Wiperless
Automobile

-와이퍼가 없는
자동차 앞 유리의 최적설계

Team : V.O.C

2004007898 한보석

2007004887 박현철

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- Car Aerodynamics work
- Review of Past work

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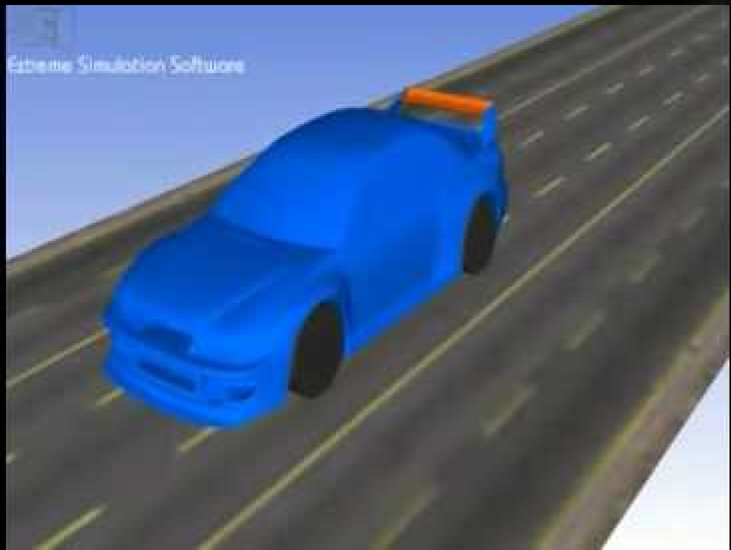
- New Problem Statement → Add more Constraint
- Effects of other initial values
- Graphical solution
- Calculate as MATLAB & EXCEL
  (use various algorithm)

3. Conclusion

- Compare to real design

Aerodynamic work

- Make a shape as streamline



Find a proper angle for wiper less window

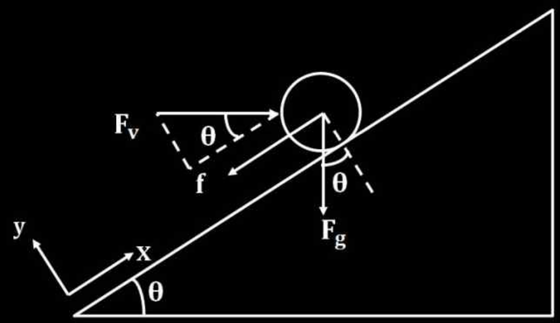
$$g1: 10^\circ \le \theta \le 45^\circ$$

$$g2: F_V \cos\theta - f - F_g \sin\theta \ge 0$$

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

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

Lotus Effect



- 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.

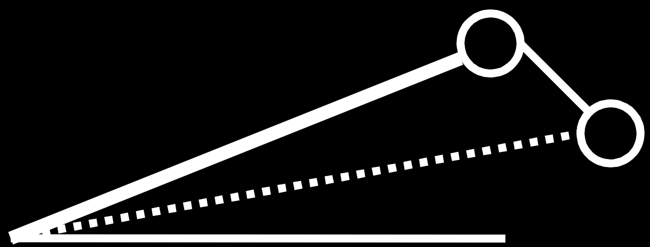
Main Body

-New Constraints & summary

Angle →10˚~35˚

⑦ 일정 범위 속도(30km/h~85km/h)와 일정 각도(10˚~45˚) 사이에서 분석한다 → 10˚~35˚로 수정 (boundary condition)

- **Find Proper Cd to determine Fd**
- **Find Proper angle for field of vision**



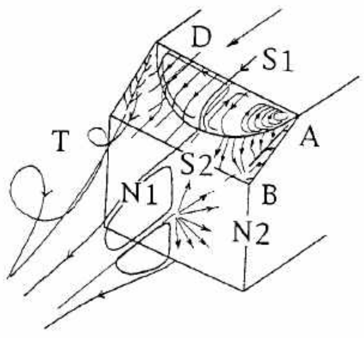


Fig. 4 – Ahmed's wake flow behaviour [1], schematic view.

