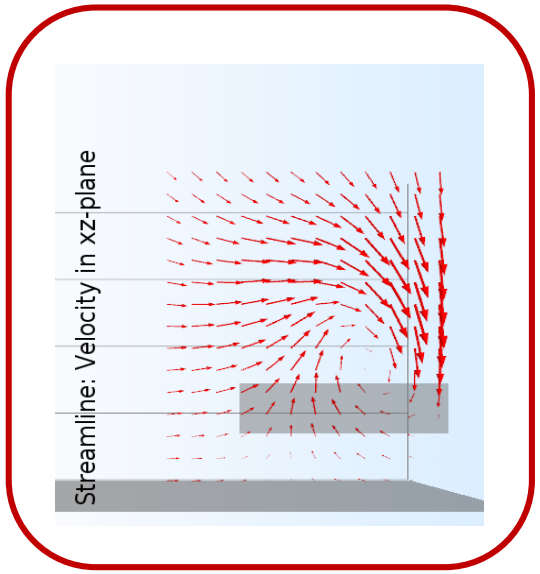
D=0.4

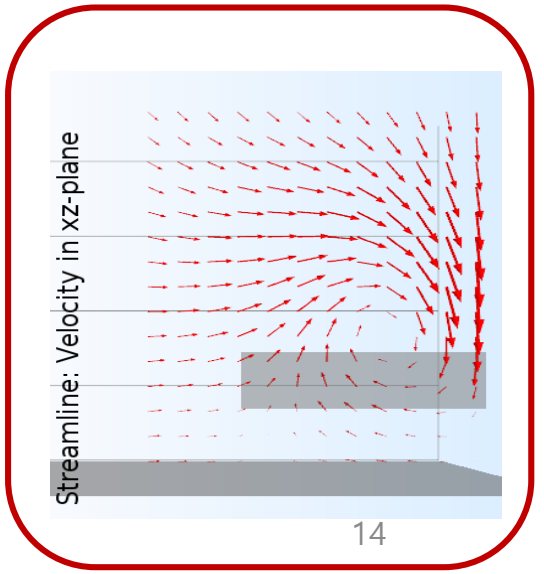


D=0.5



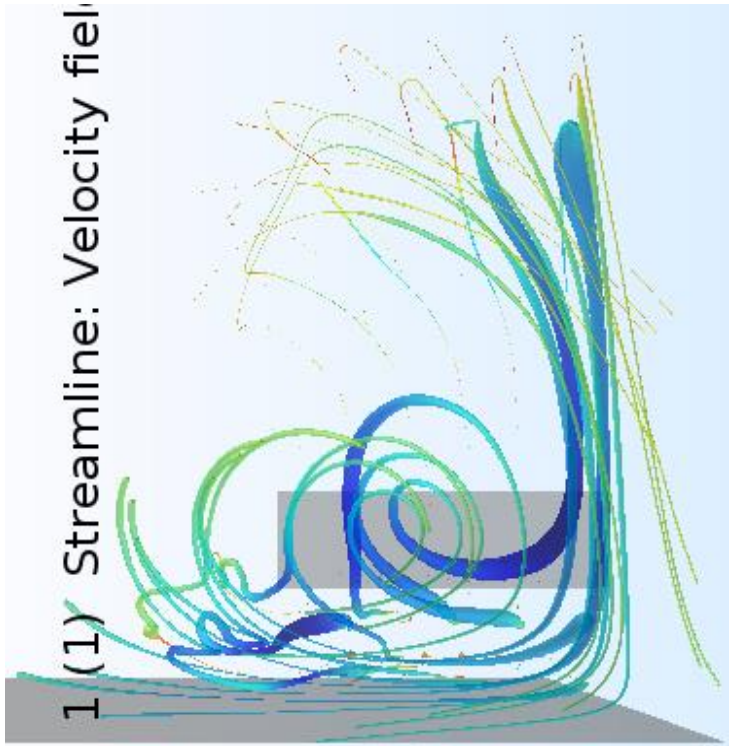




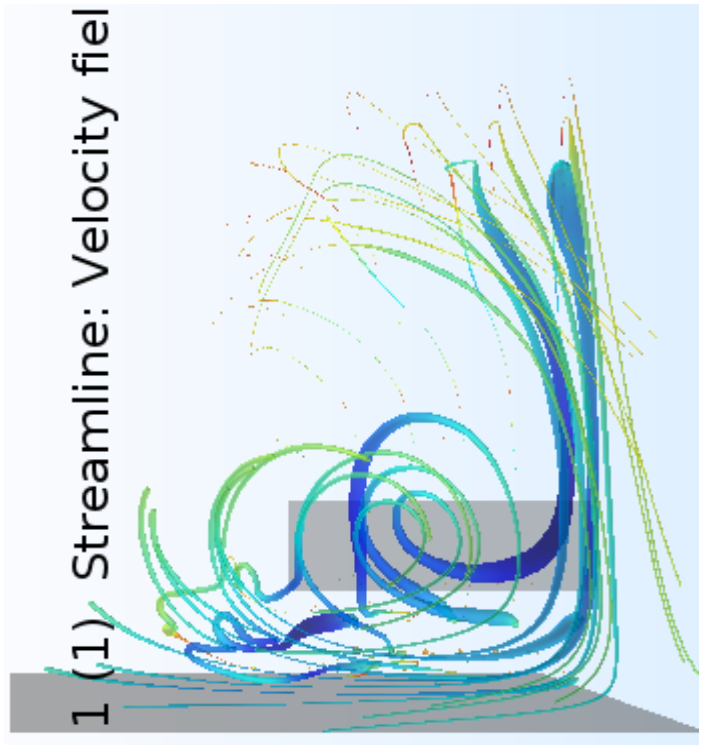


Cd 분석-no Spoiler, Spoiler(0도)

