자동차용 LPG용기 설계

Final project

Optimus Prime

2004007520 민병웅

2004007757 이호택

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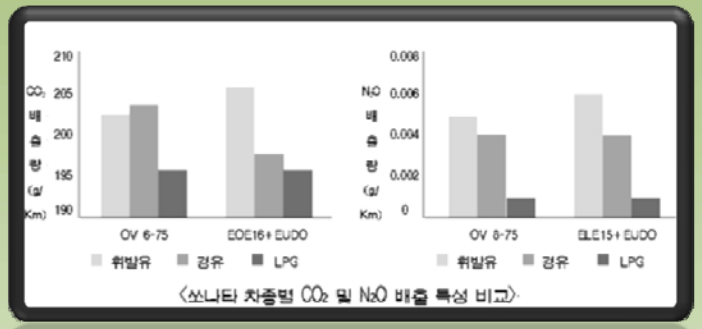
Introduction

“저탄소 녹색성장”



〈쏘나타 차종별 CO_2 및 N_2O 배출 특성 비교〉

*문제점 : **무거운 LPG 가스통**

차 종 : DAMAS(다마스)
총용량 : 48ℓ
업체명 : GM대우자동차

차 종 : LABO
제품 SIZE : 3.2t×ø345×602
총용량 : 49ℓ
업체명 : GM대우자동차

<출처> ttp://www.lpgtank.com/

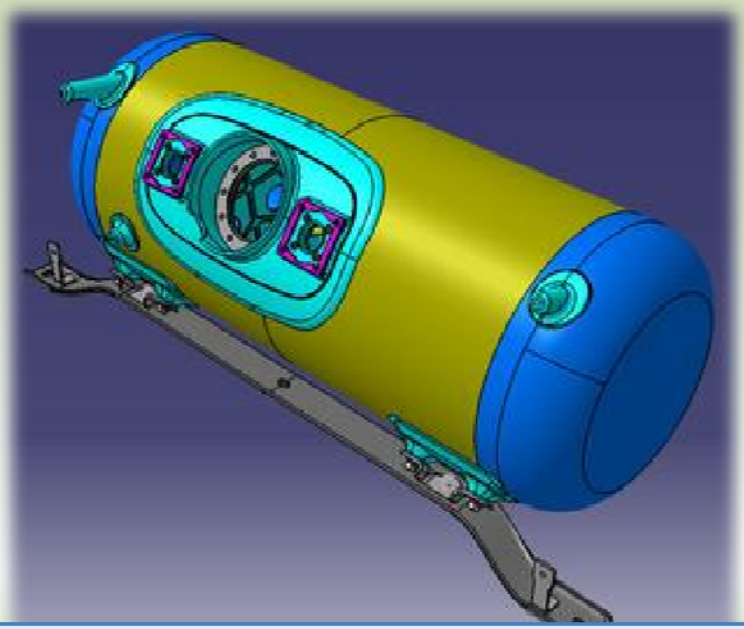
Problem Formulation Process

- *Step1 : Problem/Project Statement*
  - 차량에 들어가는 LPG가스통을 설계 함에 있어 KS 규격 (http://www.standard.go.kr KS B ISO 20826, KS D 3533) 을 만족하면서 용기의 경량화를 추구한다.
  - 비용을 최소화 하는 반지름과 두께의 값을 구한다.

※Assume

*용기의 모양

*반지름 R >> 두께 t



Closed-end, thin walled cylindrical pressure vessel

Problem Formulation Process

Step2 : Data and Information Collection

용기의 내압 : $P_{\text{int}} = 3MPa$ ※$S.F = 2$

길이 : $l = 0.8m$

$$\sigma_c = \frac{PR}{t}$$ (Circumferential stress)

$$\varepsilon_c = \frac{PR(2-v)}{2Et}$$ (Circumferential strain)

$$\frac{V}{A} = \frac{F_{\max}}{2\pi Rt} \le \tau_a \quad (F_{\max} = \frac{mv}{\Delta t})$$ (Shear stress by shock power)

※충격 테스트 조건 : (1t , 10(m/s) , △t=0.02s)

<출처>병진재료역학 5.7 압력용기

Problem Formulation Process

(Step2 : Data and Information Collection)

- 가스통의 재료는 **탄소강**판 / 물성치

$\rho = 7850 kg/m^3 (\text{mass density})$

$E = 210 GPa (\text{Young's moduluous})$

$\upsilon = 0.3 (\text{Poisson's ratio})$

$\sigma_a = 210 MPa (axial\ stress)$

$\tau_a = 168 MPa (shear\ stress)$

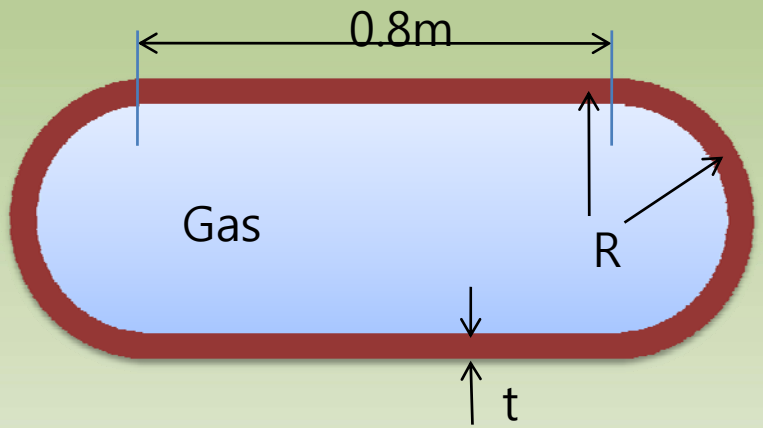
KS B 6733 압력용기의 재료에 대한 규격 제8조 3항.
재료의 허용전단응력은
허용인장응력의 80%를 계산에 적용하여야 한다.

