2009 – Final Project

〈Design of Flywheel 〉

[Olleh_e+]

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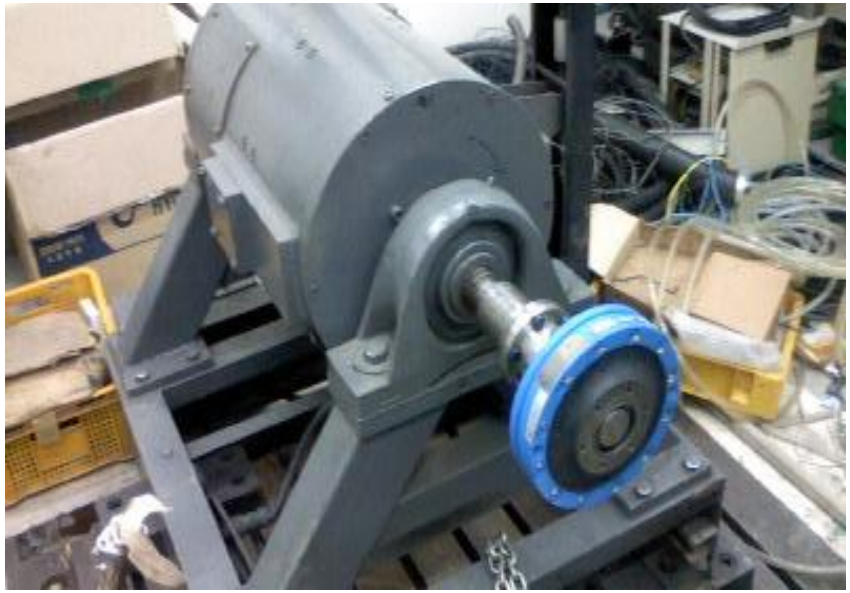
Contents

1. Introduction



◆ Subject of project

- Flywheel

◆ Project objective

- 다양한 알고리즘 사용으로 최적해 계산
- 기존 설계와 비교 분석 및 고찰

◆ Conception

- Fmincon(Matlab)
- Excel solver
- Pattern search
- Genetic Algorithm

2. Modified problem formulation

◆ Project statement & Data

$(\mathrm{S.F}) \times \sigma_e \le \sigma_y$

$\sigma_y = 250\ \mathrm{MPa}$

$\mathrm{S.F} = 2$

$\omega = 4500\ \mathrm{rpm}$

동0 험을 하기 위해 다이나모를 사용하려 하는데 적
절한 요하다. 동아리에서 사용할 플라이휠을 제작하
고자 사항은

기존설계: J=0.06

$\rho = 7870\ \mathrm{kg/m^3}$

$\sigma_y = 250\ \mathrm{MPa}$

$\nu = 0.3$

위해 일 수준 이상의 값을 가져야
한 응력이 파손범위 이내 한다. 그리
름이 폭의 너비보다 4배를 넘지 말아야 하며, 플라이 휠의 재질은
steel로 한다. 그리고 최대 작동 속 다. 동
아리 자금 사정을 고려하여 최소의 비용으로 제작하는 것을 목적으
로 한다.