NO Spoiler

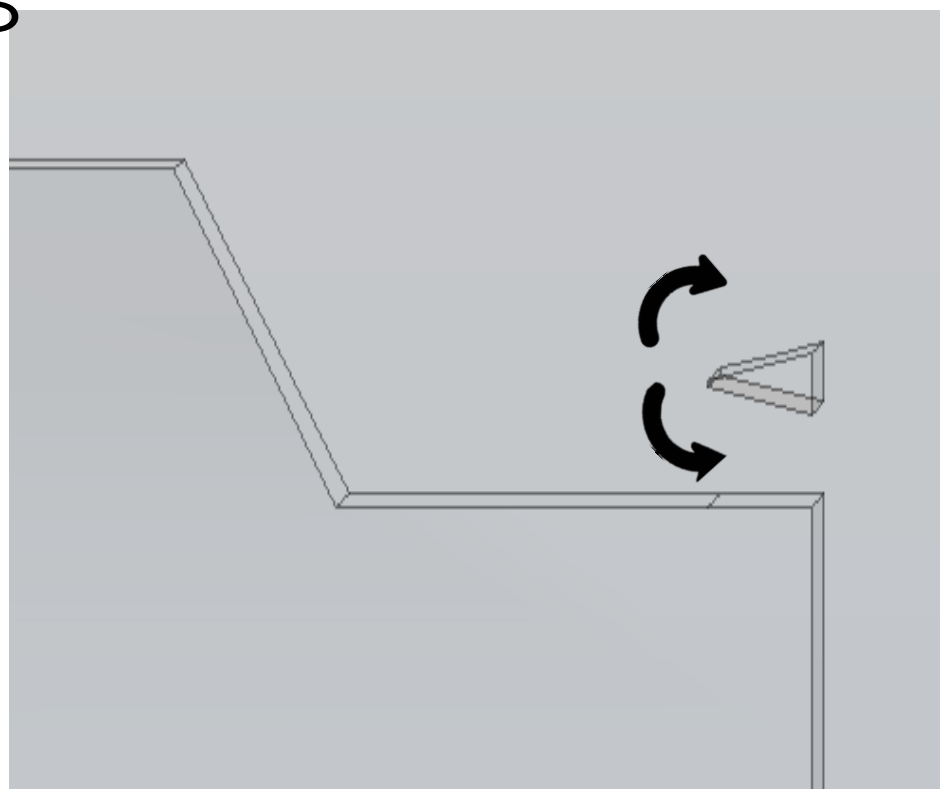


Spoiler

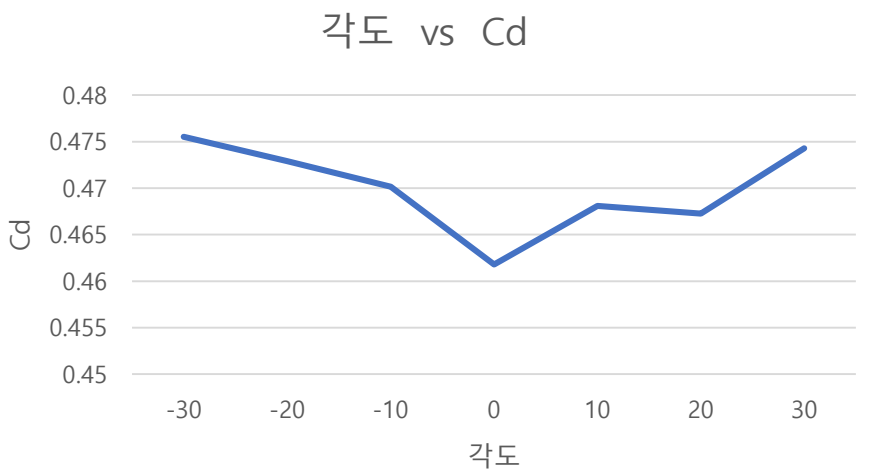


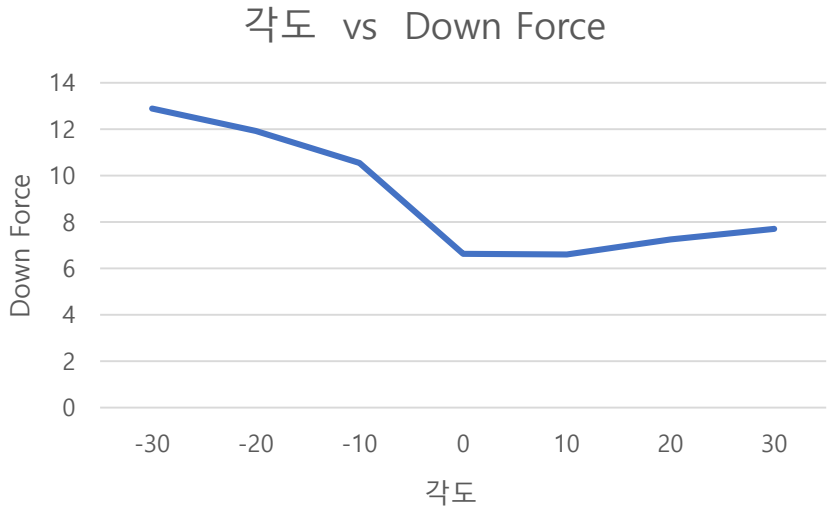
Spoiler Aerodynamic Properties – 3

Spoiler 각도에 따른 Lift와 Drag 측정



Spoiler Aerodynamic Properties – 3





결과

Downforce 최대 각도:-30도

