최적설계 프로젝트 2차 발표

보온병(의) 신

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  - Project Statement
  - Design Variables
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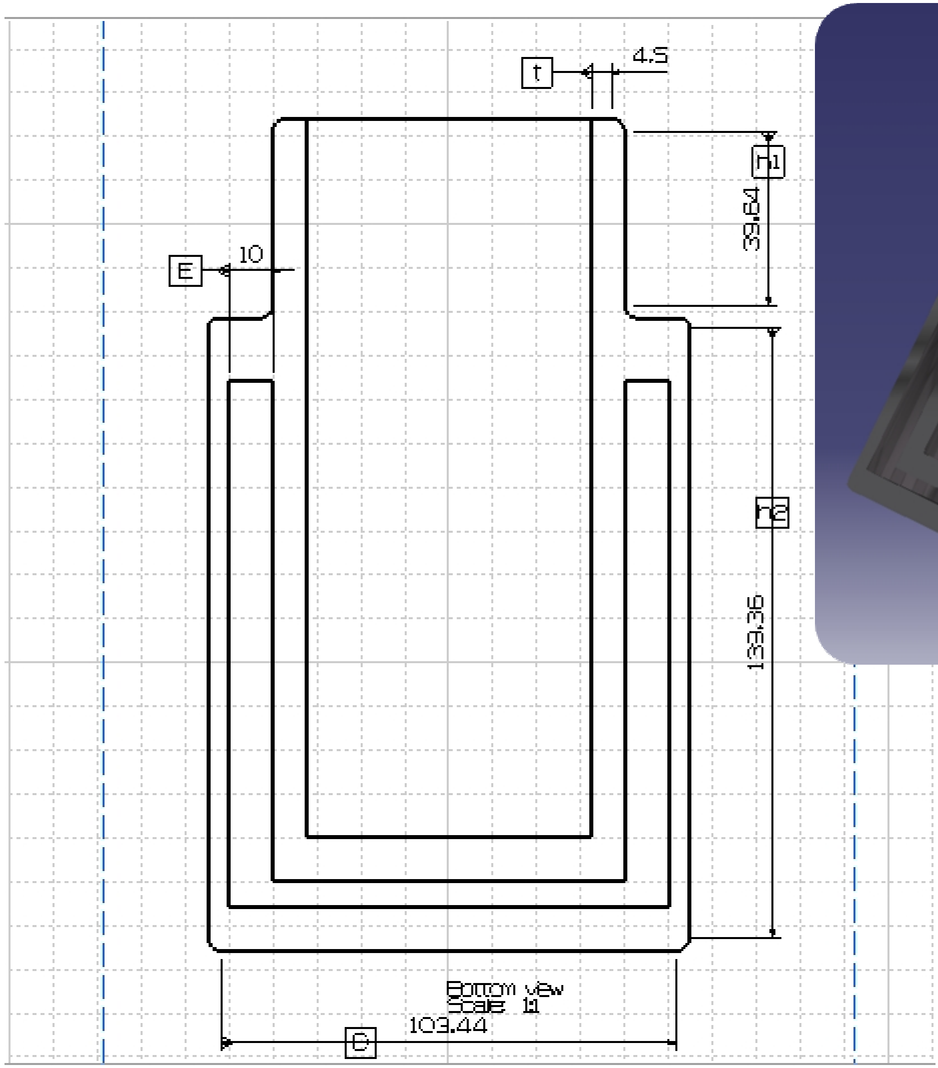
Step1. Project Statement

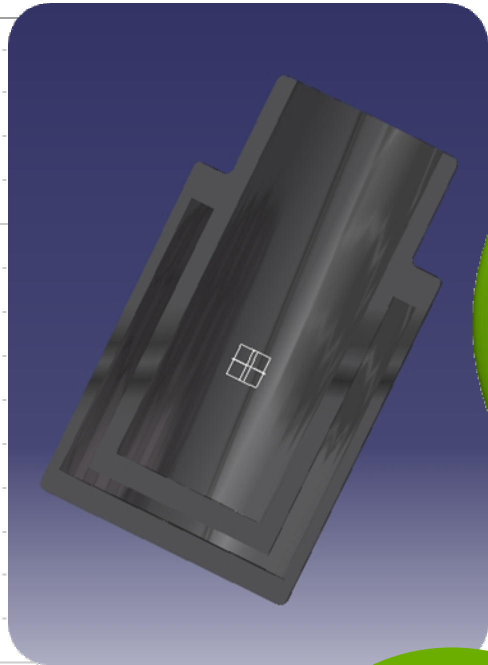
- 부피가 500mL인 보온병

- STS304의 비중 : $\rho = 8.00\ \text{g/cm}^3$
- 두께 0.3mm
- 탄성계수 : $E = 193\ \text{GPa}, \quad G = 86\ \text{GPa}$
- 열전도계수 : $K_{STS\,304} = 16.2\ \text{W/mK}$
- 항복강도 : $\sigma_Y = 215\ \text{MPa}$

Reference : Online Materials Information Resource (matweb.com)

Step2. Design Variables

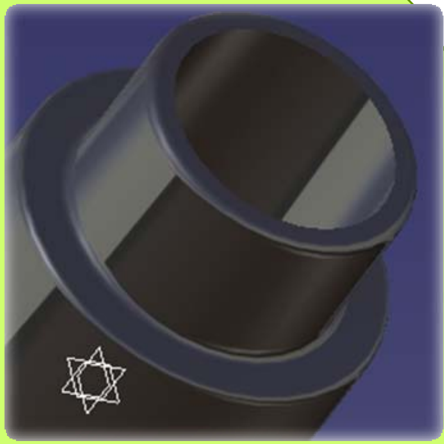




D
Diameter of the bottle

H
Height of the bottle

Step3. Theorems & Constraints



❖ Theorem 1

Heat conduction in cylinders,

$$\frac{1}{r}\frac{d}{dr}\left(kr\frac{dT}{dr}\right)=0$$

General solution of upper eqn. is

$$T(r)=C_1\ln r+C_2$$

Thus, the heat transfer rate is

$$Q'=-k(2\pi rL)\frac{\partial T}{\partial r}=\frac{2\pi kL(T_i-T_0)}{\ln(r_0/r_i)}=\frac{T_i-T_0}{\ln\left(r_0/r_i\right)/2\pi kL}$$