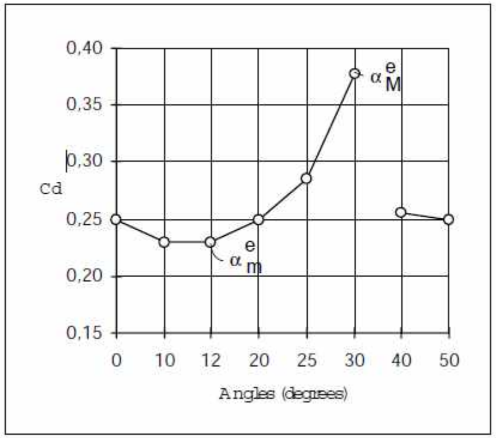


Fig. 5 – Ahmed's aerodynamic drag, [1]

Main Body

-New Constraints & summary

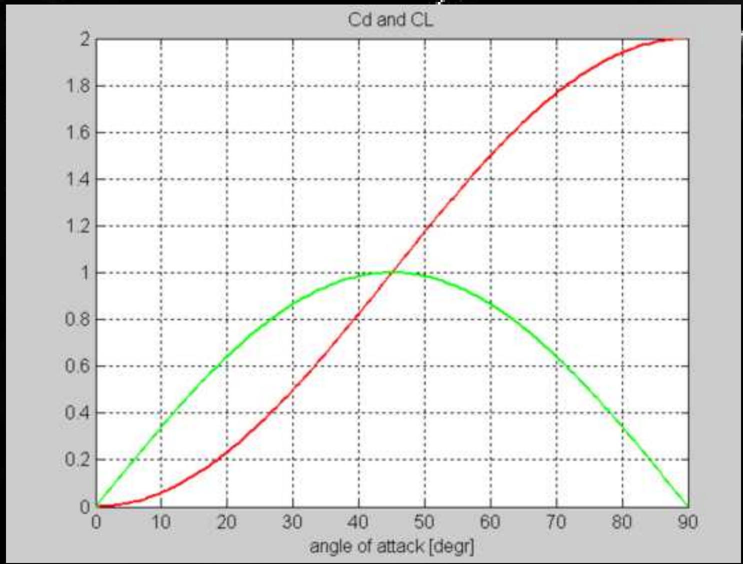
Drag & Lift Force

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

$$F_d = C_d \rho_{air} A_{car} \frac{V^2}{2} \leq 200N$$

$$F_l = C_l \rho_{air} A_{car} \frac{V^2}{2} \leq 160N$$

$$\frac{C_d}{C_l} = \tan\alpha \quad \text{(streamline body)}$$



Main Body

-New Constraints & summary

POWER for efficiency

- **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

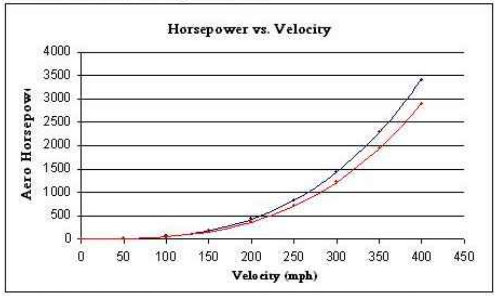
$$P = C_d \rho A_{air} \frac{V^3}{2}$$

FRONTAL AREA (ft^2) = 20

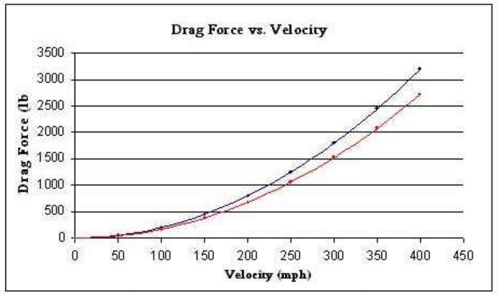
Baseline	C_D =	.390
	C_DA =	7.80
Improvement	C_D =	.332
	C_DA =	6.63

Coefficient of Drag (C_D): Dimensionless number that expresses the efficiency of the shape. The lower the CD, the more "friendly" the shape is to the air.