<출처>http://www.matweb.com

Carbon steel

Problem Formulation Process

- *Step3 : Design variables*



- *Step4 : Objective function - minimize*

$$mass(R,t) = 7850 \cdot 2\pi Rt(0.8 + 2R)$$

무게 경량화!

- **Step5 : Modified -Constraints**

$$g1 = \frac{F_{\max}}{2\pi\tau_a} - Rt \le 0$$

충격력에 의한 전단 허용 응력

$$g2 = \frac{PR}{\sigma_a} - t \le 0$$

탄소강판의 허용 응력

$$g3 = \frac{PR(2-v)}{2E\varepsilon_c} - t \le 0$$

변형률 조건

$$g4 = 0.049 - \frac{4}{3}\pi R^3 - \pi R^2 L \le 0$$

$$-> 0.12686 - R \le 0$$

용기의 체적

Solution & Comparison 1 (**2** variables)

Excel(Solver)-GRG

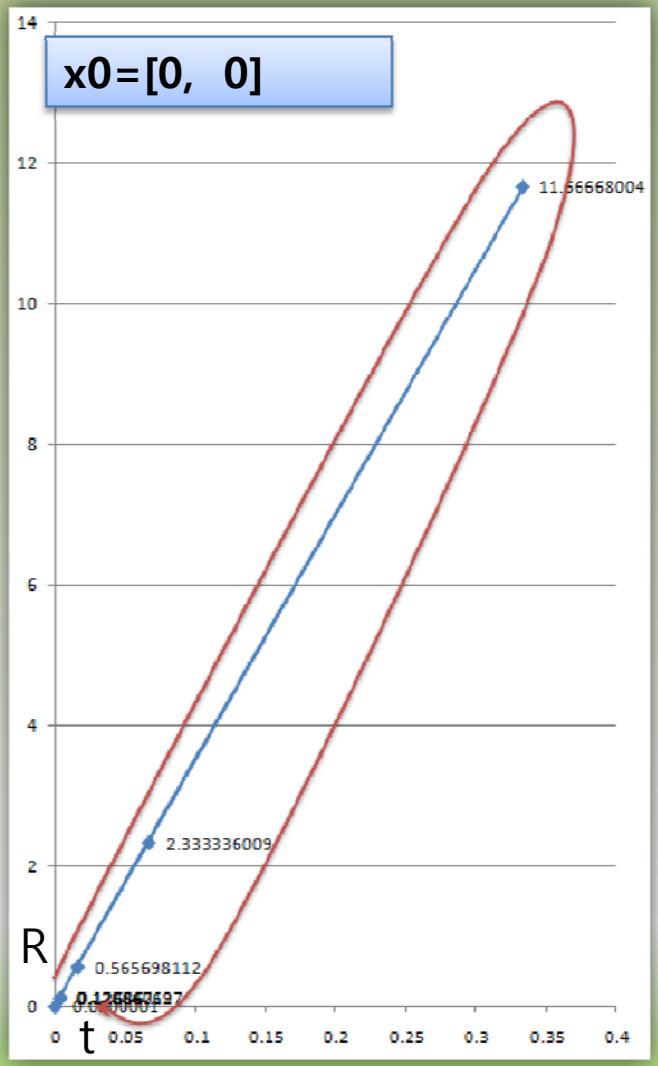
	해찾기	
F	24.62274317	24.61816
t	0.003734539	0.003734
R	0.12686	0.12680
tau	-8.81706E-08	
sigc	-0.000109967	
ec	-0.000653653	
R	0	

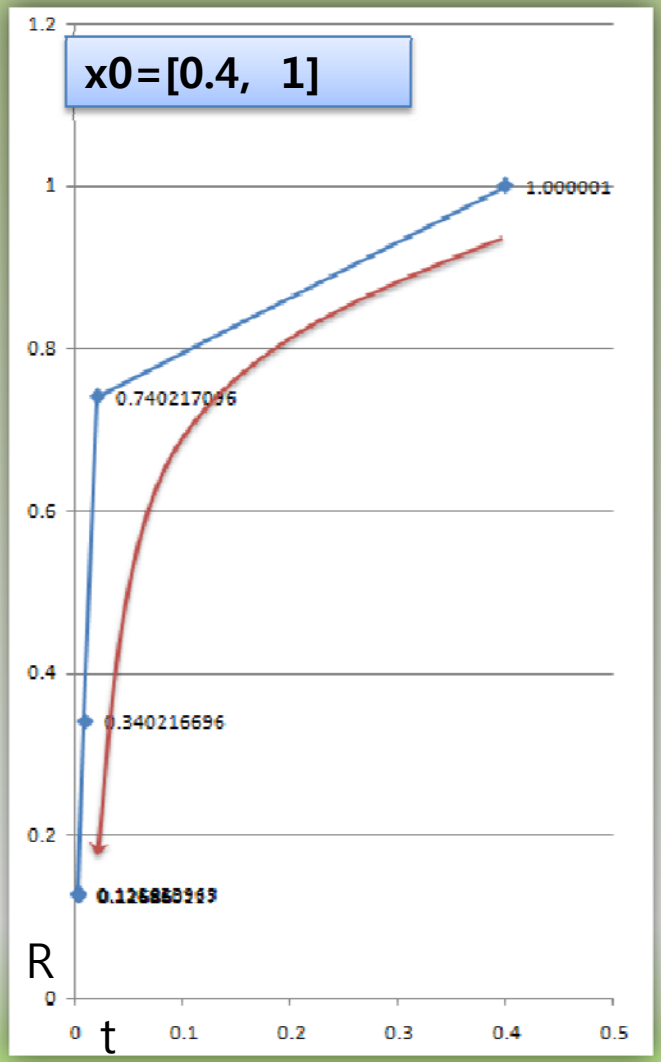
R = 0.12686(m)

t = 0.0037(m)