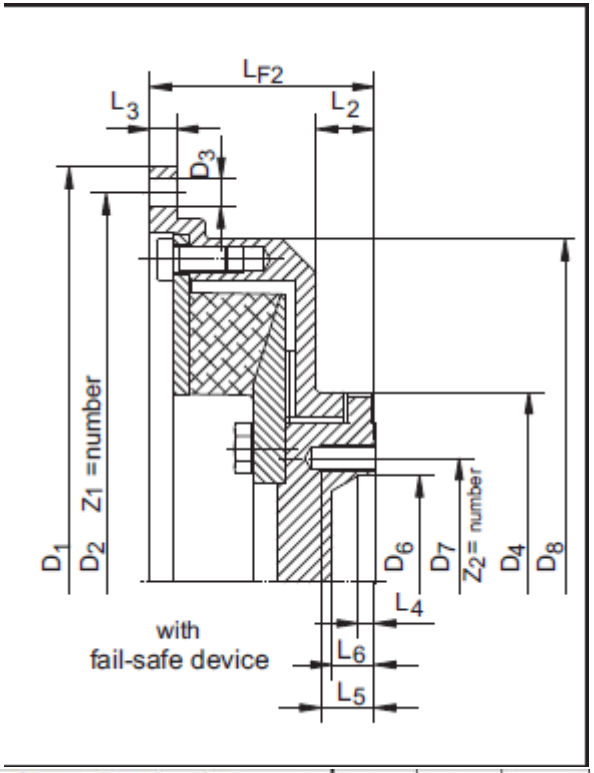
$R_o \le 4b$

비용절감 = 무게 최소화

2. Modified problem formulation

◆ Assumptions

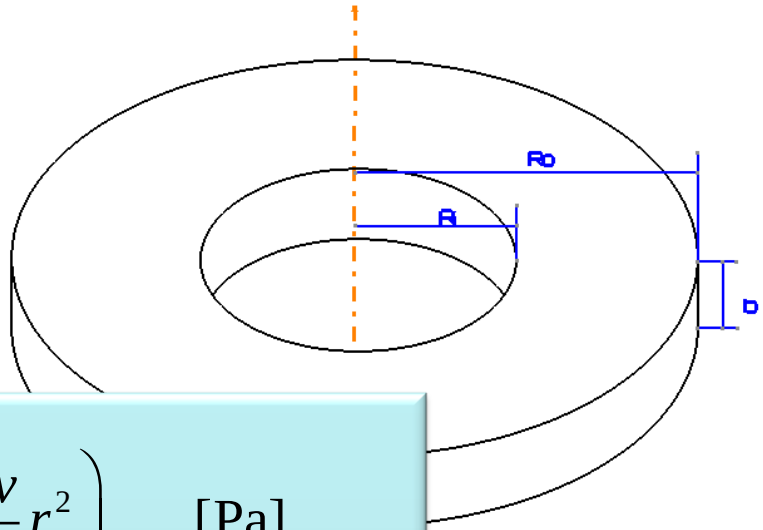
- Flywheel 의 damping 효과 무시
- Bolt, flange 무시
- Shaft는 기존설계와 같은 크기
  - ✓ Ri = 0.05396 m



AC-VSK coupling size	Flywheel connection dimensions					D_4	D_8	L_3	L_F	MECHANICS cardan shaft connecting dimensions							J_1 [kgm²]	J_2 [kgm²]	Total weight [kg]
	SAE size	D_1	D_2	D_3	Z_1					Size	D_6 H7	L_4	L_5	L_6	L_7	M			
-15.[1].F2	8	263.5	244.5	10.5	6	140	215	8	83	4C	107.92	5.8	36.5	9.5	87.3	5/16"-24	0.055	0.010	8.8
	10	314.3	295.3	10.5	8					5C	115.06	5.1	42.9	14.26	88.9	3/8"- 24	0.084		10.2

2. Modified problem formulation

- **Design Variables**
  - R_o [radius]: Flywheel 의 외경 [m]
  - b [width]: Flywheel 의 폭 [m]