Step3. Theorems & Constraints

LOGO

- Constraint 1
- 보온병 접촉부분의 전도에 의한 에너지

$$\frac{T_i - T_0}{\dfrac{\ln \dfrac{D}{D-1}}{2\pi kt}} \le 1.5W$$

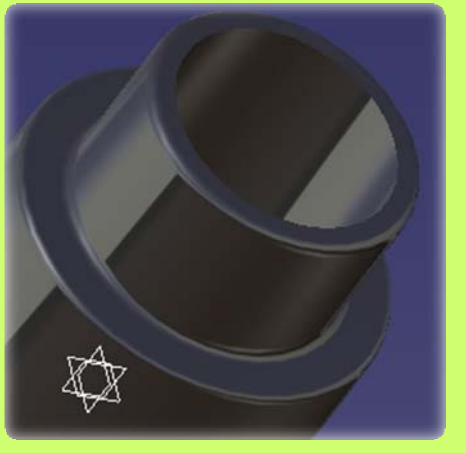
$$D \le 8.047326cm$$

Step3. Theorems & Constraints

- Theorem 2

  Heat transfer from finned surfaces

  Assume that the upper side of Thermos bottle is like a thin fin. And spread the rolled surface, as width is pi*D.



$$\frac{\theta}{\theta_0} = \frac{\cosh m(L-x)}{\cosh mL}$$

$$Q'_{fin} = -kA\frac{d\theta}{dx} = \sqrt{kAhP\theta_0}\tanh mL$$

Step3. Theorems & Constraints

❖ Constraint 2

$$\sqrt{k\pi(D-1)t \cdot h \cdot 2\{\pi(D-1)+t\}}(T_i - T_\infty)\tanh\sqrt{\frac{hP}{kA}}L \le 1.5W$$

$$mL \simeq \sqrt{\frac{2h}{kA_m}}L^{\frac{3}{2}}, A_m = t \cdot L$$

thus,

$$2.34502D^2 - 35.67129D + 123.67551 \le 0$$

$$5.347 \text{ cm} \le D \le 9.8658 \text{ cm}$$

Step3. Theorems & Constraints

LOGO

❖ Theorem 3

Strain Energy

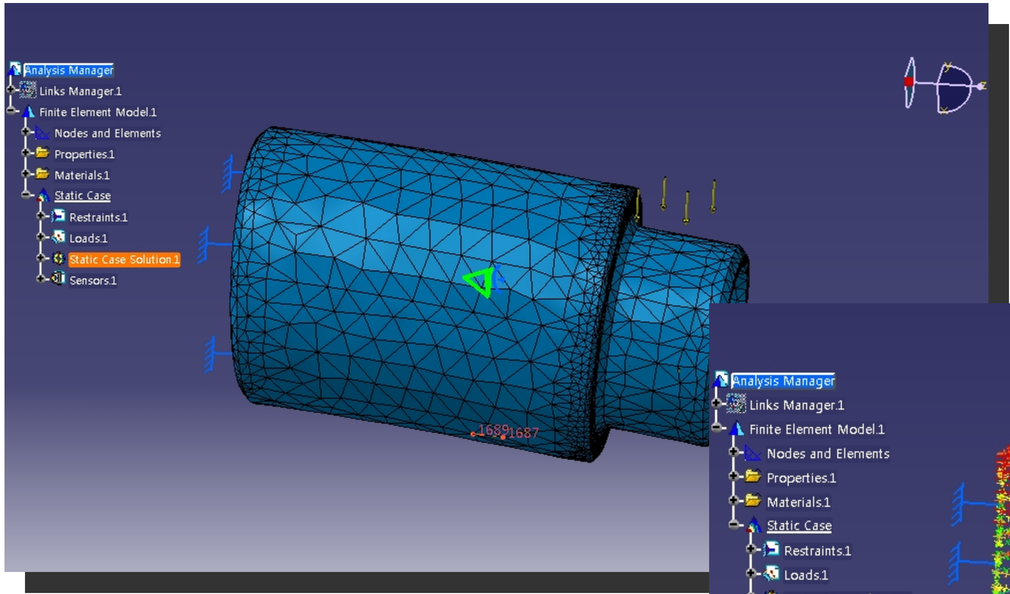
$$U_{\tau} = \int \frac{\tau_{xy}^{2}}{2G} dV = \frac{3P^{2}L}{5GA} \qquad U = mgh = \frac{3P^{2}L}{5GA}$$