	Baseline		Improvement	
Speed (mph)	Aero Horsepower	Drag Force (lbs)	Aero Horsepower	Drag Force (lbs)
0	0	0	0	0
50	7	50	6	42
100	53	200	45	170
150	180	449	153	382
200	426	798	362	678
250	831	1247	707	1060
300	1437	1796	1221	1526
350	2281	2444	1939	2078
400	3405	3192	2894	2714



Aero Horsepower: Amount of power required to move the object through the air. It takes 8 times the HP to go twice the speed.



Drag force: In order to double your speed, your drag force will increase by 4 times.

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

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

$$g1 : C_d \rho_{air} A_{car} \frac{V^2}{2} - 200 \le 0$$
$$g2 : 4 - C_d \rho_{air} A_{car} \frac{V^2}{2} \le 0$$
$$g3 : C_l \rho_{air} A_{car} \frac{V^2}{2} - 160 \le 0$$
$$g4 : C_d \rho_{air} A_{car} \frac{V^3}{2} - 5000 \le 0$$
$$g5 : 10^\circ - \theta \le 0$$
$$g6 : \theta - 35 \le 0$$

Main Body

-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℃, 1atm)

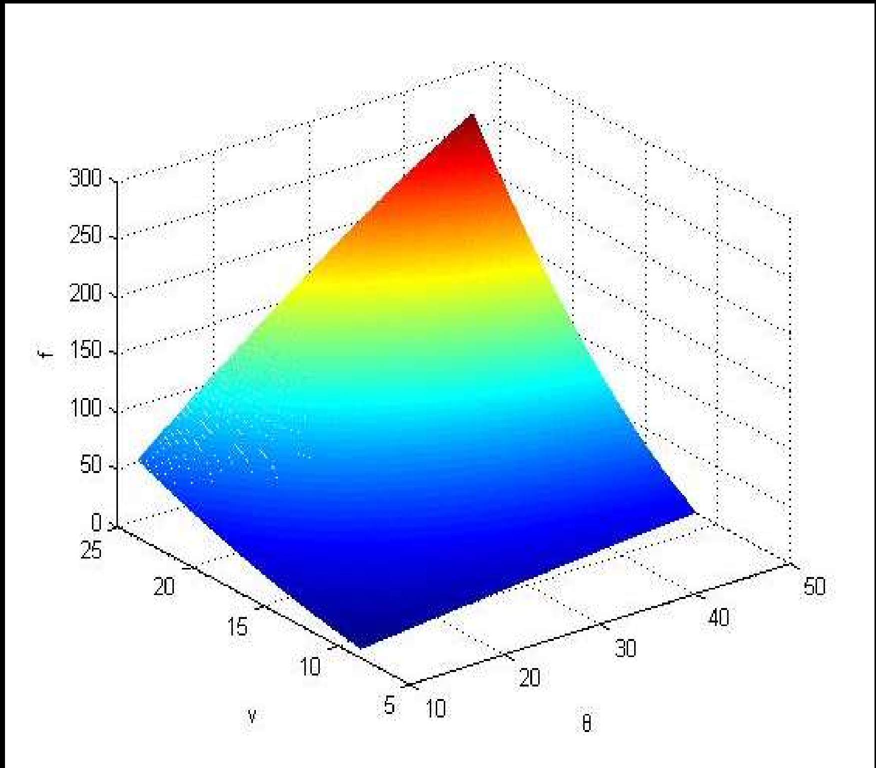
⑥ All other properties are used from Grandeur, Hyundai (window)

