Wiperless Automobile

-와이퍼가 없는 자동차 앞 유리의 최적설계

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Contents

1. Introduction

- Car Aerodynamics work
- Review of Past work

2. Main Body

- New Problem Statement -> Add more Constraint
- Effects of other initial values
- Graphical solution
- Calculate as MATLAB & EXCEL
 - (use various algorithm)

3. Conclusion

- Compare to real design

Introduction

-Car Aerodynamic Work & Design

Aerodynamic work

• Make a shape as streamline





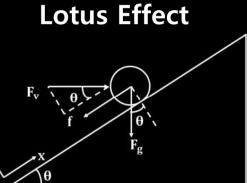
Find a proper angle for wiper less window

$$g1:10^{\circ} \le \theta \le 45^{\circ}$$

$$g2: F_{V} \cos \theta - f - F_{g} \sin \theta \ge 0$$

$$g3: C \rho_{air} A_{car} \frac{V^{2}}{2} \le 83.45N (85km / h, 45^{\circ})$$

$$g4: C \rho_{air} A_{car} \frac{V^{2}}{2} \ge 26.4N (30km / h, 10^{\circ})^{v} \setminus 10^{\circ}$$



- Add more constraints
 - ✓ Past : consider only drag force
 - ✓ Current : consider Lift force, Power, field of vision

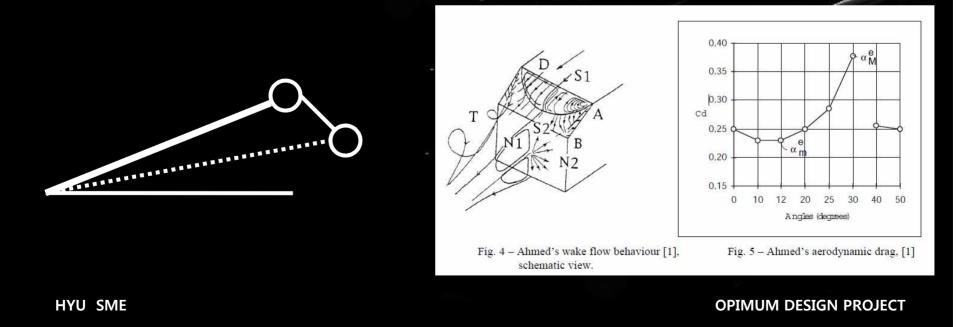
What's the Design Point?

- OBJECTIVE : Design wiper less car window
- Aerodynamically find angle which can reduce Drag Force
- Find proper angle to reduce power consumption
- Set up proper angle for field of vision
- Find relationship between velocity & front window angle.

-New Constraints & summary

Angle $\rightarrow 10^{\circ} \sim 35^{\circ}$

- ⑦ 일정 범위 속도(30km/h~85km/h)와 일정 각도(10°~45°) 사이에서 분석
 한다 → 10°~35°로 수정 (boundary condition)
- Find Proper Cd to determine Fd
- Find Proper angle for field of vision



-New Constraints & summary

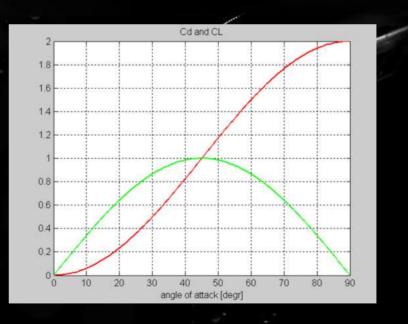
Drag & Lift Force

- Minimum & Maximum Drag force
 - ✓ Drag force should be reduced
 - ✓ Lift Force also should be reduced for accident

$$F_{d} = C_{d} \rho_{air} A_{car} \frac{V^{2}}{2} \le 200N$$

$$F_{l} = C_{l} \rho_{air} A_{car} \frac{V^{2}}{2} \le 160N$$

$$\frac{C_{d}}{C_{l}} = \tan \alpha \text{ (streamline body)}$$

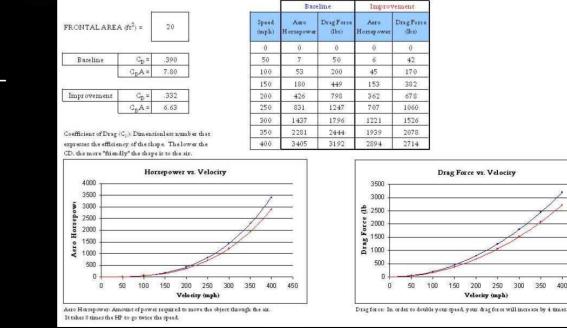


-New Constraints & summary

POWER for efficiency

- Find Proper V & theta to reduce fuel efficiency ullet
 - \checkmark The power required to overcome the aerodynamic drag
 - \checkmark 80% of fuel is used for overcoming the drag force