- **Cost function**
  - Min

- **Cons**

$$g_1:$$

$$g_2:$$

$$g_3:$$

$$g_4: \quad -b \le 0$$

$$g_5: \quad \mathrm{S.F} \times \sigma_e - \sigma_y \le 0$$

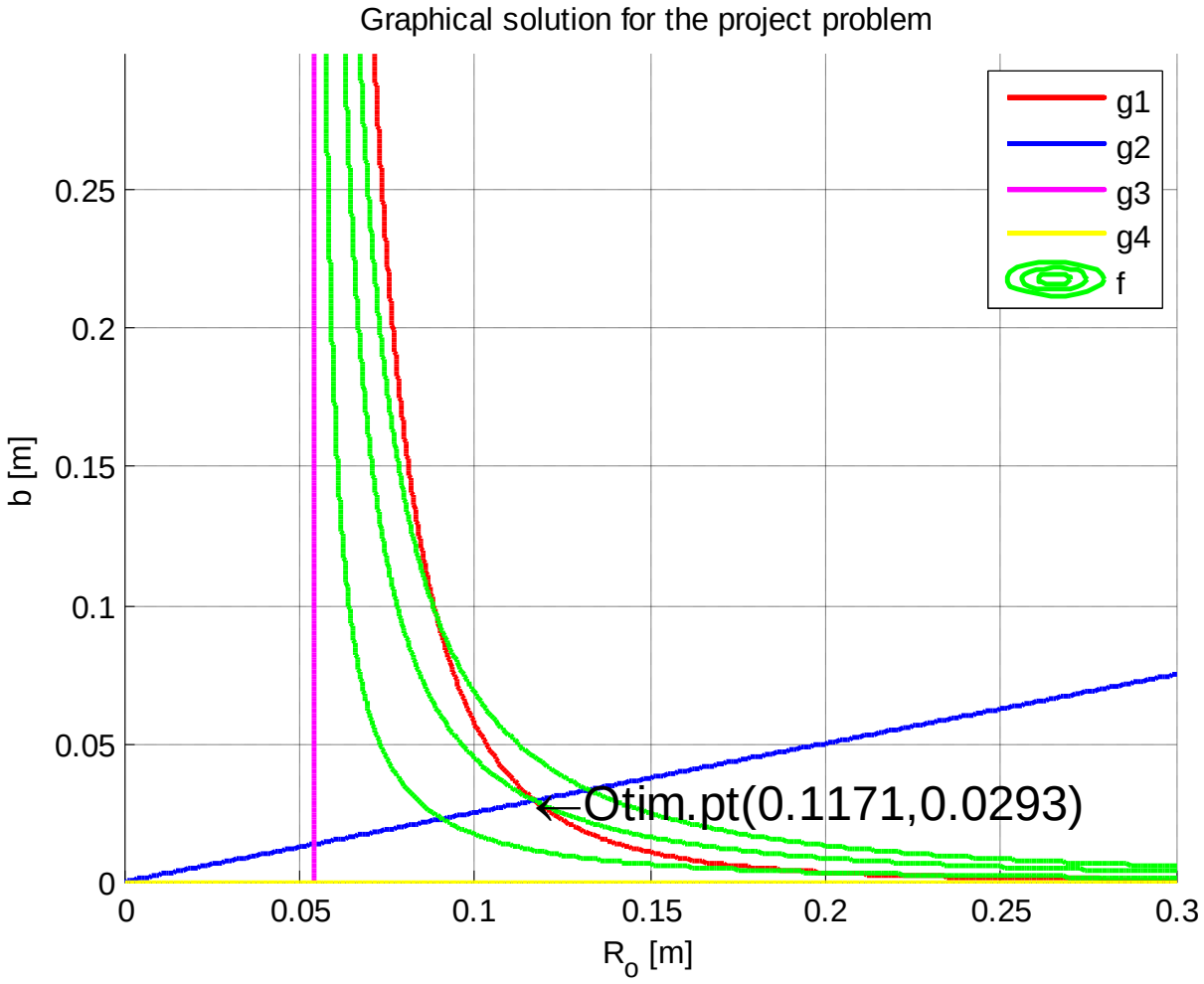
$$\sigma_t = \rho\omega^2 \frac{3+\nu}{8}\left(r_i^2 + r_0^2 + \frac{r_i^2 r_o^2}{r^2} - \frac{1+3\nu}{3+\nu} r^2 \right) \quad [\mathrm{Pa}]$$

$$\sigma_r = \rho\omega^2 \frac{3+\nu}{8}\left(r_i^2 + r_0^2 - \frac{r_i^2 r_o^2}{r^2} - r^2 \right) \quad [\mathrm{Pa}]$$

$$\sigma_e = \sqrt{\sigma_r^2 - \sigma_r\sigma_t + \sigma_t^2} \quad [\mathrm{Pa,\ von\ Mises\ stress}]$$