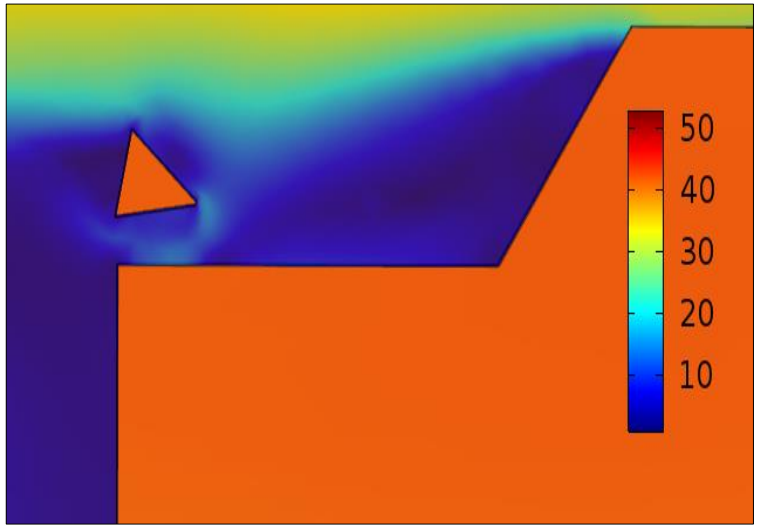
Downforce 최소 각도 : 0도

Cd 최대 각도 : -30도

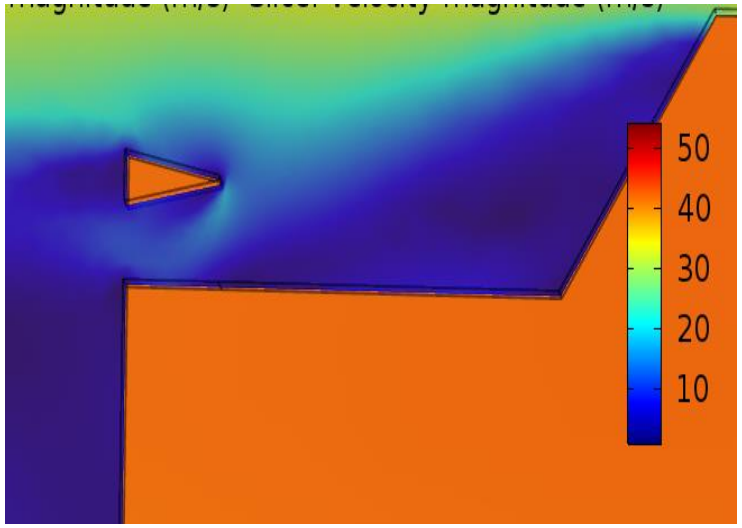
Cd 최소 각도 : 0도

	0도	-30도
연비	↑	↓
안정성	↓	↑

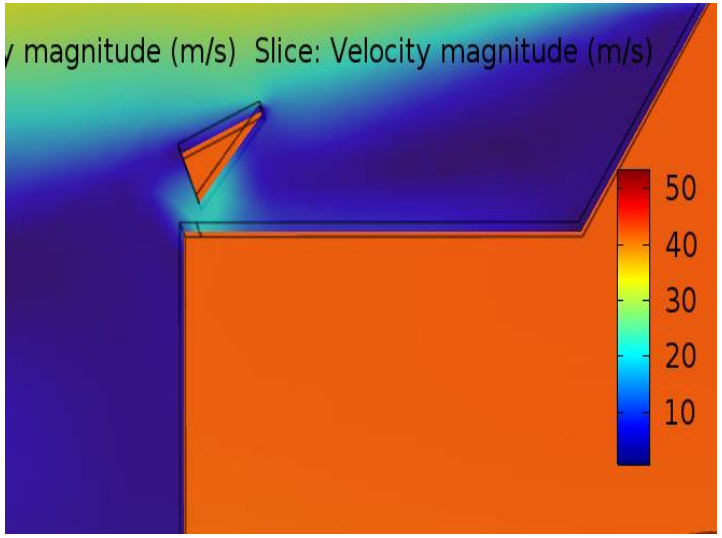
Down force 분석



-30도



0도

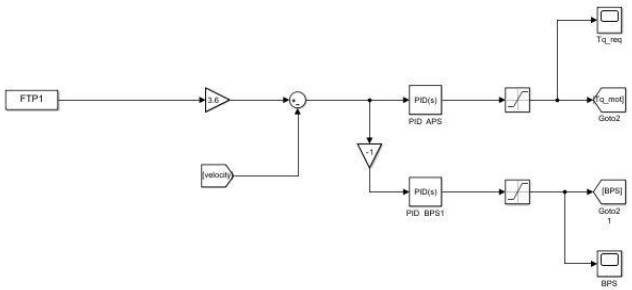