$$P = C_d \rho A_{air} \frac{V^3}{2}$$



350 400 450

-New Constraints & summary

Summary of Constraints

• Find Proper V & theta to reduce fuel efficiency

- ✓ The power required to overcome the aerodynamic drag
- ✓ 80% of fuel is used for overcoming the drag force

$$f: (\text{drag force})-(\text{frictioin force})-(\text{gravity})$$
$$= F_V \cos \theta - f - F_g \cos \theta$$
$$= \left(CA\rho \frac{V^2}{2}\right)(\cos \theta - \mu \sin \theta) - mg(\mu \cos \theta + \sin \theta)$$

$$g1: C_{d} \rho_{air} A_{car} \frac{V^{2}}{2} - 200 \le 0$$

$$g2: 4 - C_{d} \rho_{air} A_{car} \frac{V^{2}}{2} \le 0$$

$$g3: C_{l} \rho_{air} A_{car} \frac{V^{2}}{2} - 160 \le 0$$

$$g4: C_{d} \rho_{air} A_{car} \frac{V^{3}}{2} - 5000 \le 0$$

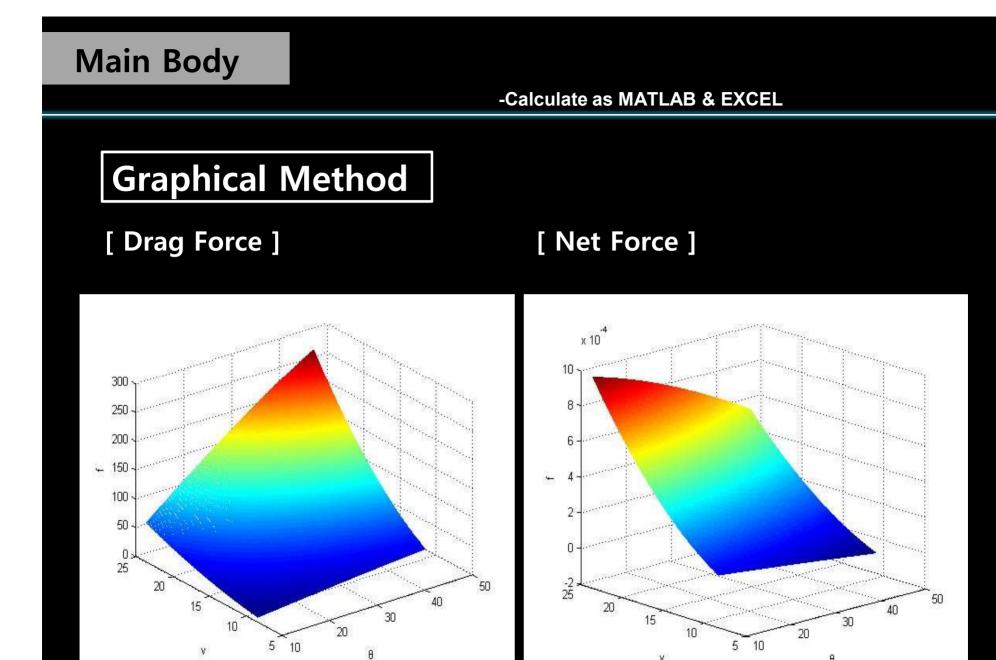
$$g5: 10^{\circ} - \theta \le 0$$

$$g6: \theta - 35 \le 0$$

-New Constraints & summary

ASSUMPTION

- ① Assume that surface can be used for Lotus effects
- ② Assume that water drop is a solid
- ③ Wind flow parallel compare to ground
- ④ Only consider water drop which go over upside
- (5) Assume that normal state (20°C, 1atm)
- 6 All other properties are used from Grandeur, Hyundai (window)
- \bigcirc Analysis that car speed is btw 30km/h~85km/h and angle is btw10°~40°



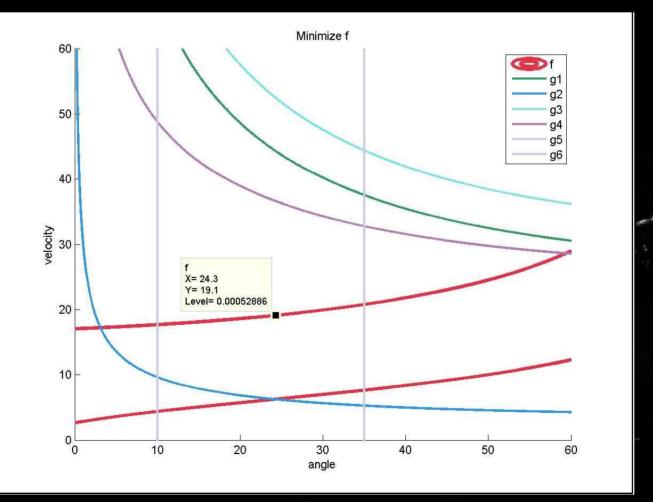
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OPIMUM DESIGN PROJECT