3. Optimization

Graphical Solution



3. Optimization

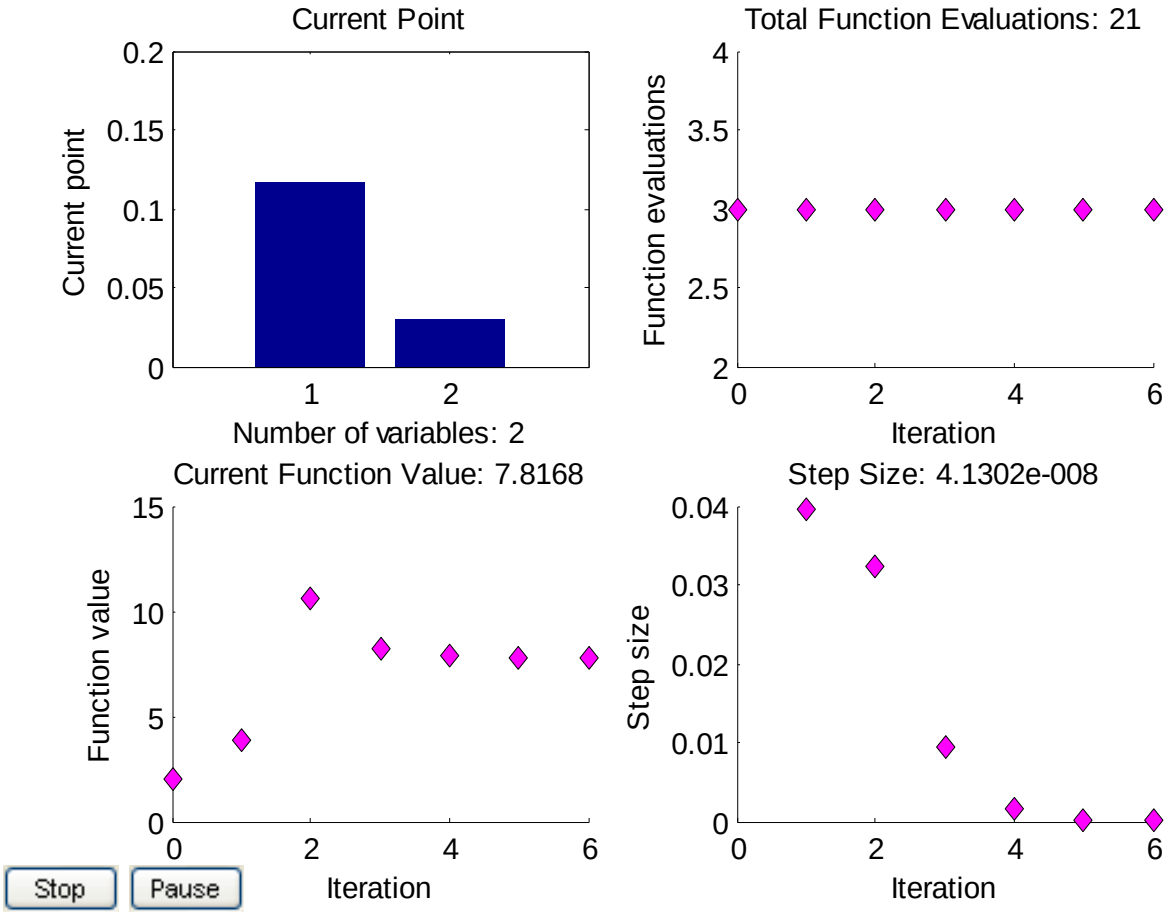
◆ Algorithm(Matlab)