⑦ Analysis that car speed is btw 30km/h~85km/h and angle is btw10˚~40˚

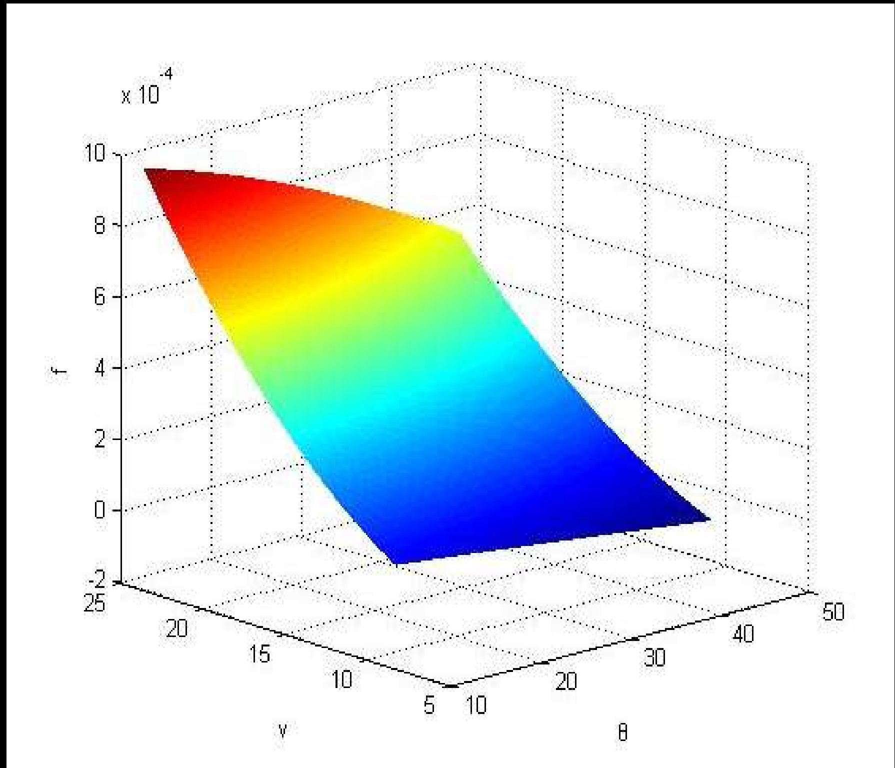