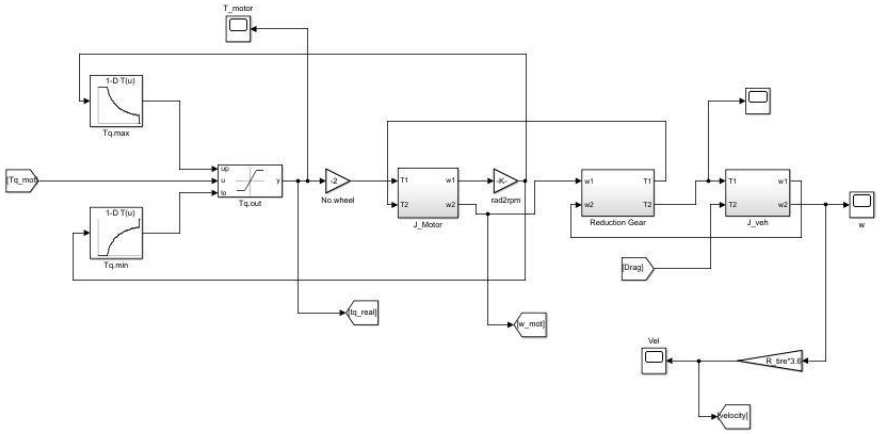
30도

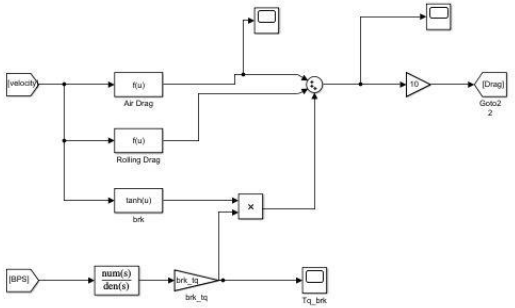
SOC

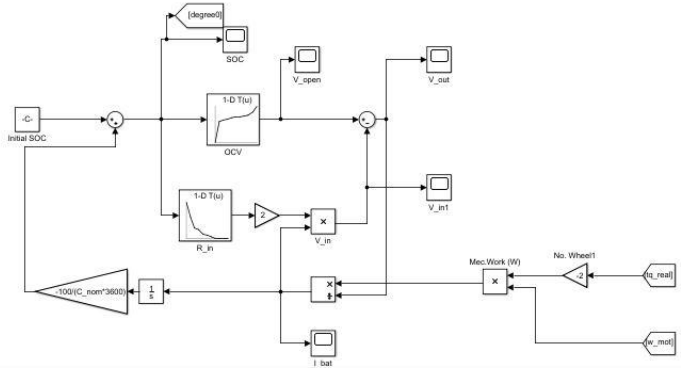
Soc를 이용한 효율 계산

Simulink Modeling for SOC









SOC

Soc를 이용한 효율 계산

◎ Volvo 740 을 전기차로 가정.

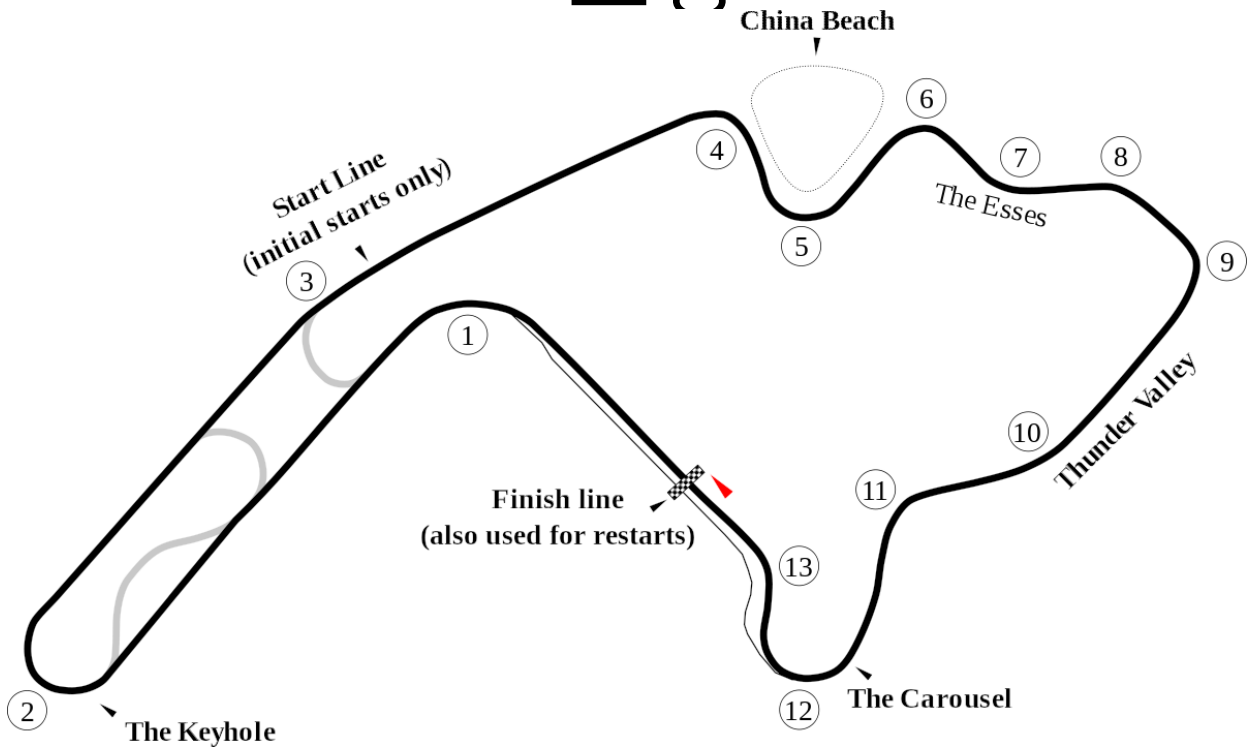
◎ 모델의 값을 Volvo 740에 맞도록 변경.