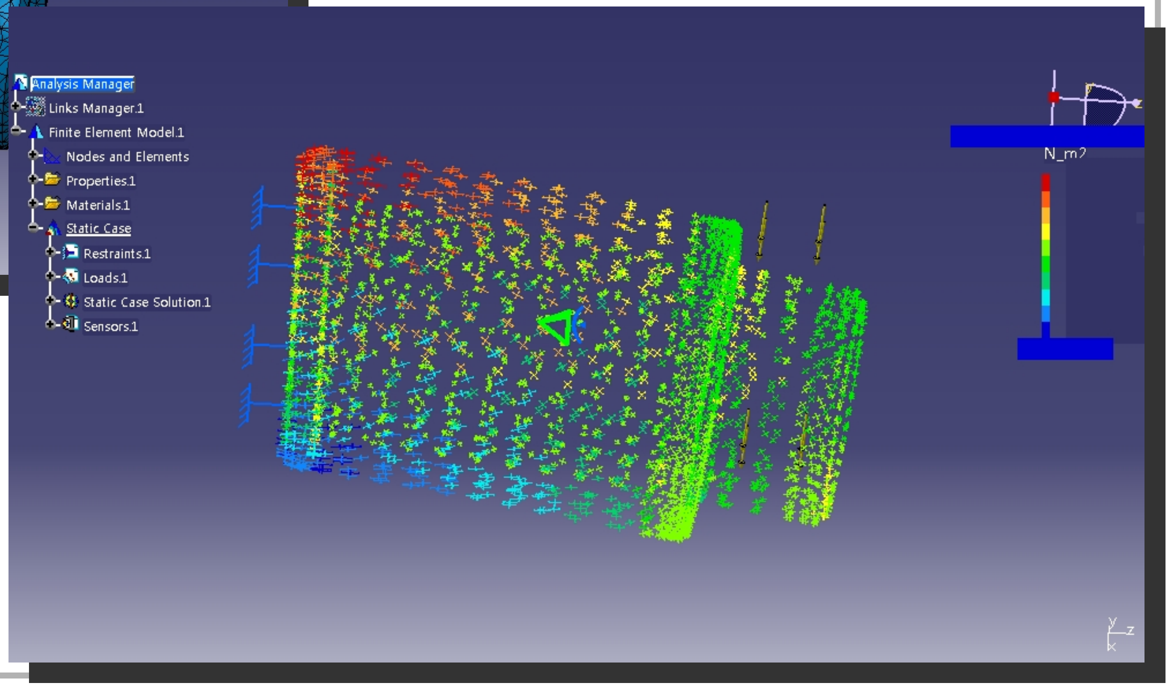
By the Potential Energy

$$\frac{\mathrm{D}^{2}}{\mathrm{H}} \leq 0.1899$$

Step3. Theorems & Constraints

❖ Strain(Deflection) simulation





Step3. Theorems & Constraints

LOGO

- Theorem 4

For Buckling

$$P_{cr} = \frac{\pi^2 EI}{L_e} = \frac{\pi^2 EI}{2L} = \frac{(\pi D)^3 Et}{32H} \qquad P_{cr} > P$$

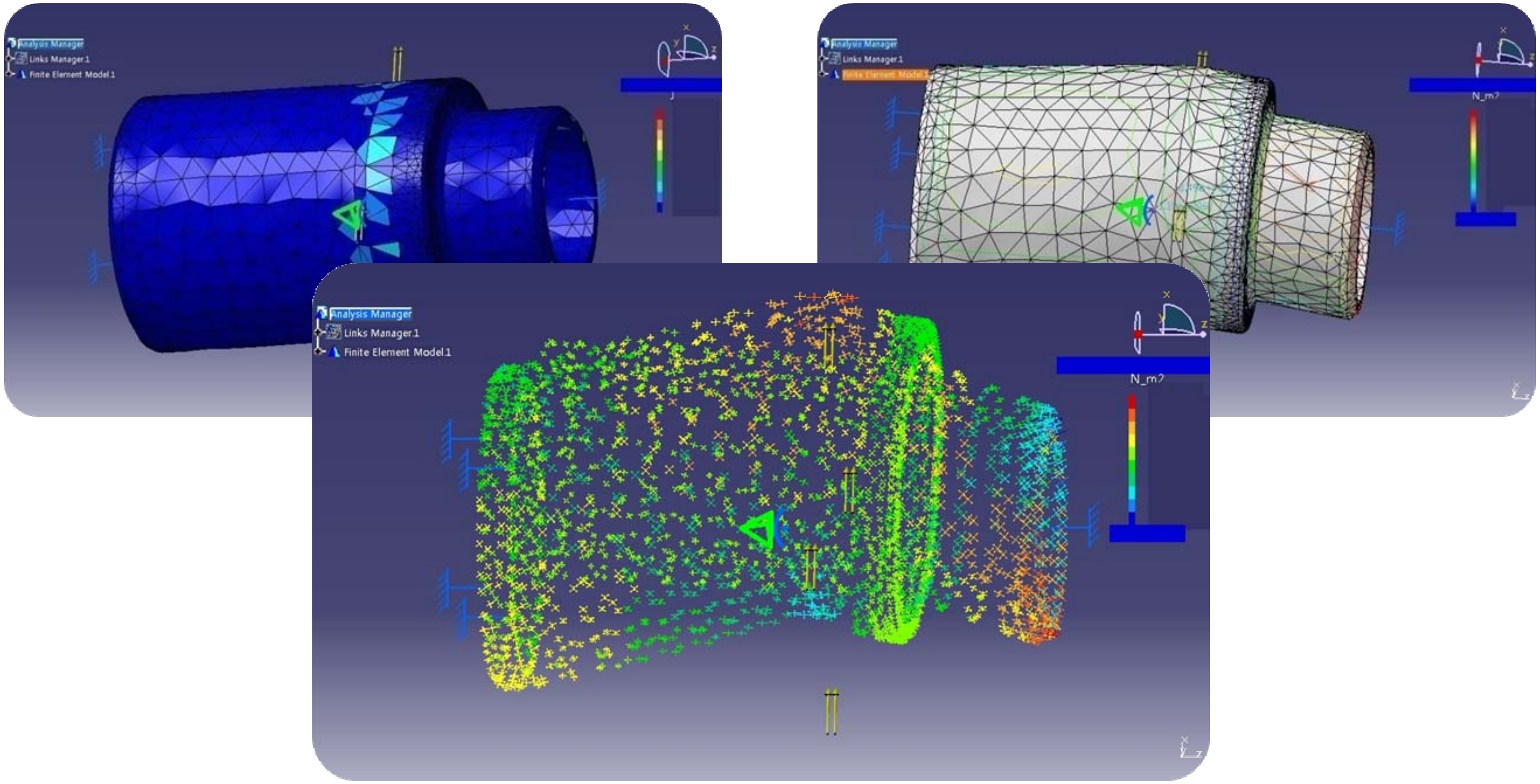
$$(\because I \approx \frac{\pi d^3}{16} t)$$

: P=60 kN ;