-Calculate as MATLAB & EXCEL

Graphical Method

[Drag Force]



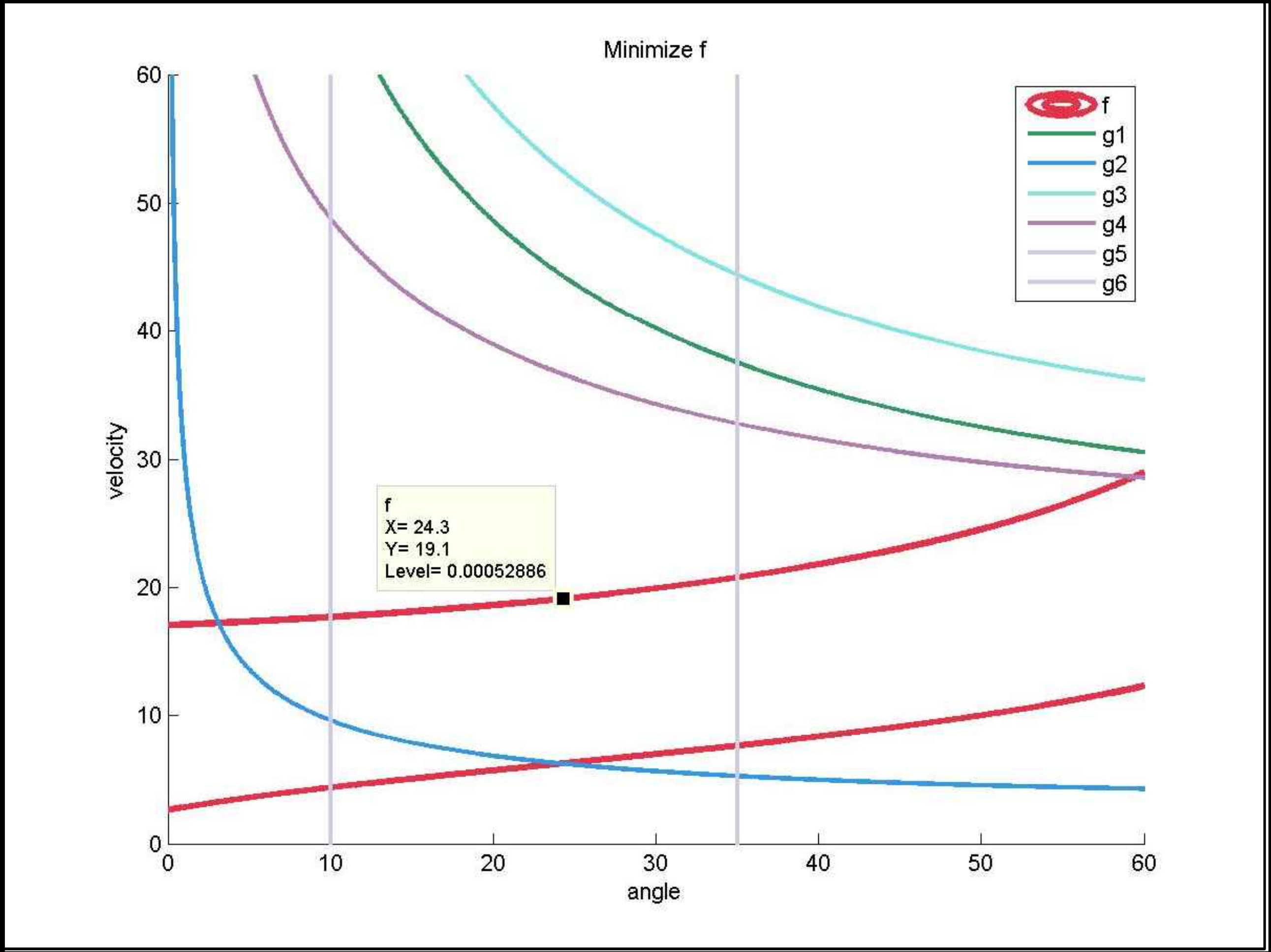
[Net Force]