◎ 모델의 상황을 연구하고자 하는 상황의 조건으로 변경.


SOC_m30
SOC_m20
SOC_m10
SOC_0
SOC_10
SOC_20
SOC_30
SOC_none
20
15
0
200
400
600
800
1000
1200

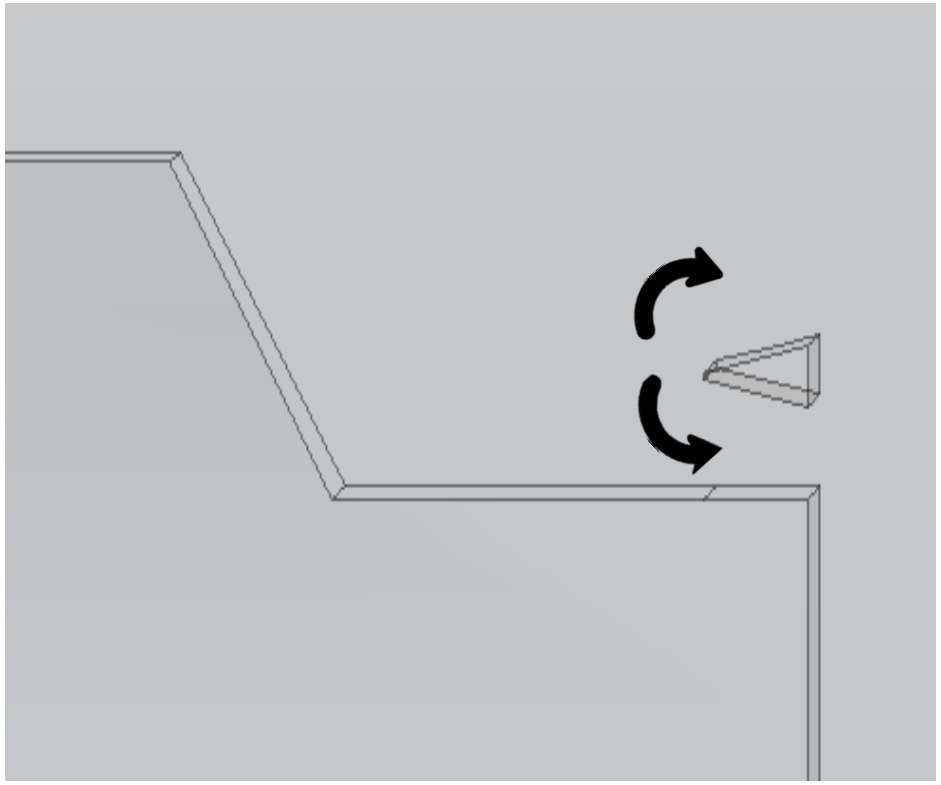
PID 제어

실제 도로에 따른 Active Spoiler 조정



Mid-Ohio Sports Car Course

제어



PID 제어

Conditions

조건

◎ 직선 구간은 연비 효율을 고려한 최소한의 drag force를 받는 0도

◎ 코너링 구간은 안정성을 고려하여 속도와 회전 반경에 따라 5단계로 나누어 각도 제어

15m/s 결과표

	cd	cl
-30	5.371	0.004434
-20	5.2918	0.27903
-10	5.2833	0.28849
0	5.2196	0.81336
10	5.2575	0.66135
20	5.269	0.69892
30	5.3526	0.50476

회전 \ 속도	High	Medium	Low
High	(1)	(2)	(3)
Medium	(2)	(3)	(4)
low	(3)	(4)	(5)