Reference : Mechanics of Materials

Step3. Theorems & Constraints

❖ Buckling Test



Step3. Theorems & Constraints

LOGO

❖ Constraint 3

$$\frac{D^2}{H} \leq 0.1899$$

❖ Constraint 4

$$D > \frac{\left\{\frac{P \times (32H)}{Et}\right\}^{\frac{1}{3}}}{\pi}$$

Constraint 5

$$\frac{\pi}{4}(D-1)^2 \times (H-0.5) = 500$$

Step4. Cost Function

- 최대한 가볍도록 설계
- 최소부피가 최소비용

$$f = \frac{\pi}{4}D^2 t + \pi D \frac{3}{4} H t + \{\frac{\pi}{4} D^2 - \frac{\pi}{4}(D - 0.005 \times 2)^2\} t + \frac{\pi}{4}(D - 0.01)^2 t + (H - 0.005)\pi(D - 0.01)t$$

- t는 병의 두께로 주어진 값(0.3 mm)

The solution of the project

❖Excel Solver

cost function	5.13075E-05	m^3
	51.30745447	cm^3
	406.8681139	g

D	H	
0.062883543	0.232508038	m
6.288354349	23.25080382	cm

Table for Graph

H	g1	g2	g3	g4	g5	f
0.1655	0.072979984	0.05347	0.08047326	0.056147	0.052017	0.106731
0.166	0.072882113	0.05347	0.08047326	0.056203	0.052332	0.10645
0.1665	0.072784696	0.05347	0.08047326	0.056259	0.052647	0.10617
0.167	0.072687732	0.05347	0.08047326	0.056316	0.052964	0.105892
0.1675	0.072591215	0.05347	0.08047326	0.056372	0.053282	0.105615
0.168	0.072495142	0.05347	0.08047326	0.056428	0.0536	0.10534
0.1685	0.072399511	0.05347	0.08047326	0.056484	0.05392	0.105066
0.169	0.072304317	0.05347	0.08047326	0.05654	0.05424	0.104794
0.1695	0.072209557	0.05347	0.08047326	0.056595	0.054562	0.104523
0.17	0.072115229	0.05347	0.08047326	0.056651	0.054884	0.104254
0.1705	0.072021328	0.05347	0.08047326	0.056706	0.055207	0.103986
0.171	0.071927852	0.05347	0.08047326	0.056762	0.055532	0.10372
0.1715	0.071834797	0.05347	0.08047326	0.056817	0.055857	0.103455
0.172	0.071742161	0.05347	0.08047326	0.056872	0.056183	0.103192

D	H	
0.062884	0.232508	m
6.288354	23.2508	cm

constraints

g1		-2.8E-07	lume=500m
g2	D	<=	0.080473
g3	0.05347	<=D<=	0.098658
g4	buckling	D>	$\frac{\left\{\frac{P\times(32H)}{E}\right\}^{\frac{1}{3}}}{\pi}$
g5	Energy	$\frac{D^2}{H} \leq 0.1899$	