Mass=24.6230kg

*초기값에 상관없이
최적 값에 수렴

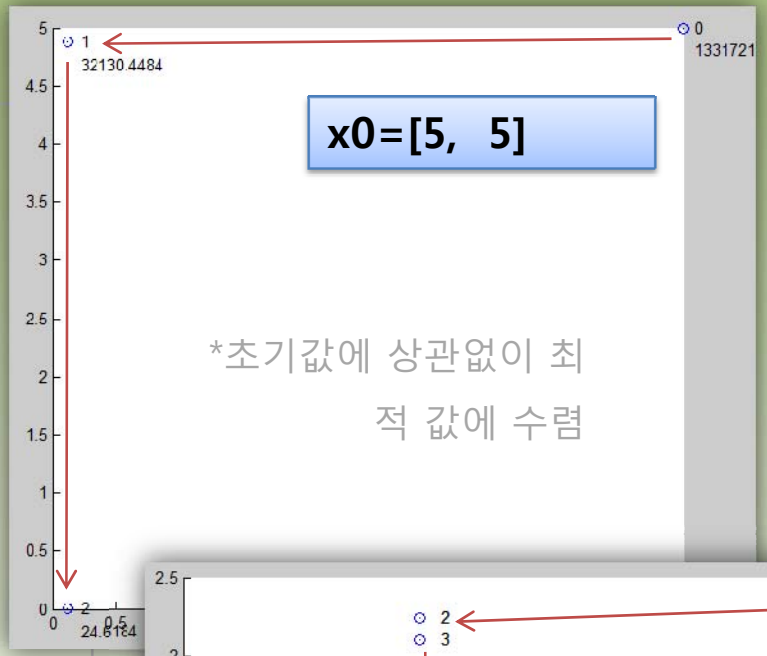




Solution & Comparison 1 (2 variables)

Matlab - fmincon(SQP-activeset)

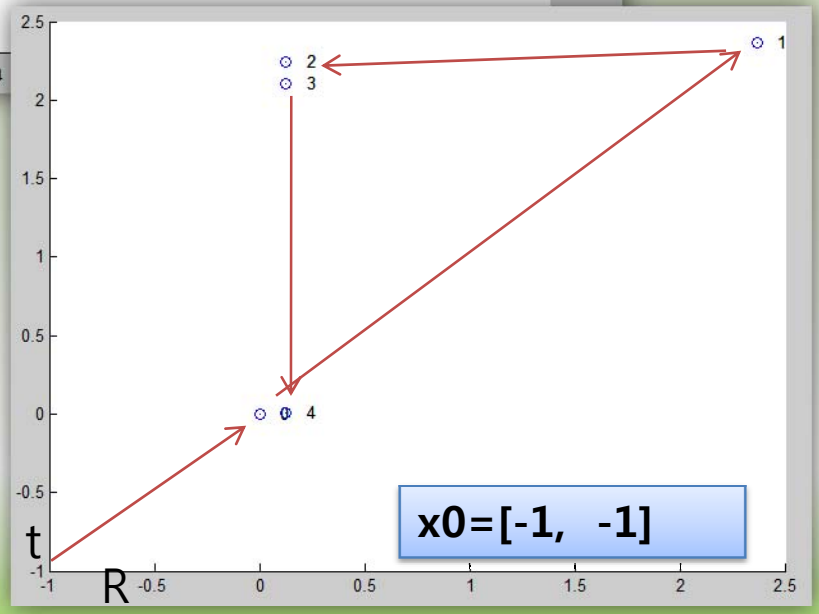
```
-------outfun.m--------추가 ------
function stop = outfun(x,optimValues,state)
   stop = false;
     switch state
       case 'init'
          hold on
       case 'iter'
         plot(x(1),x(2),'o-');
         text(x(1)+0.1,x(2),num2str(optimValues.iteration));
         text(x(1)+0.1,x(2)-0.2,num2str(optimValues.fval));
       case 'done'
         hold off
       otherwise
   end
end


lb=[0.12686 0];
x0=[5 5];
options = optimset;
options = optimset(options,'Display', '
options = optimset(options,'PlotFcns',
options = optimset(options,'Algorithm
options = optimset(options,'GradCons
options = optimset(options,'GradObj', 'off');
[x,fval,exitflag] = fmincon(@fun,x0,[],[],[],[],lb,[],@confun,options)
```



R = 0.1269(m)

t = 0.0037(m)