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-Calculate as MATLAB & EXCEL

Graphical Method



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-Calculate as MATLAB & EXCEL

Fmincon

A Optimization Tool	- D 🔀	
Eile Help		
Problem Setup and Results	Options \sum	
Solver: fmincon - Constrained nonlinear minimization	💿 Specify: 1e-1000	
Algorithm: Active set	Function tolerance: OUse default: 1e-6	
Problem	Specify: 1e-1000	
Objective function: @water	Nonlinear constraint tolerance: 🔿 Use default: 1e-6	
Derivatives: Approximated by solver	Specify: 1e-1000	
Start point: [30 30]	SQP constraint tolerance: Use default: 1e-6 	
Constraints:	O Sansibu	
Linear inequalities: A: b:	🛃 Optimization PlotFens	
Linear equalities: Aeq: beq; beq;	File Edit View Insert Tools Desktop Window Help 🛛 🛥	
Bounds: Lower: [0 0] Upper:	Current Point	
Nonlinear constraint function: @water_c	40 , , , , , , , , , , , , , , , , , , ,	
Derivatives: Approximated by solver	ː 플 30	
Run solver and view results		
Start Pause Stop	Š 10	
Current iteration: 66 Clear Results	η	
Solver stopped prematurely,	1 2 Number of variables: 2	
fmincon stopped because it exceeded the function evaluation limit, options,MaxFunEvals = 200 (the default value),	x 10 ⁻⁴ Current Function Value: 0 15	
	<u>응</u> 10 -	
Final point:		
1 2	, B 0 - 400000000000000000000000000000000	
34,673 7,437	A second as the second	
<u>×</u>	Stop Pause Iteration	

HYU SME

-Calculate as MATLAB & EXCEL

Genetic Algorithm

Optimization Tool		
īle <u>H</u> elp		
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Solver: ga - Genetic Algorithm	Specify:	
Problem	Stall generations:	
Fitness function: @water	O Specify:	
Number of variables: 2	Stall time limit: O Use default: Inf	
Constraints:	O Specify:	
Linear inequalities: A: b:		
Linear equalities: Aeq: beq: beq:	Function tolerance: Use default: 1e-6 	
Bounds: Lower: [0 0] Upper:	O Specify:	
Nonlinear constraint function: @water_c	Nonlinear constraint tolerance: 💿 Use default: 1e-6	
Run solver and view results		
	Eile Edit View Insert Tools Desktop Window Help	~
Use random states from previous run	Best: 0.00040771 Mean: 0.00040831 4000 r	
Start Pause Stop	Best fitness	
Current iteration: 4	• Mean fitnes	S
and constraint violation is less train options, roleon;	§ 2000 -	
Optimization running. Optimization terminated.	· [1000 -	
Objective function value: 4,0770587341226527E-4	0 20 40 60 80	100
Optimization terminated: average change in the fitness value less than options, TolFun	Generation	
and constraint violation is less than options, TolCon,	Current Best Individual	
	· 현 꽃 30 -	
Final point:		
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07,000, 10,400		85.8
	<u>3</u> 0 <u>1</u> 2	
X	Stop Number of variables (2)	

HYU SME

-Calculate as MATLAB & EXCEL

Pattern Search

📣 Optimization Tool		
Eile Help		
Problem Setup and Results	Options	
Solver: patternsearch - Pattern Search	O Specify:	~
Problem	Max function evaluations: O Use default: 2000+numberOfVariables	
Objective function: @water	O Specify:	
Start point: [15.15]	Time limit: O Use default: Inf	
Constraints:	O Specify:	
Linear inequalities: A: b:	X tolerance: O Use default: 1e-6	
Linear equalities: Aeq: beq:	Pattern Search	
Bounds: Lower: [0 0] Upper:	File Edit View Insert Tools Desktop Window Help	
Nonlinear constraint function: @water_c		
Run solver and view results	x 10 ⁻⁴ Best Function Value: 3.3645e-009	
Use random states from previous run	a a	
Start, Pause Stop	en 3 - • tipita - • tipita - • tipita - •	
Current iteration: 3	<u> </u>	
Opumization terminateus mesn size less trian opuons, roilviesn	Ē 1-	
and constraint violation is less than options, TolCon,		
Optimization running, Optimization terminated,	0 0.5 1 1.5 2 2.5 3 Iteration	
Objective function value: 3,3644838498601923E-9	Current Best Point	
Optimization terminated: mesh size less than options, TolMesh and constraint violation is less than options, TolCon,	40	
	- · · · · · · · · · · · · · · · · · · ·	
Final point:	5 m	
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32, 293 7, 128		
<	1 2 Stop Number of variables (2)	