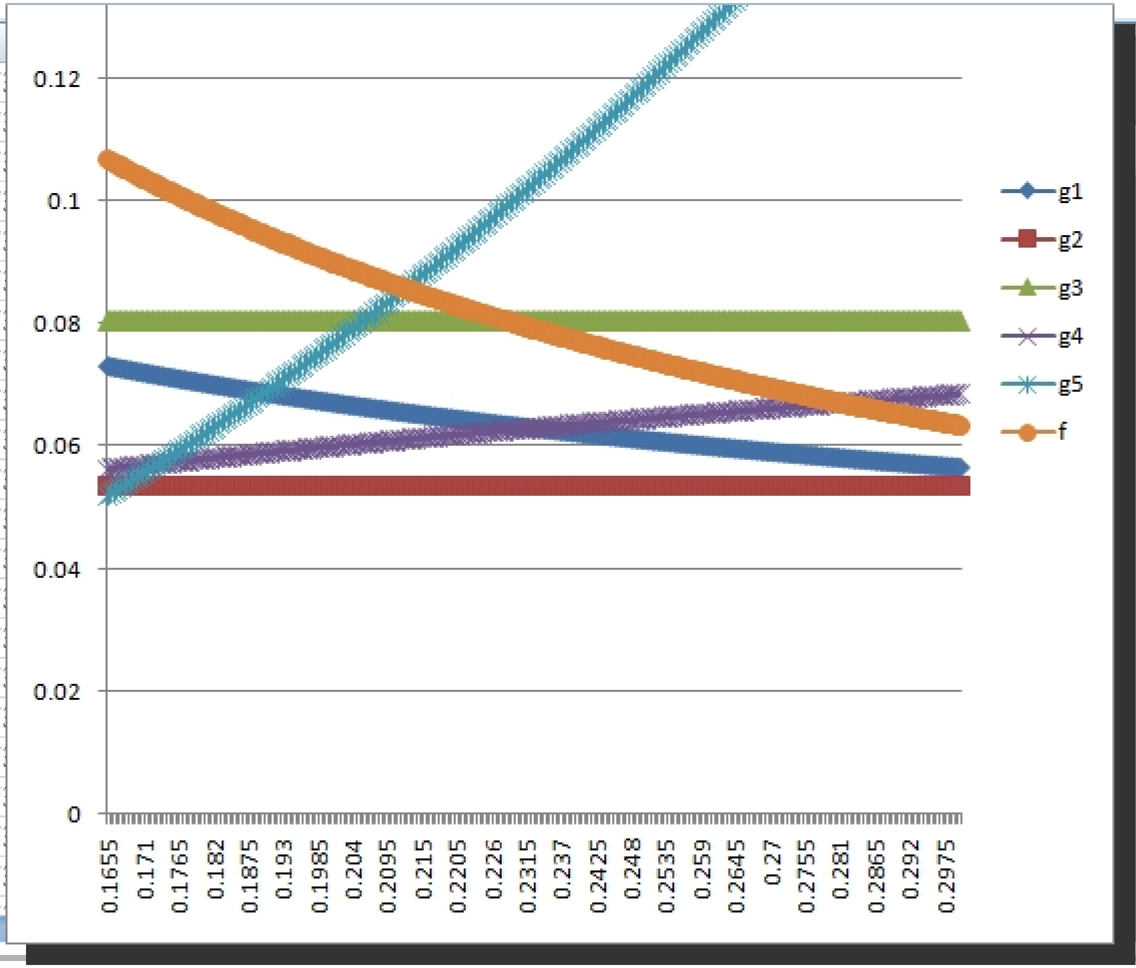
Sheet1 Sheet2 Sheet3

The solution of the project

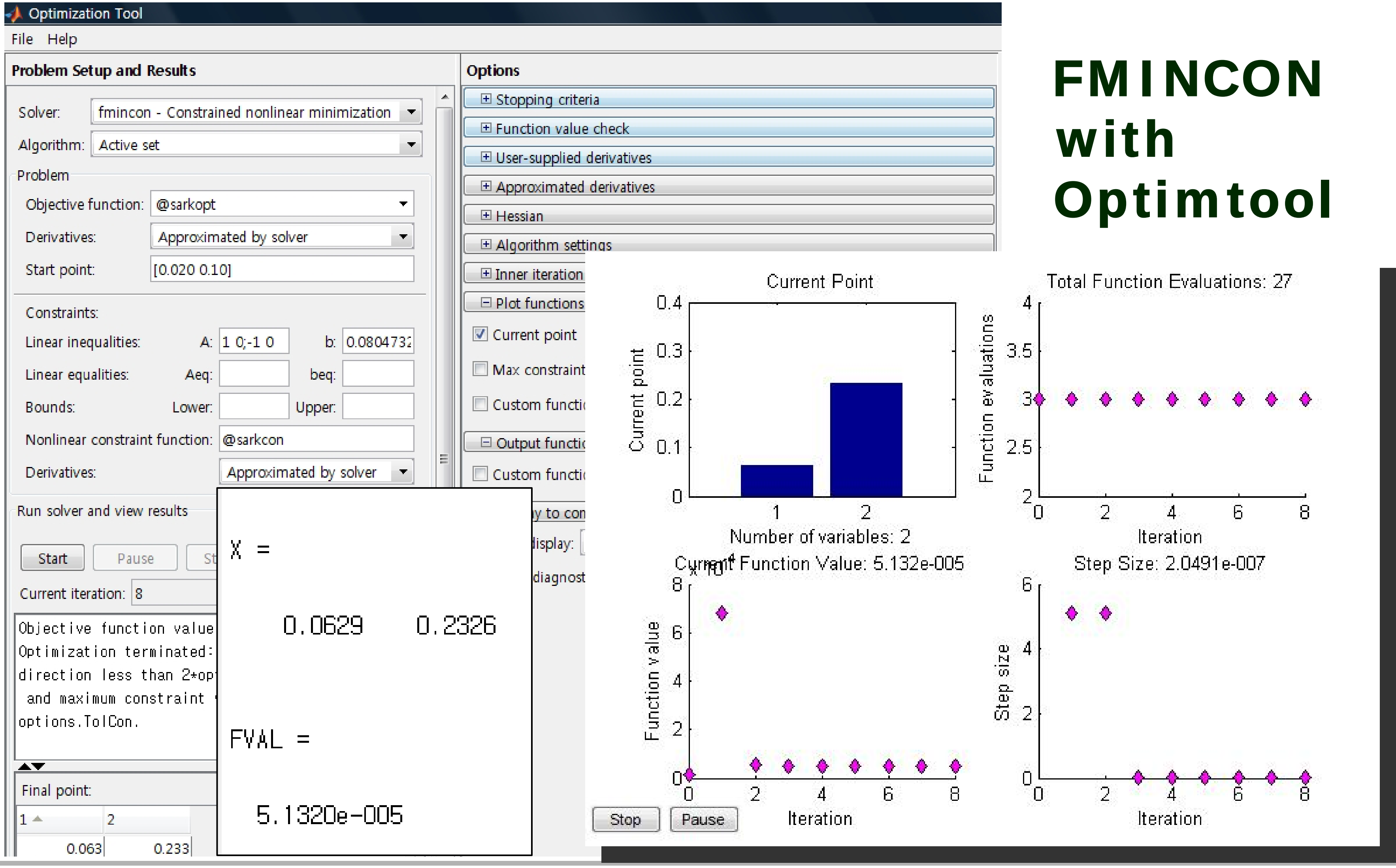
❖Excel Solver

	A	B	C	D
21	0.1715	0.071834797	0.05347	0.08047
22	0.172	0.071742161	0.05347	0.08047
23	0.1725	0.07164994	0.05347	0.08047
24	0.173	0.07155813	0.05347	0.08047
25	0.1735	0.07146673	0.05347	0.08047
26	0.174	0.071375735	0.05347	0.08047
27	0.1745	0.071285144	0.05347	0.08047
28	0.175	0.071194952	0.05347	0.08047
29	0.1755	0.071105158	0.05347	0.08047
30	0.176	0.071015757	0.05347	0.08047
31	0.1765	0.070926748	0.05347	0.08047
32	0.177	0.070838127	0.05347	0.08047
33	0.1775	0.070749892	0.05347	0.08047
34	0.178	0.07066204	0.05347	0.08047
35	0.1785	0.070574567	0.05347	0.08047
36	0.179	0.070487472	0.05347	0.08047
37	0.1795	0.070400752	0.05347	0.08047
38	0.18	0.070314404	0.05347	0.08047
39	0.1805	0.070228424	0.05347	0.08047
40	0.181	0.070142812	0.05347	0.08047
41	0.1815	0.070057563	0.05347	0.08047