(1) : -20도

(2) : -10도

(3) : 30도

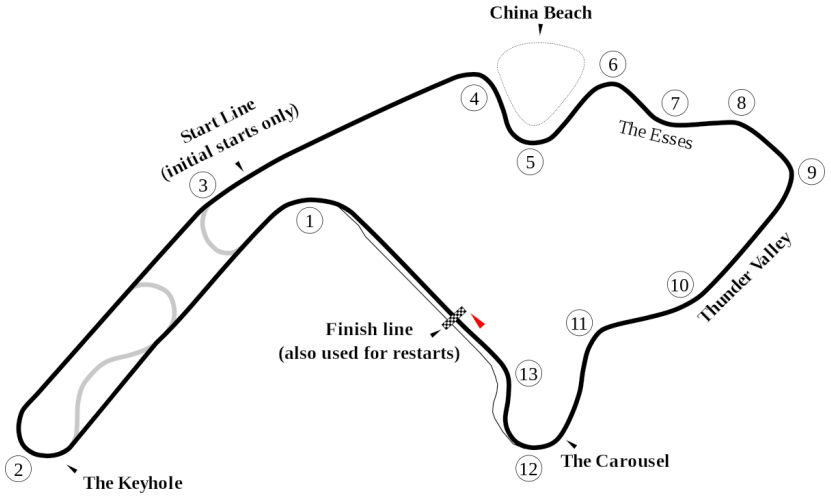
(4) : 10도

(5) : 20도

Small Lift
&
Stable

PID 제어

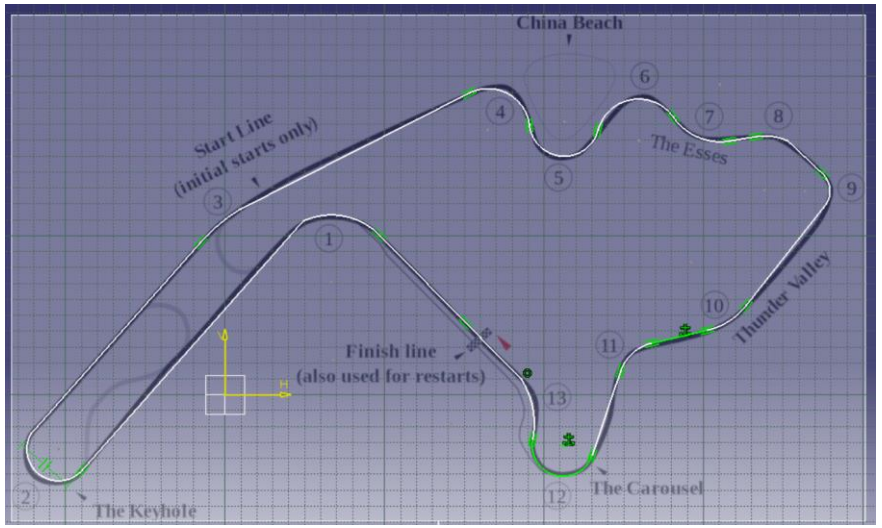
Catia, Simulink를 이용한 Modeling



trace

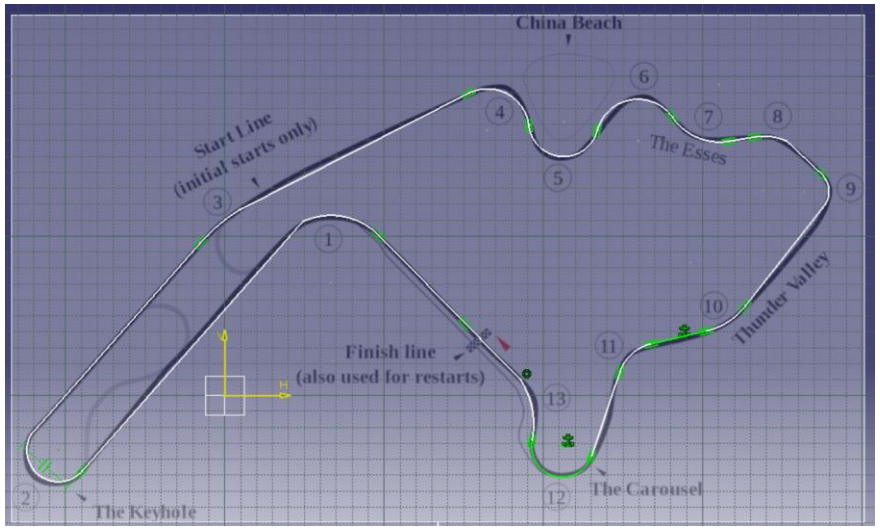
좌표화

Catia



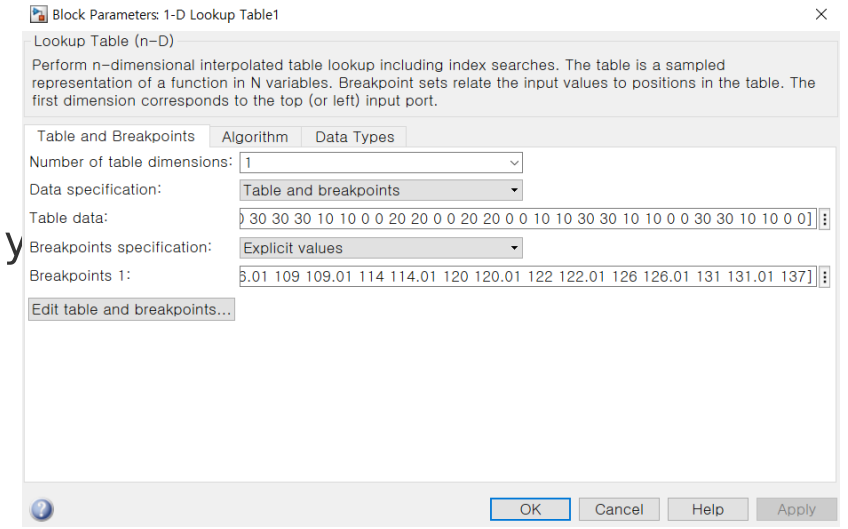
PID 제어