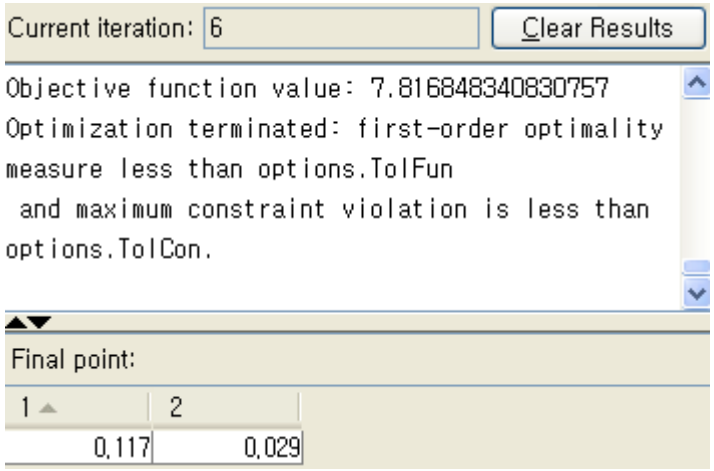
```
function [g,h]=ConstraintsFunc(x,ri)
den=7870;
sy=250*10^6;
j0=0.065;
ri=0.0540;
ro=x(1);
b=x(2);

g(1)=-pi*den*(ro^4-ri^4)*b*0.5+j0;
g(2)=ro-4*b;
g(3)=ri-ro;
g(4)=-b;
options=[];
[alpha, von]=fminbnd('VonMisesStress',ri,ro,options,ri,ro);
g(5)=-von-sy;

h=[];
end
```

```
function von=VonMisesStress(x,ri,ro)
den=7870;
w=471.239;
v=0.3;
ri=0.0540;
c=den*w^2*(3+v)/8;

st=c*(ri^2+ro^2+ri^2*ro^2/x^2-(1+3*v)/(3+v)*x^2);
sr=c*(ri^2+ro^2-ri^2*ro^2/x^2-x^2);

von=-sqrt(st^2-st*sr+sr^2);
end
```