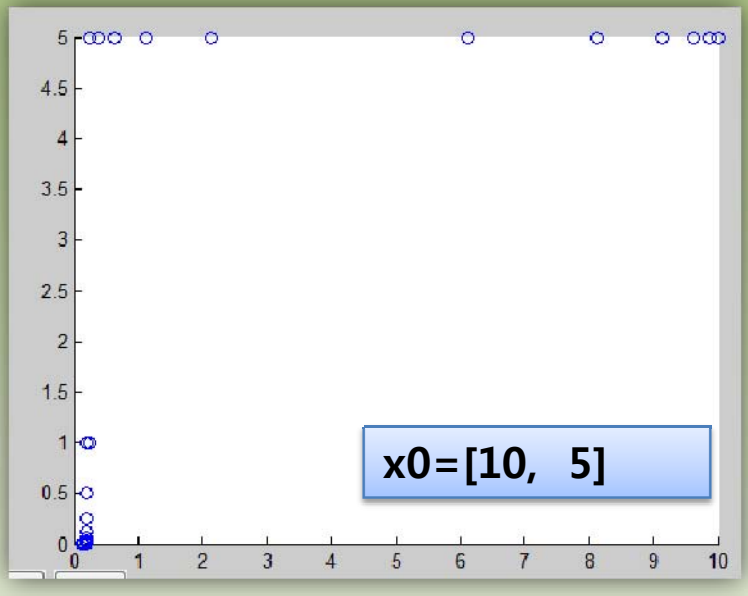
Mass=24.6076kg



Solution & Comparison 1 (**2** variables)

Matlab - **Pattern search**

```
--------------outfun.m-----------
function stop = outfun(x,optimValues)
   stop = false;
   hold on
   plot(x.x(1),x.x(2),'o')
   hold off
end

>>lb=[0.12686 0];
x0=[10 5];
options = psoptimset;
options = psoptimset(options,'PlotFcns', { @outfun });
[x,fval,exitflag,output] =
patternsearch(@fun,x0,[],[],[],[],lb,[],@confun,options)
```

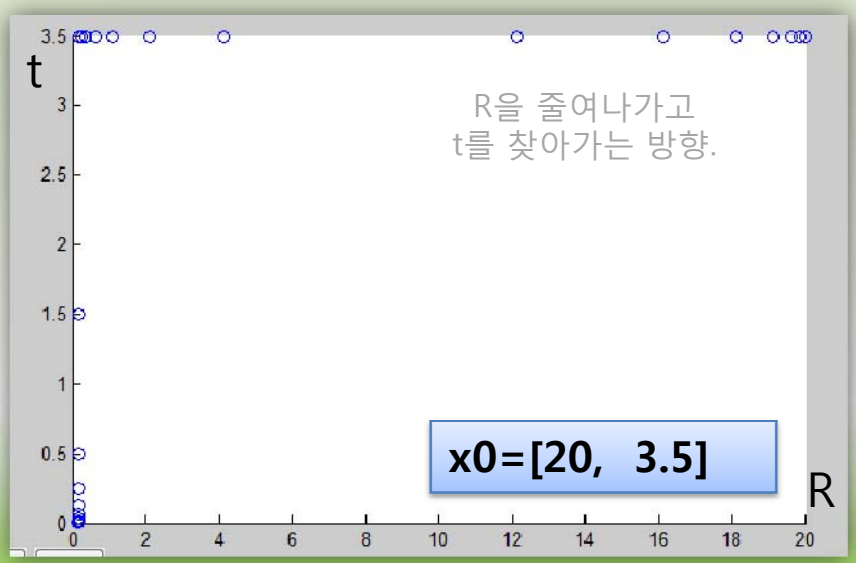


*초기값에 상관없이
일정한 값에 수렴

R = 0.1269(m)

t = 0.0037(m)

Mass=24.6180kg



Solution & Comparison 1 (**2** variables)

Matlab - G.A

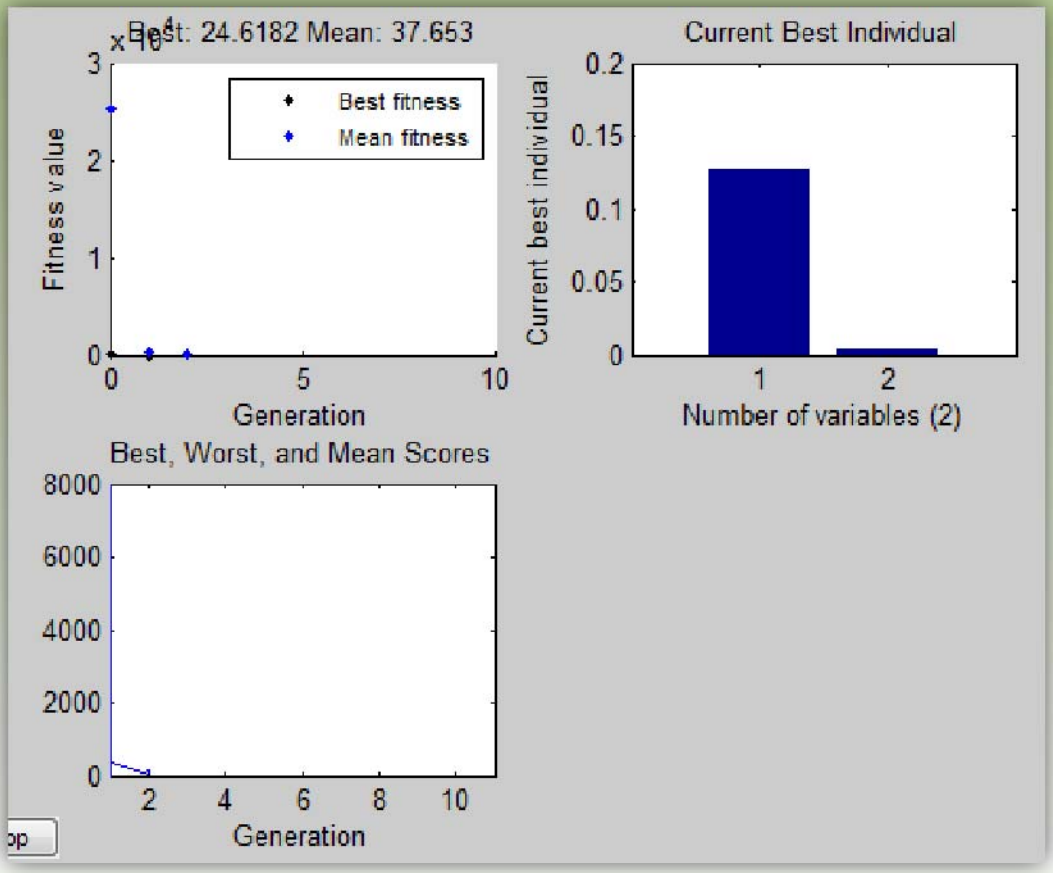
```
lb=[0.12686 0];
options = gaoptimset;
options = gaoptimset(options,'Display', 'off');
options = gaoptimset(options,'OutputFcns', { [] });
[x,fval,exitflag,output] =
ga(@fun,2,[],[],[],[],lb,[],@confun,options)
```