Main Body

-Calculate as MATLAB & EXCEL

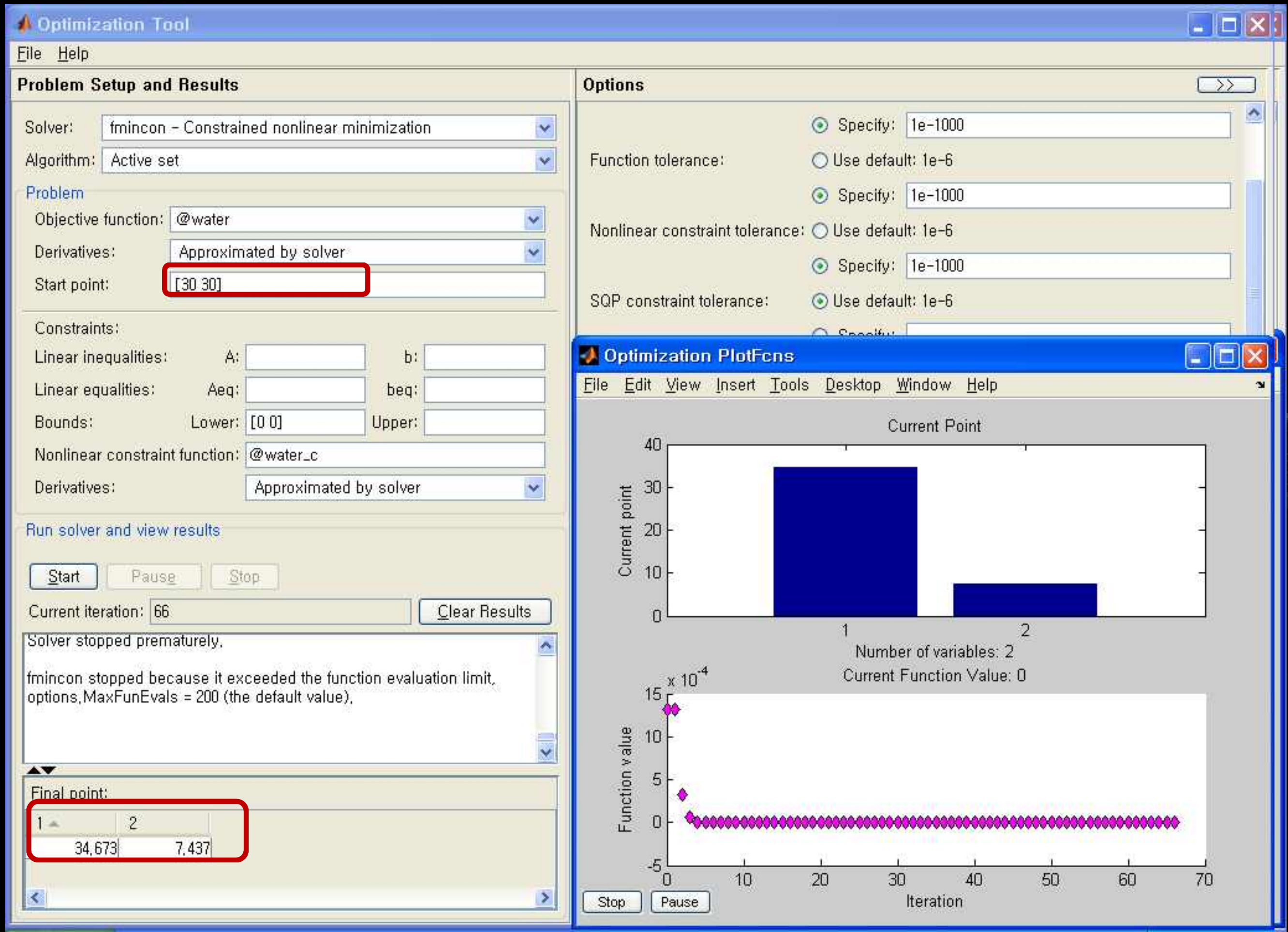
Graphical Method



Main Body

-Calculate as MATLAB & EXCEL

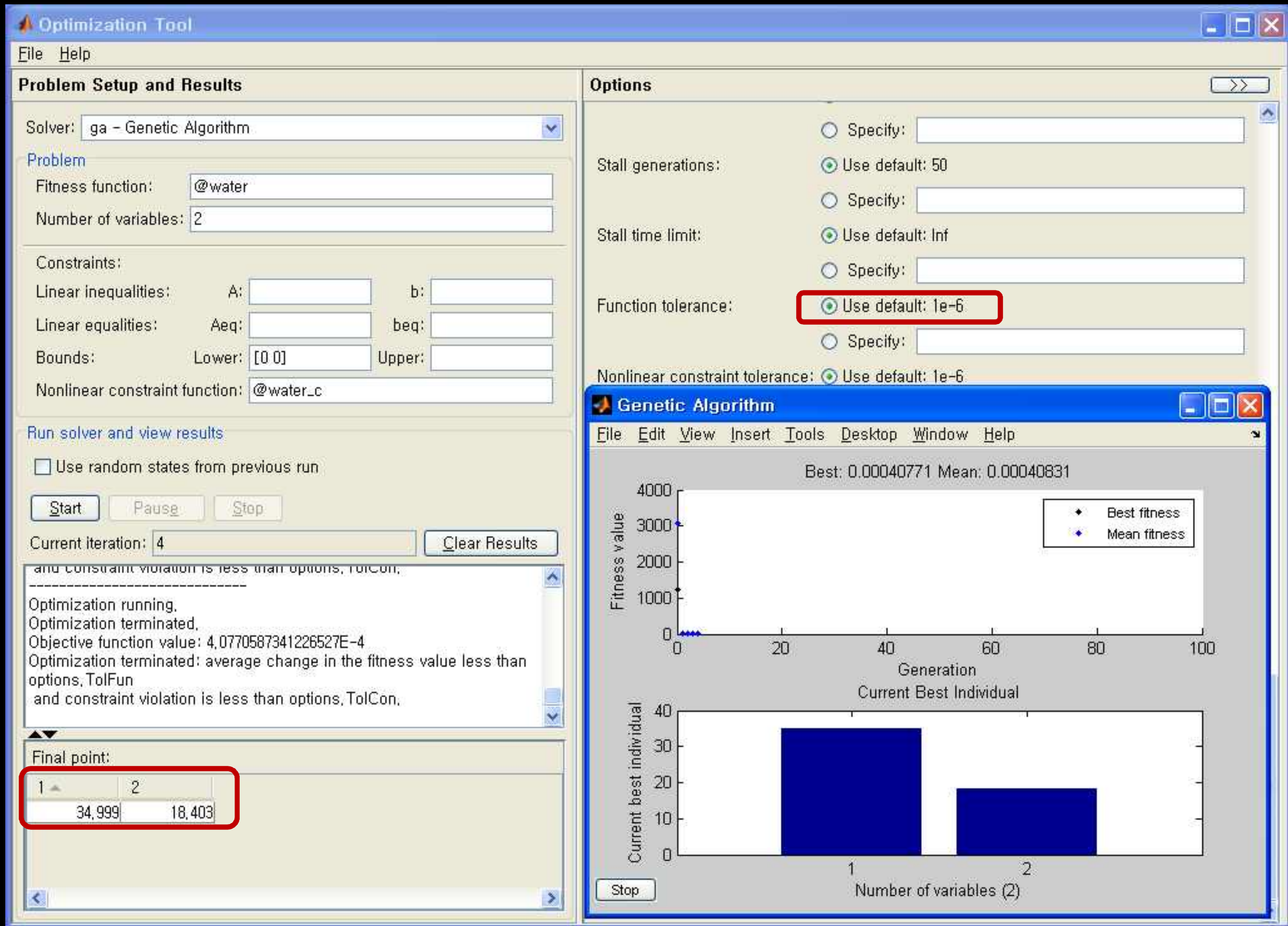
Fmincon



Main Body

-Calculate as MATLAB & EXCEL

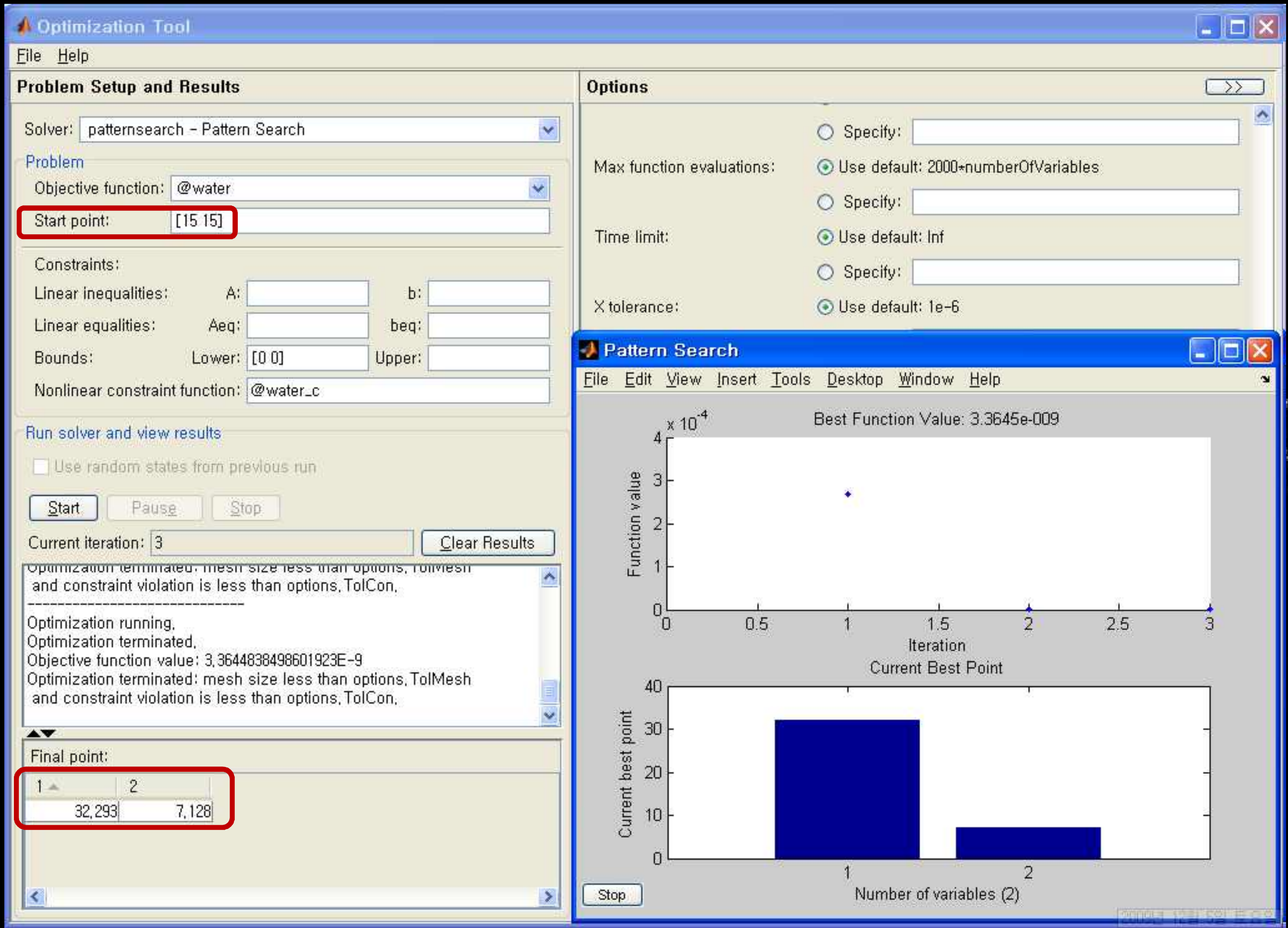
Genetic Algorithm



Main Body

-Calculate as MATLAB & EXCEL

Pattern Search



-Calculate as MATLAB & EXCEL

Excel Solver

	A	B	C	D	E	F	G	H	I
1							$g1: C_d \rho_{air} A_{car} \frac{V^2}{2} - 200 \le 0$		
2	각도변환	1.000.E+01		>>>>>>>	0.17453293	rad			
3		3.500.E+01		>>>>>>>	0.61086524	rad	$g2: 4 - C_d \rho_{air} A_{car} \frac{V^2}{2} \le 0$		