Sheet1 Sheet2 Sheet3

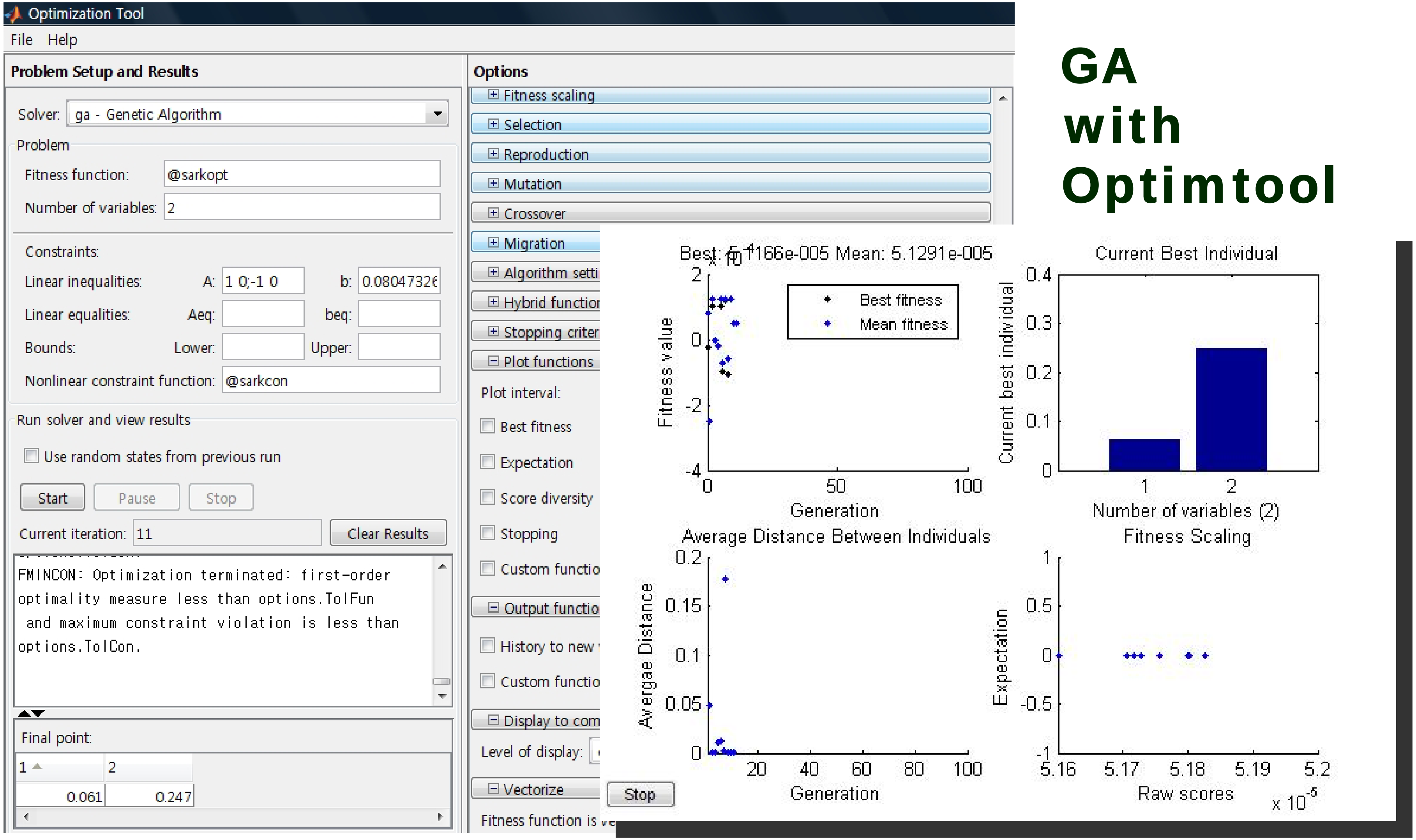


The solution of the project



FMINCON with Optimtool

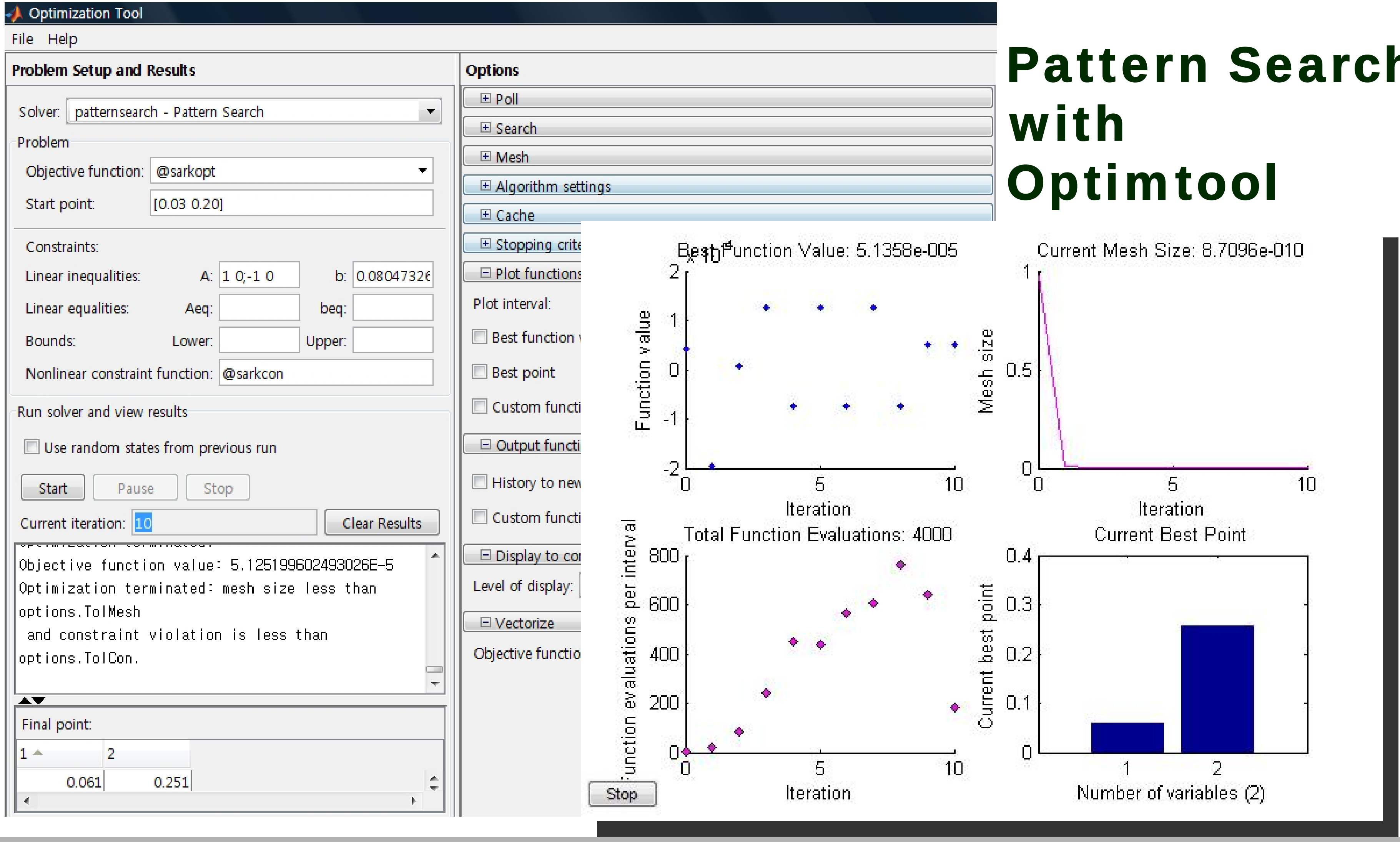
The solution of the project



GA with Optimtool

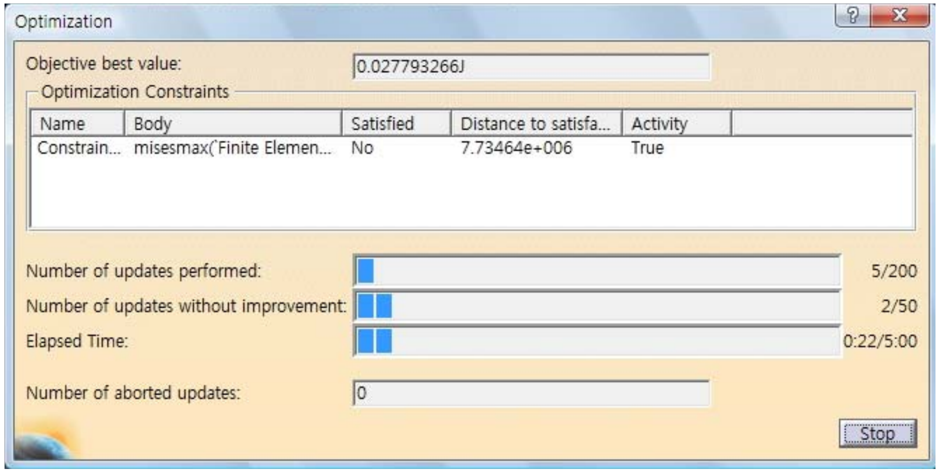
The solution of the project

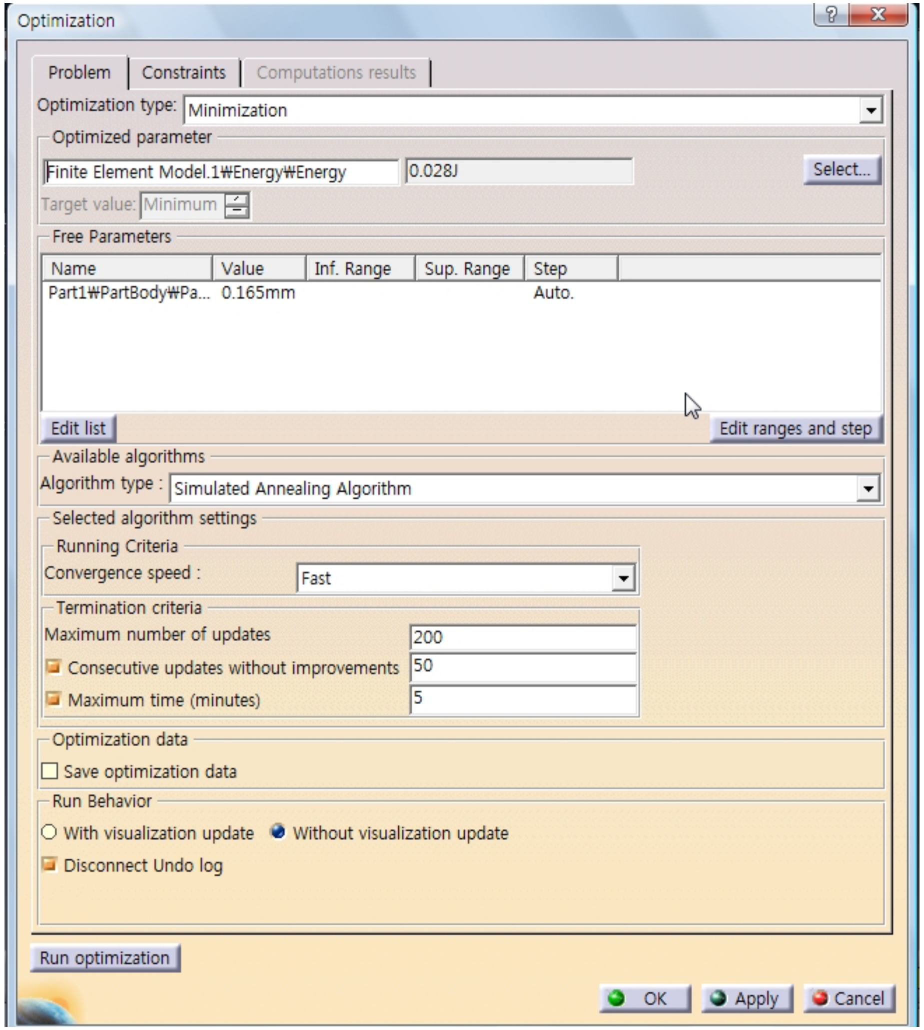
Pattern Search with Optimtool



The solution of the project

❖ CATIA Optimization

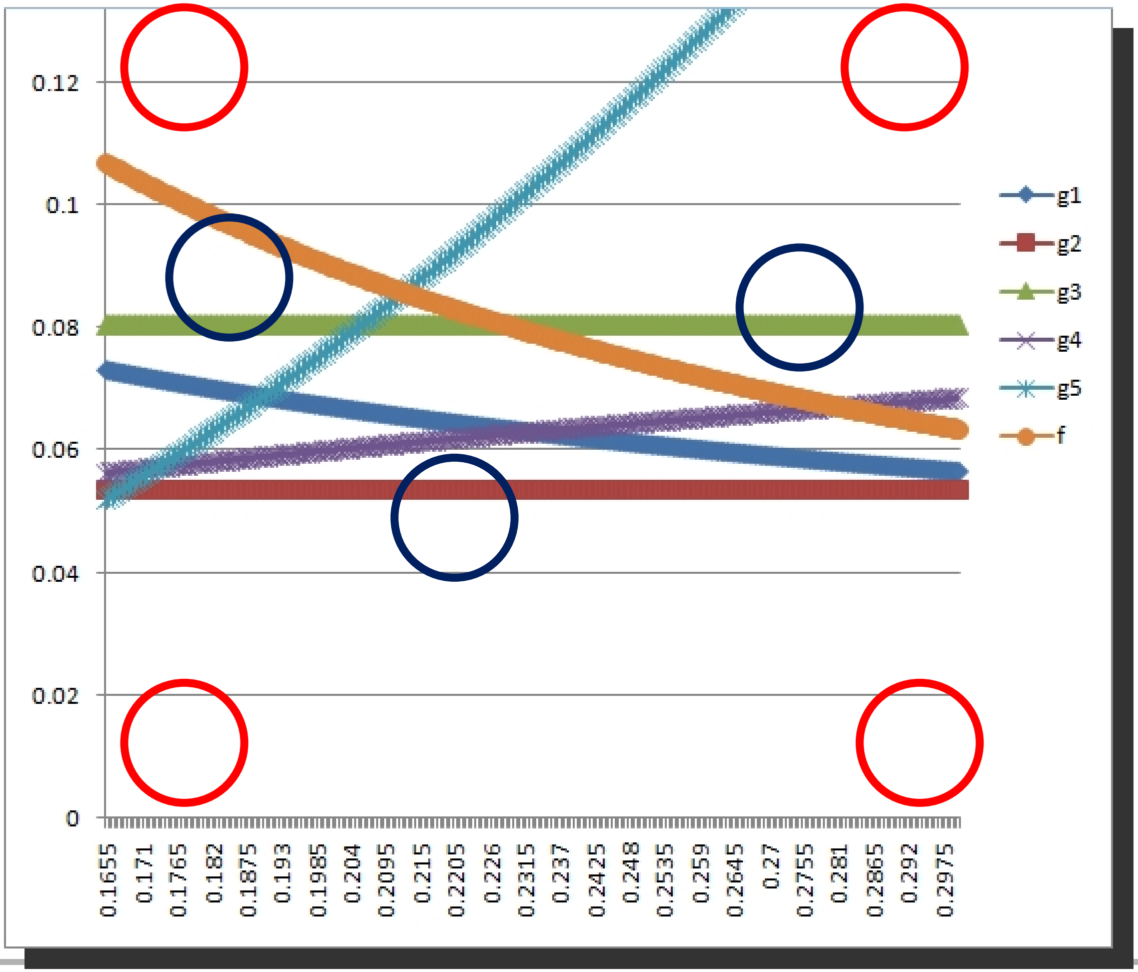




by Simulated Annealing
>>>couldn't find<<<

Discussion #1

❖ About the Initial Values



Discussion #1

❖ About the Initial Values

Initial Values	Solver	Fmincon	PS		GA