R = 0.1269(m)

t = 0.0037(m)

Mass=24.6182kg

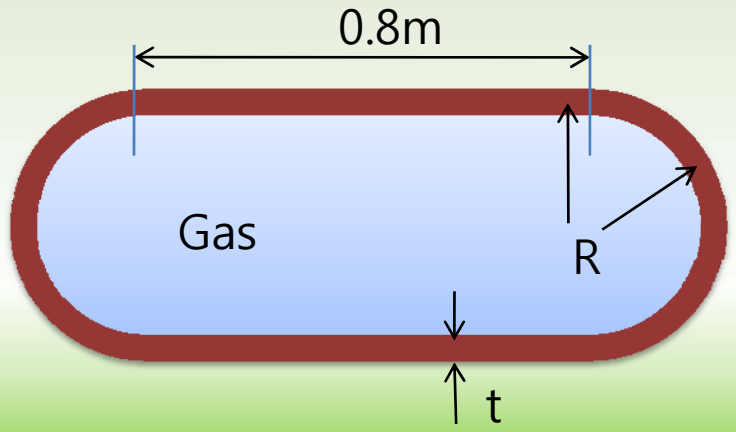
*여러 차례 시도해도 계속 위와 같은 값을 출력해내었다.



Solution & Comparison 1 (**2** variables)

"Comparison"

	Solver-GRG	fmincon-SQP	Pattern search	G.A
R	0.1269(m)	0.1279(m)	0.1269(m)	0.1269(m)
t	0.0037(m)	0.0037(m)	0.0037(m)	0.0037(m)
Mass	**24.6230(kg)**	**24.6076(kg)**	**24.6180(kg)**	**24.6182(kg)**



Solution & Comparison 2

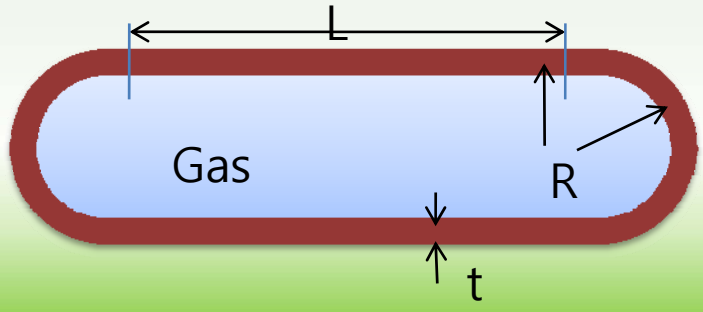
*3 variables

$$m(R,t,L) = 7850 \cdot 2\pi Rt(L+2R)$$

무게 경량화!