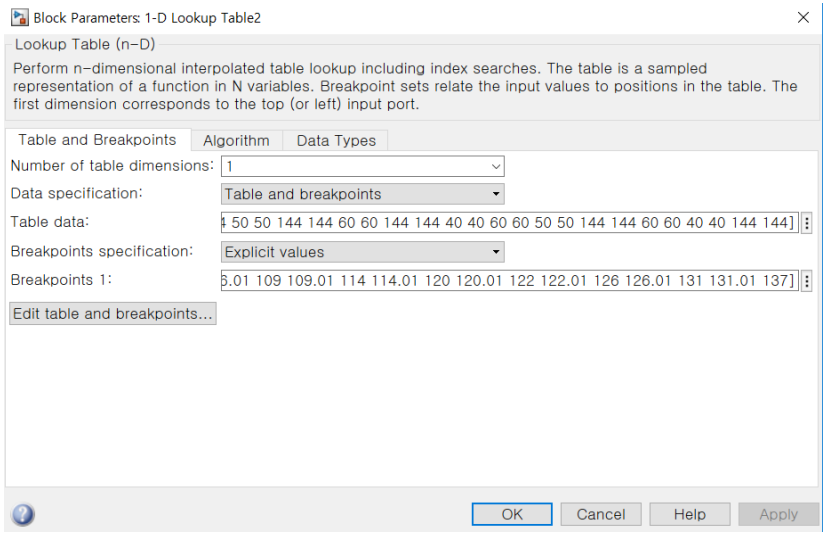
Catia, Simulink를 이용한 Modeling



Anguler Velocity

Tangantial Velocity

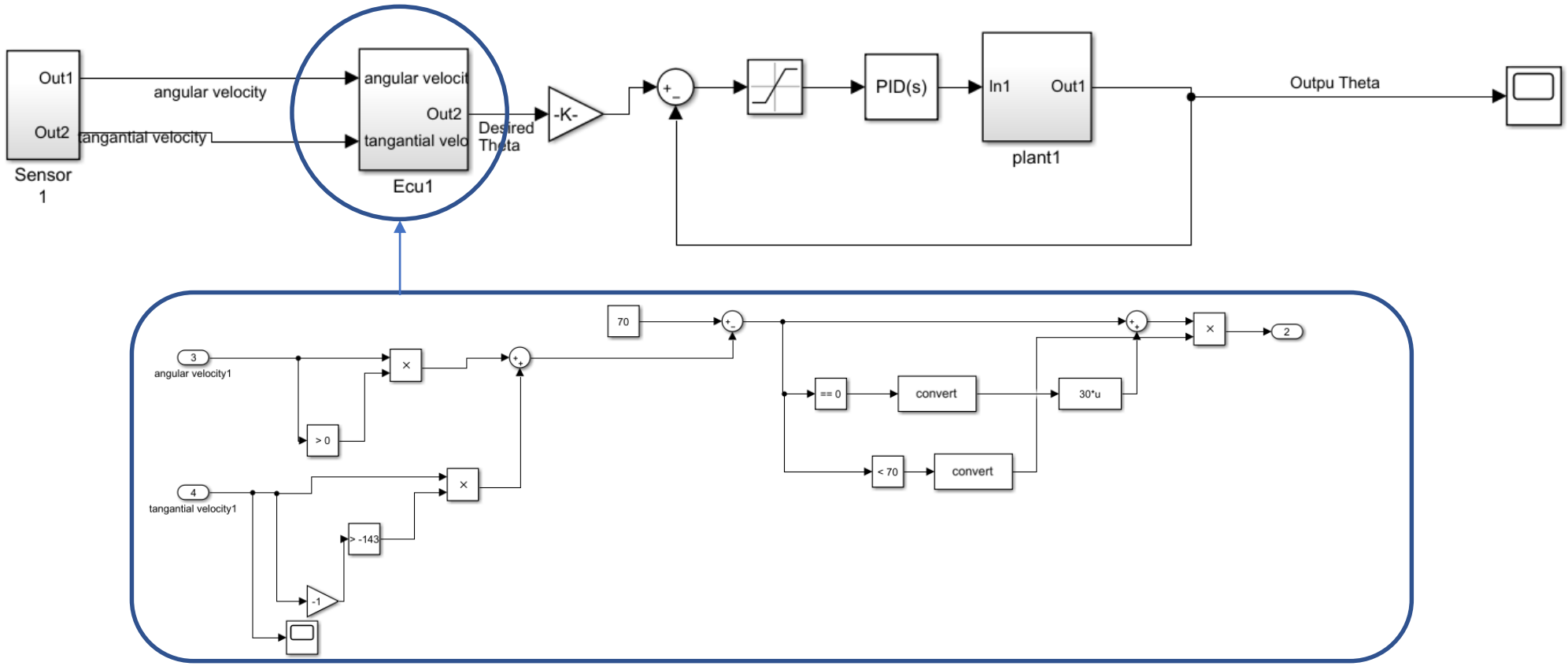




PID 제어

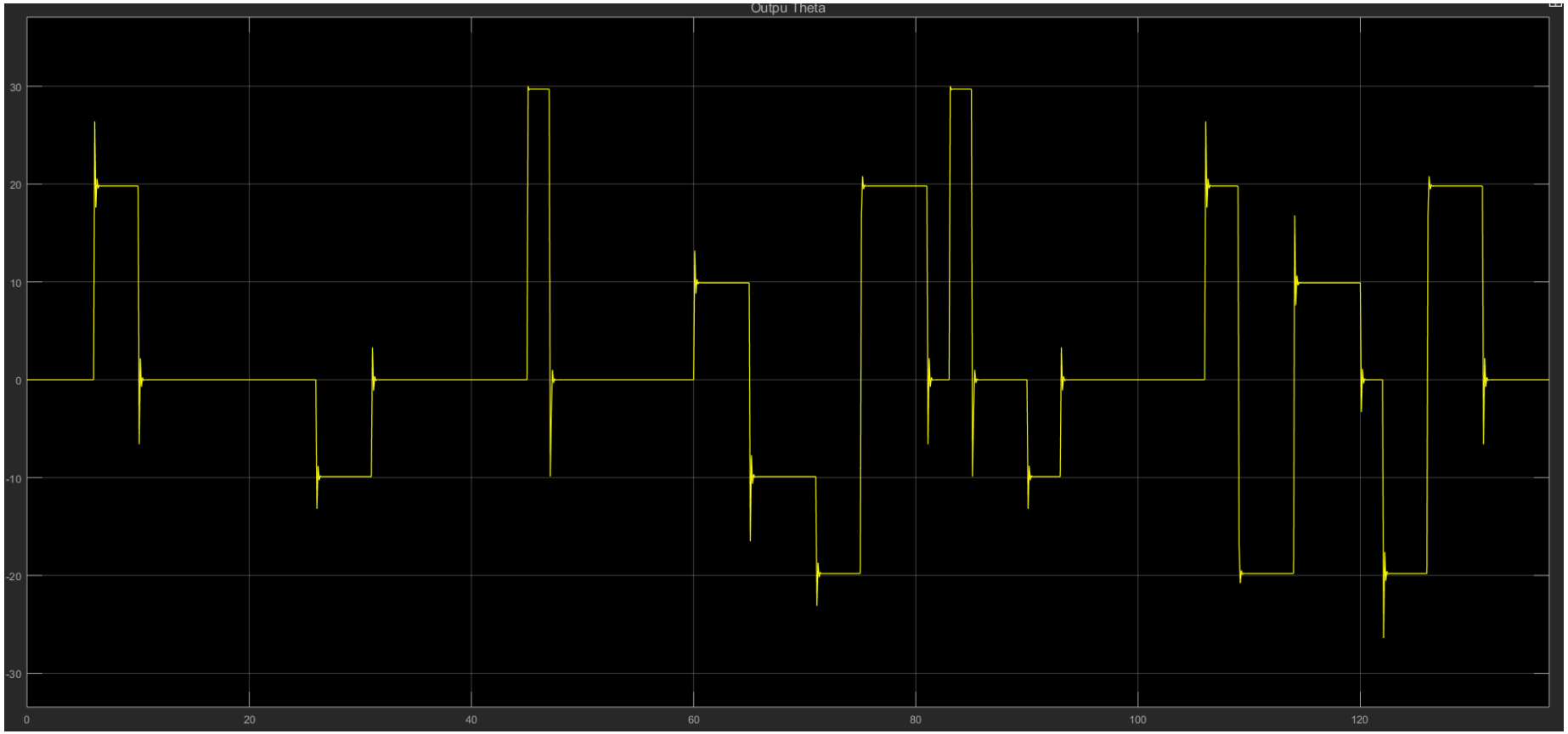
Catia, Simulink를 이용한 Modeling

Simulink



PID 제어

Comsol 결과 분석



Reference

◎ 유체역학 전공책 : "Introduction to Fluid Mechanics"
- Fox and Mcdonalds

◎ "Airflow Over an Ahmed Body"
- COMSOL Multiphysics 5.4

◎ "Effects of rear spoilers on ground vehicle aerodynamic drag"
- Halil Sadettin Hamut, Rami Salah El-Emam, Murat Aydin, Ibrahim Dincer

◎ "Evaluating the Importance of Rear Spoiler on Energy Efficiency of Electric Vehicles"
- S. M. R. Tousi1, P. Bayat2, P. Bayat3


Q A