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OPIMUM DESIGN PROJECT

23				$= \left[CA \rho - \frac{1}{2} \right]$	$\cos\theta - \mu(mg\cos\theta)$	$s\theta + \left[\frac{CA\rho}{2} \right] \sin \theta - mgs$	anθ
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25	물방울지름	2.000.E-03		$= CA \rho \frac{V^{2}}{2}$	$(\cos\theta - \mu\sin\theta)$	$-mg(\mu\cos\theta+\sin\theta)$	
26	물방울밀도	9.982.E+02		(2). , (
27	중력가속도	9.810.E+00	0	26.5021265	27.063735	35	
28	물방울질량	1.254.E-05	0	6.40000119	6.469603837	7,479274004	
29	물방울무게	1.231.E-04	-1.231.E-05	-1.033.E-11	1.586.E-12	-1.234.E-12	
30	물방울단면적	3.142.E-06	-2.000.E+02	-1.955.E+02	-1.953.E+02	-1.921.E+02	
31	마찰계수(mu)	1.000.E-01	4.000.E+00	-5.142.E-01	-7.033.E-01	-3.924.E+00	
32	항력계수	1.000.E+00	-1.600.E+02	-1.574.E+02	-1.573.E+02	-1.555.E+02	
33			-5.000.E+03	-4.971.E+03	-4.970.E+03	-4.941.E+03	
34		시나리오 요약 / fm	ncon pattern ga Sheet2	-16,502126	-17.063735	-25	

회색으로 표시됩니다.

변경 셀 값을 나타냅니다. 각 시나리오의 변경 셀들은

참고: 현재 값 열은 시나리오 요약 보고서가 작성될 때의

5		ı/h >>>>>> 8.33	33.E+00 m/s	$g3: C_i \rho_{av} A_{var} \frac{\nu}{2} - 160 \le 0$	0	
오 요약						1
	현재 값:	1	2	3	4	5
:						
\$H\$11	35.000001	1	35.000001	35.000001	35.000001	35.000001
\$H\$12	7.457240286	1.000001	1.291975241	9.560616784	7.457247743	7.457240286
:						
\$H\$13	-4.746.E-07	-1.256.E-05	-7.825.E-05	5.114.E-05	-4.744.E-07	-4.746.E-07
1.4.4.	5 2 요약 \$H\$11 \$H\$12	5 <u>3.000.E+01</u> km/ 2 요약 현재 값: 5 5 5 5 7.457240286	5 <u>3.000.E+01 km/h</u> >>>>>> 8.3 2 요약 현재 값: 1 \$H\$11 35.000001 1 \$H\$12 7.457240286 1.000001	2 요약 현재값: 1 2 \$H\$11 35.000001 1 35.000001 \$H\$12 7.457240286 1.000001 1.291975241	2 요약 현재값: 1 2 3 \$H\$11 35.000001 1 35.000001 \$H\$12 7.457240286 1.000001 1.291975241 9.560616784	2 요약 현재값: 1 2 3 4 \$H\$11 35.000001 1 35.000001 35.000001 \$H\$12 7.457240286 1.000001 1.291975241 9.560616784 7.457247743

н $d_{a}\rho_{av}A_{car}\frac{V^2}{2}-200\leq 0$ $-C_d \rho_{av} A_{var} \frac{V^2}{2} \leq 0$ 1.080.E+02 km/h <<<<<< > 3.000.E+01 m/s 4 속도변화

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1							gl:Cas
2	각도변환	1.000.E+01		>>>>>>	0.17453293	rad	
3		3.500.E+01		>>>>>>	0.61086524	rad	g2:4-

Main Body

Excel Solver

-Calculate as MATLAB & EXCEL

Conclusion

- Summary & comments

Found OPIMUM ANGLE!!

[Graphical]

$\theta = 24.3^{\circ}$

[Computational]

$\theta = 34.5^{\circ}$

Reference

Papers & Thesis

- Modelling of Stationary Three-Dimensional Separated Air Flows around an Ahmed Reference Model
- Hybrid method for aerodynamic shape optimization in automotive industry
- Effect of cross winds on high-speed trains: development of a new experimental methodology
- Experimental and Computational Aerodynamic Investigations of a Car
- Mean and time-varying flow measurements on the surface of a family of idealised road vehicles

Q & A

ThE eND ThANk YoU

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