$$g4 = 0.049 - \frac{4}{3}\pi R^3 - \pi R^2 L \le 0$$

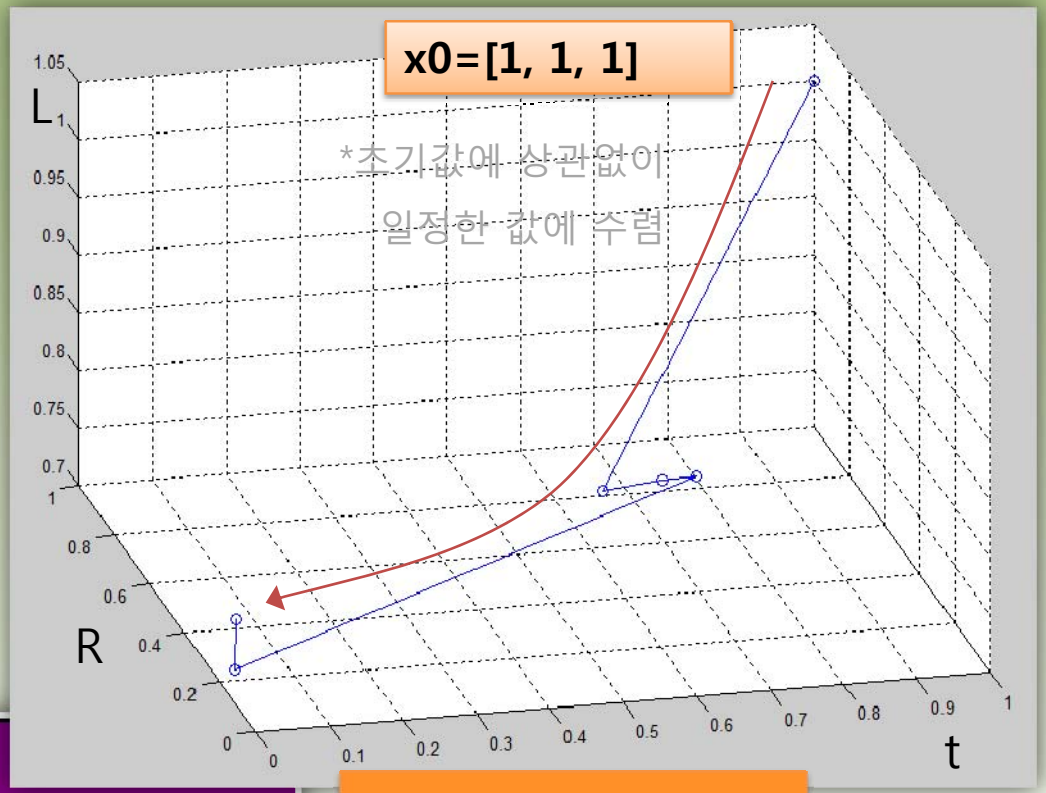
용기의 체적



Solution & Comparison 2 (**3** variables)

Excel(Solver)-GRG

		해찾기	
	F	23.98573229	24.61816
	t	0.003678799	0.003734
	R	0.128757973	0.12686
	L	0.769136002	
g1	tau	6.90602E-10	
g2	sigc	-6.86517E-16	
g3	ec	-0.00055182	
g4	R	-6.21268E-07	



시나리오 요약

		1	2	3	4	5	6	현재 값:
	F101	1	0.52	0.589272	0.628186	0.003759	0.003678799	0.003679
	F102	1	0.2	0.15077	0.123211	0.131568	0.128757973	0.128758
	F103	1.000001	0.840001	0.855097	0.863133	0.725628	0.769136771	0.769136
결과 셀:								
	F100	147969.1	6360.702	5068.475	4235.796	24.11994	23.98575026	23.98573
	F104	-0.99953	-0.10353	-0.08837	-0.07693	-2.1E-05	6.90602E-10	6.91E-10
	F105	-0.97143	-0.51429	-0.58496	-0.62467	4.29E-17	-6.80012E-16	-6.8E-16
	F106	-0.97571	-0.51514	-0.58561	-0.62519	-0.00056	-0.00055182	-0.00055

R = 0.1287(m)

t = 0.0037(m)

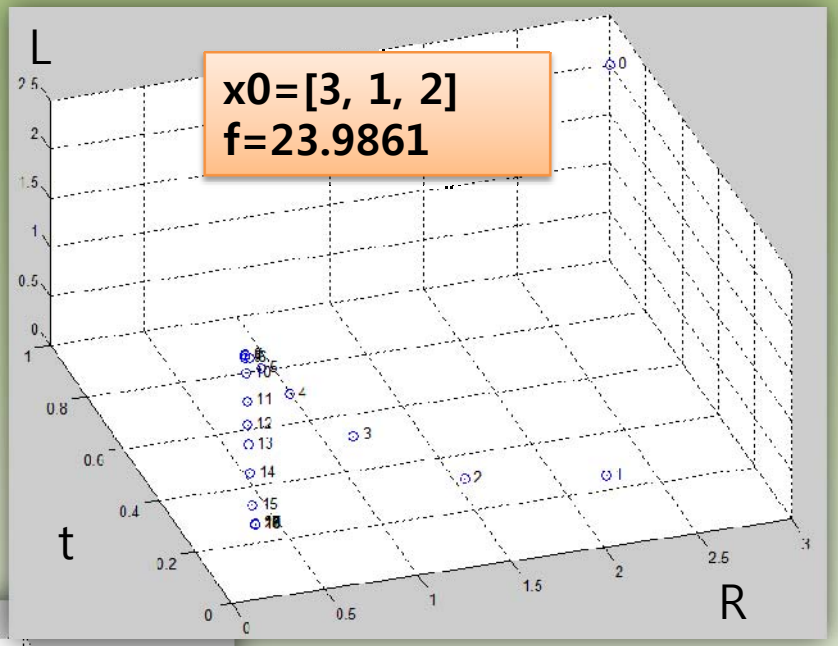
L = 0.7691(m)

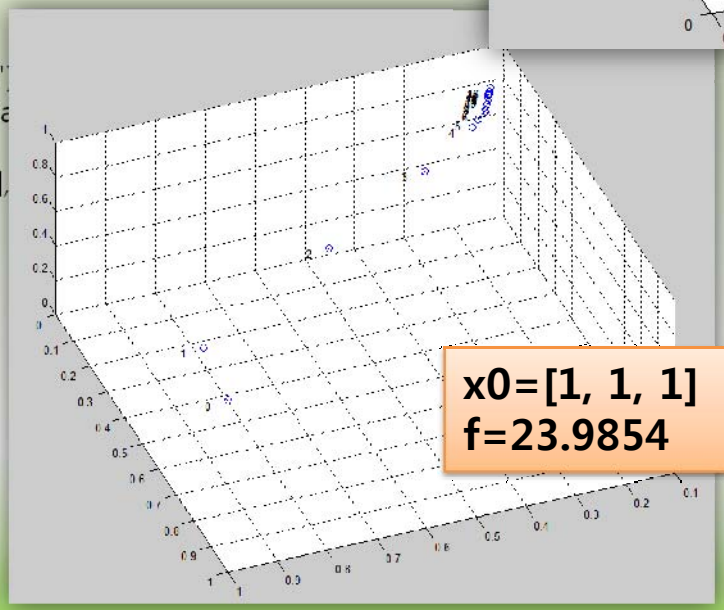
Mass=23.9857kg

Solution & Comparison 2 (**3** variables)