3. Optimization

◆ Fmincon(MATLAB)-1

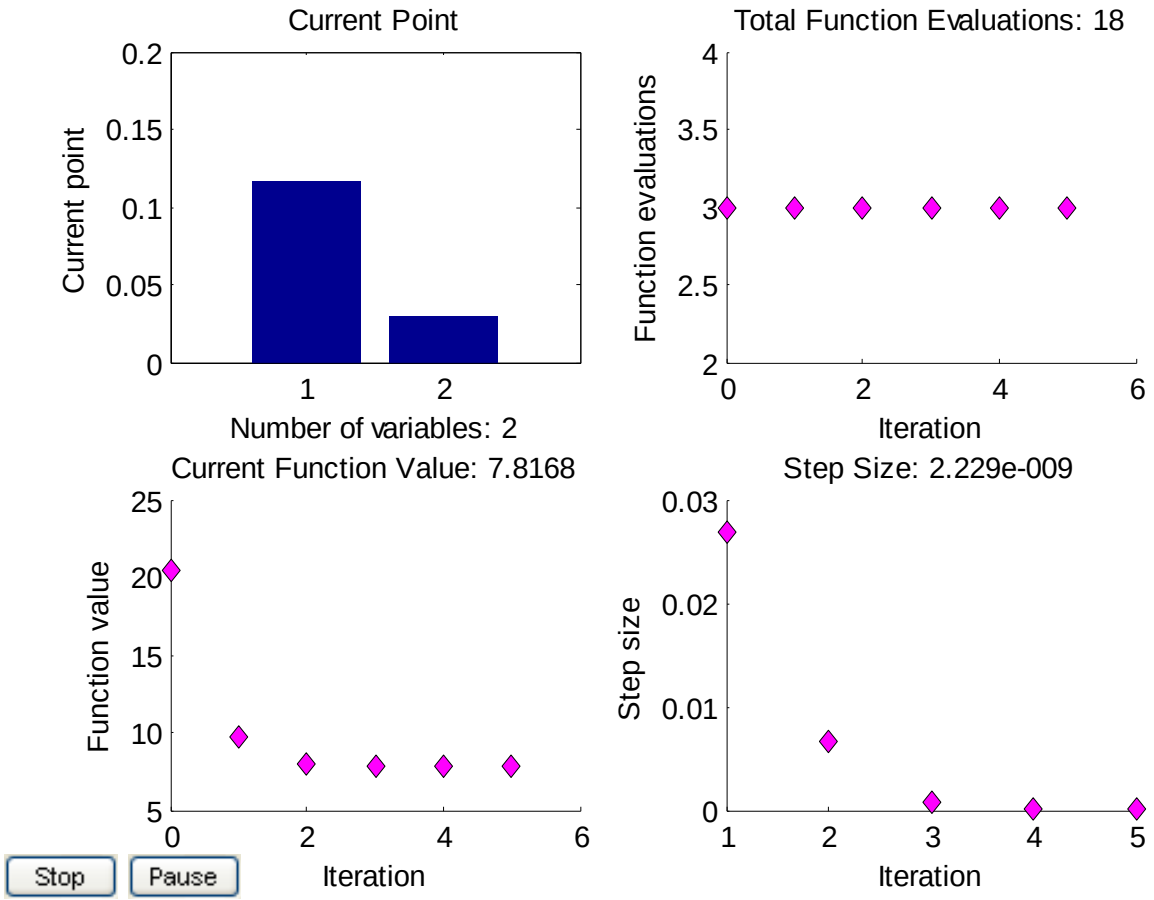


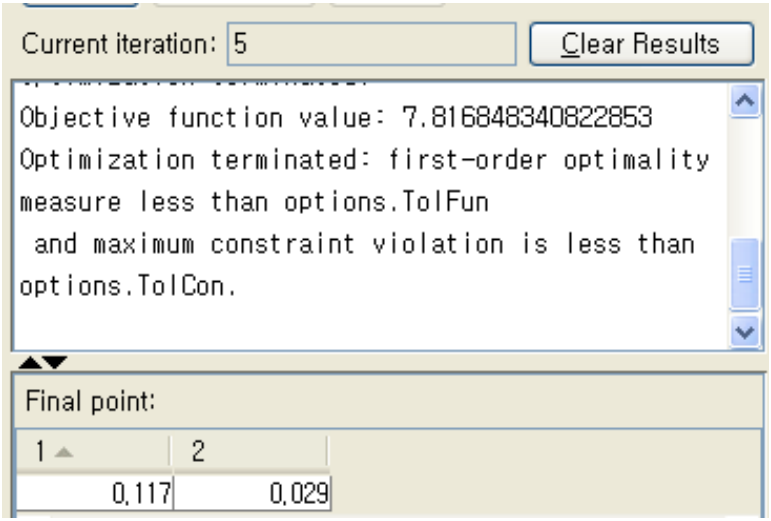


초기값 : 기존설계
[0.11604, 0.02901]

3. Optimization

◆ Fmincon(MATLAB)-2





초기값 : 기존 설계
[0.1318, 0.057]

3. Optimization

◆ Excel solver

ρ(density)	7870
ri	0.05396
v(poisson's ratio)	0.3
ω	471.239
σy	250000000
safe factor	2
J(origin)	0.065
σt	11054163.56
σr	9022335.611
σe	10191305.04

Cost Function: $f = \rho\pi\left(r_o^2 - r_i^2\right)b$

Constraints:

$$g_1: \quad -\frac{\pi}{2}\rho\left(r_o^4 - r_i^4\right)b + J_{\text{origin}} \le 0$$