4	속도변환	1.080.E+02	km/h	<<<<<<<	3.000.E+01	m/s			
5		3.000.E+01	km/h	>>>>>>>	8.333.E+00	m/s	$g3: C_l \rho_{air} A_{car} \frac{V^2}{2} - 160 \le 0$		

시나리오 요약							
		현재 값:	1	2	3	4	5
변경 셀:							
a	\$H\$11	35.000001	1	35.000001	35.000001	35.000001	35.000001
v	\$H\$12	7.457240286	1.000001	1.291975241	9.560616784	7.457247743	7.457240286
결과 셀:							
	\$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

참고: 현재 값 열은 시나리오 요약 보고서가 작성될 때의 변경 셀 값을 나타냅니다. 각 시나리오의 변경 셀들은 회색으로 표시됩니다.

$$= \left(CA\rho\frac{\ }{2}\right)\cos\theta - \mu\left(mg\cos\theta + \left(CA\rho\frac{\ }{2}\right)\sin\theta\right) - mg\sin\theta$$

$$= \left(CA\rho\frac{V^2}{2}\right)(\cos\theta - \mu\sin\theta) - mg(\mu\cos\theta + \sin\theta)$$

	A	B	C	D	E	F	G	H	I
23									
24	물방울								
25	물방울지름	2.000.E-03							
26	물방울밀도	9.982.E+02							
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					10	-16.502126	-17.063735	-25	

Solver / 시나리오 요약 / fmincon / pattern / ga / Sheet2

Conclusion

Found OPIMUM ANGLE!!

[Graphical]

$$\theta = 24.3°$$

[Computational]

$$\theta = 34.5°$$

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