Matlab - fmincon(SQP)

```
-----fun.m------------
function f=fun(x)
f=7850*2*pi*x(1)*x(2)*(x(3)+2*x(1));

--------confun.m----------------
function[c,ceq]=confun(x)
c(1)=5/(2*pi*1680)-x(1)*x(2);
c(2)=6*x(1)/210-x(2);
c(3)=6*x(1)*(2-0.3)/(2*210)-x(2);
c(4)=0.049-pi*x(1)^2*(4/3*x(1)+x(3));
ceq=[];

>>x0=[1 1 1];
lb=[0 0 0];
options = optimset;
options = optimset(options,'Display', 'off'
options = optimset(options,'Algorithm', '
sequential quadratic Programming
[x,fval,exitflag] =fmincon(@fun,x0,[],[],[],[],
```



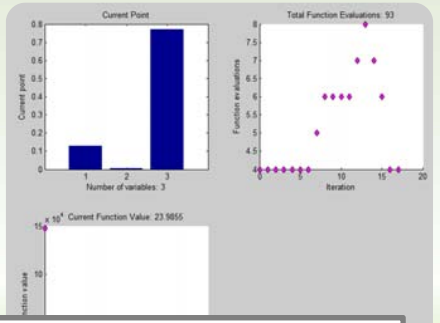


R = 0.1288(m)

t = 0.0037(m)

L = 0.7691(m)

Mass=23.9854kg

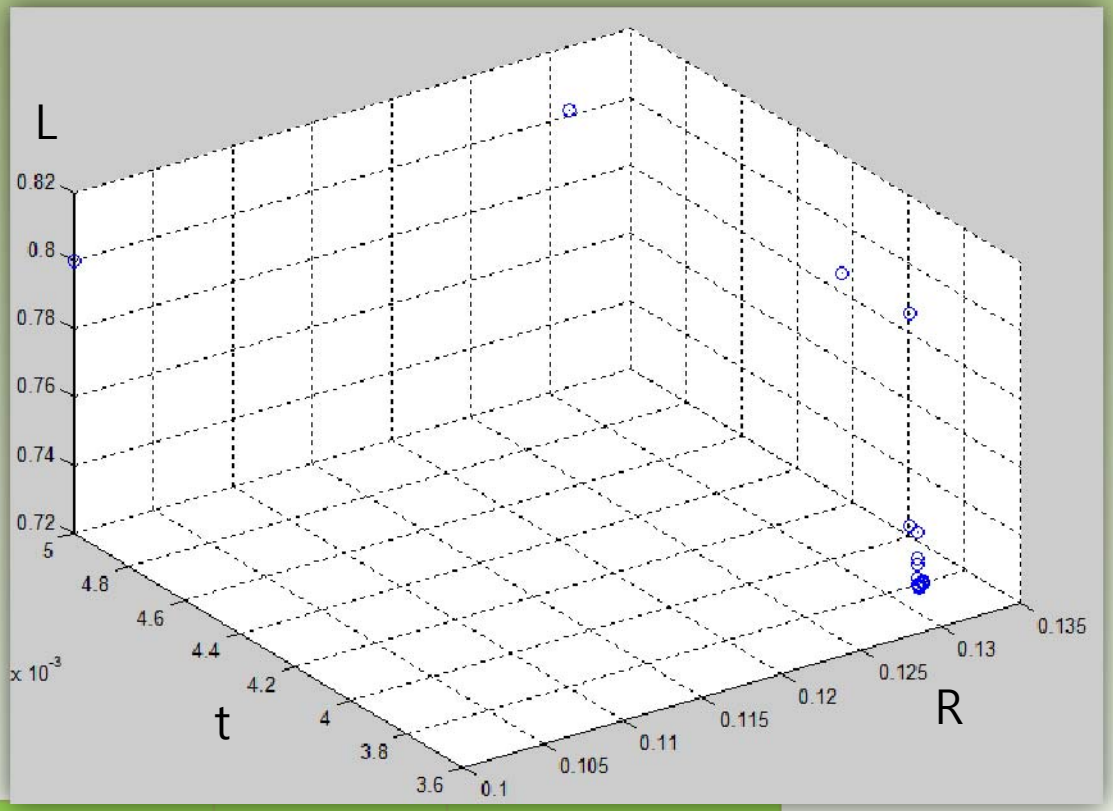


목적 함수의 값이 약간 차이는 있으나 대체로 일정하게 수렴하였다.