0.1 0.01	6.28898 23.2579	0.063 0.233	0.081 0.000		0.062 0.241
0.1 1	6.28898 23.2579	0.059 0.274	0.060 0.259		0.061 0.251
0.001 0.01	6.28898 23.2579	0.053 0.342	0.052 0.000		0.059 0.273
0.001 1	6.28898 23.2579	0.053 0.342	0.059 0.270		0.063 0.232
0.09 0.185	6.28898 23.2579	0.063 0.234	0.052 0.000		
0.06 0.22	6.28898 23.2579	0.063 0.233	0.061 0.251		
0.08 0.28	6.28898 23.2579	0.062 0.242	0.056 0.308		

Discussion #2

❖ Old Solution(1st) : D=5.39cm, H=27.65cm

>>Optimum Sol.(2nd) : D=6.288cm, H=23.25cm

Zojirushi Thermos bottle

D=7cm, H=23cm

But!!

Weight of Thermos

cost function	5.13075E-05	m^3
	51.30745447	cm^3
	406.8681139	g

Zojirushi 280g

Discussion #2

❖ STS304 와 STS304CU

Physical Properties	Metric
Density	8.00 g/cc

Mechanical Properties	Metric
Hardness, Brinell	123
Hardness, Knoop	138
Hardness, Rockwell B	70.0
Hardness, Vickers	129
Tensile Strength, Ultimate	505 MPa
Tensile Strength, Yield	215 MPa
Elongation at Break	70.0 %
Modulus of Elasticity	193 - 200 GPa
Poissons Ratio	0.290
Charpy Impact	325 J
Shear Modulus	86.0 GPa

Mechanical Properties	Metric
Hardness, Rockwell B	85.0
Tensile Strength, Ultimate	620 MPa
Tensile Strength, Yield	330 MPa
Modulus of Elasticity	193 - 200 GPa

505 MPa / 215 MPa < 620 MPa / 330 MPa

❖ Thickness of Thermos

❖ 감사합니다.