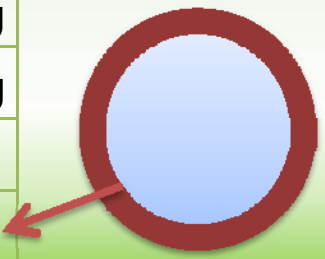
Solution & Comparison 2 (**3** variables)

Matlab - Pattern search

```
x0=[1 1 1];
lb=[0 0 0];
options = optimset;
options = optimset(options,'Display',
'off');
options =
optimset(options,'Algorithm',
'active-set'); % SQP - sequential
quadratic Programming
[x,fval,exitflag]
=fmincon(@fun,x0,[],[],[],[],lb,[],@con
fun,options)
```



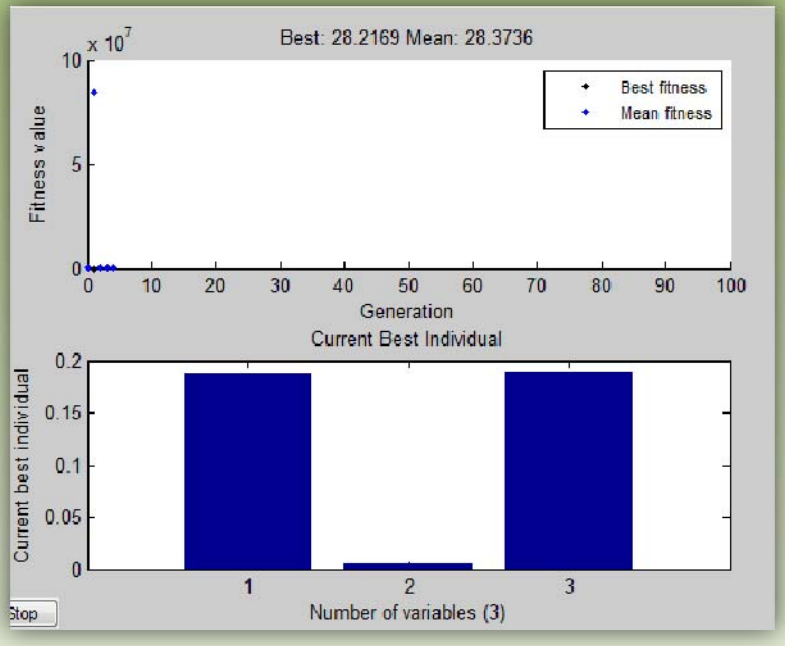
x0	R	t	L	mass
0.1 0.005 1	0.1179	0.004	0.9655	27.94311375kg
0.1 0.005 0.8	0.131774	0.003765	0.722537	24.12968402kg
0 0 0	x	x	x	X
1 1 1	0.227	0.006	0	32.9654kg



Solution & Comparison 2 (**3** variables)

Matlab - G.A

```
lb=[ 0 0 0];
options = gaoptimset;
options = gaoptimset(options,'MutationFcn',
@mutationadaptfeasible);
options = gaoptimset(options,'Display', 'off');
options = gaoptimset(options,'PlotFcns',
{  @gaplotbestf @gaplotbestindiv });
[x,fval,exitflag,output,population,score] =
ga(@fun,3,[],[],[],[],lb,[],@confun,options)
```

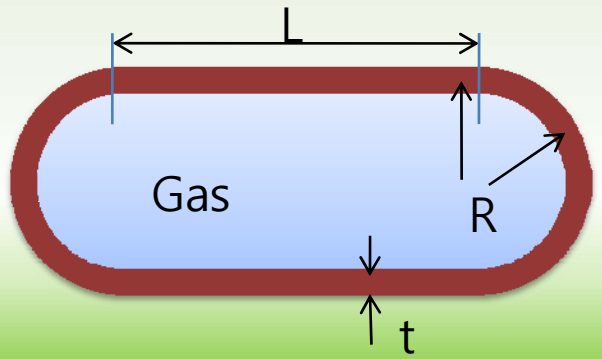


R	t	L	∵확률에 의한 탐색 방법
x1	x2	x3	f
0.188295	0.00538	0.188857	**28.25197034 kg**
0.1266	0.0037	0.8428	**25.3218545 kg**
0.1704	0.0049	0.31	**26.80172457 kg**
0.227	0.0065	0.001	**33.11312249 kg**

Solution & Comparison 2 (**3** variables)

"Comparison"

	Solver-GRG	fmincon-SQP	Pattern search (초기값에 따라 다름)	G.A (일정치 않음)	2 Variables…
R	0.1287(m)	0.1288(m)	0.1318(m)	0.1266(m)	0.1279(m)
t	0.0037(m)	0.0037(m)	0.0038(m)	0.0037(m)	0.0037(m)
L	0.7691(m)	0.7691	0.7225	0.8428(m)	0.8(m)=const
Mass	**23.9857(kg)**	**23.9854(kg)**	**24.1297(kg)**	**25.3219(kg)**	**24.6076 (kg)**



비 교 및 검 토

•기존 설계와의 비교

	최적 값	라보(LABO)
R	0.1288 m	0.1725 m
t	0.0037 m	0.0032 m
l	0.7691 m	0.6020 m
Mass	23.985 kg	23~27 kg

차 종 : LABO
제품 SIZE : 3.2t×ø345×602
총용량 : 49ℓ
업체명 : GM대우자동차

- 기존 설계와 비교 했을 때 어느 정도의 경량화를 이룸
- 기존 값과 두께에서는 비슷한 수치를 나타내었지만
  반지름(R)과 용기 길이(L)에서 차이를 보임

고 찰

- 왜 실제 제품과 형상의 차이가?

  실제 제품 설계에는 다른 구속조건들이 더 있을 것이다.

  (예: 자동차 내 용기 설치 공간 제약 등)

-더 나은 설계?

위에서의 제한 조건의 경우라면, 다른 재질을 사용하여

경량화를 이룰 수 있으나, 재료 가격 상승, 제조 공정 문제 등 발생