$$g_2: \quad r_0 - 4b \le 0$$

$$g_3: \quad r_i - r_o \le 0$$

$$g_4: \quad -b \le 0$$

$$g_5: \quad \text{S.F} \times \sigma_e - \sigma_y \le 0$$

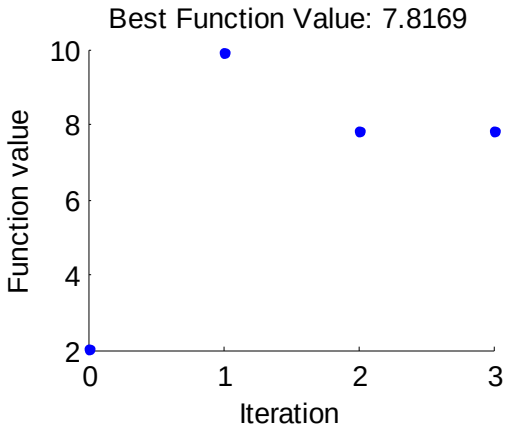
		초기값	해찾기
Design variables	ro [m]	0.13175	**0.1171066**
	b [m]	0.057	**0.0292767**
Minimize function	f [kg]	20.3590975	**7.8191895**
Constrains	g1	-0.14133685	4.5684E-07
	g2	-0.09625	0
	g3	-0.07779	-0.11710664
	g4	-0.057	-0.02927666
	g5	-229617390	-229617390

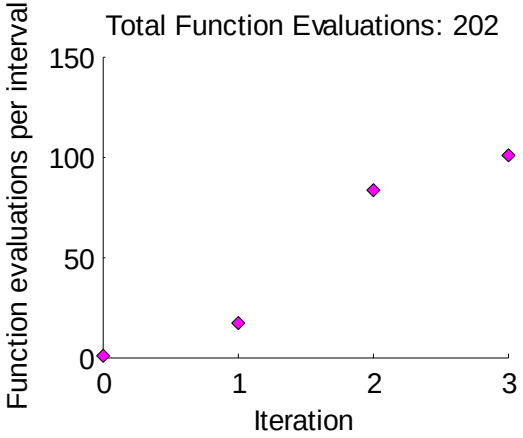
제한 조건

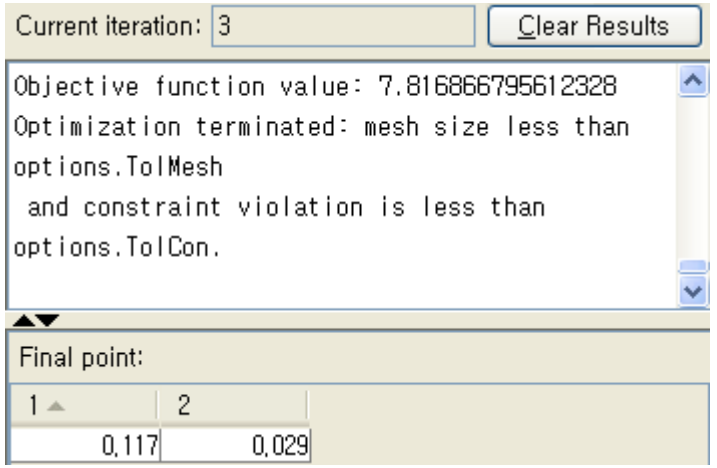
셀	이름	계산 값	라그랑지 승수
F18	g1 해찾기	4.5684E-07	-82.0490256
F19	g2 해찾기	0	-21.2288604
F20	g3 해찾기	-0.117106642	0
F21	g4 해찾기	-0.029276661	0
F22	g5 해찾기	-229617389.9	0

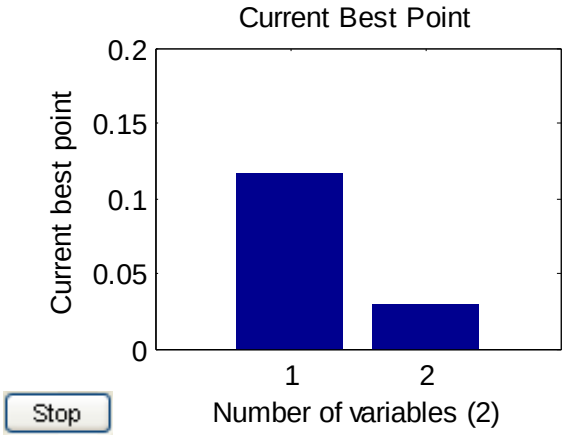
3. Optimization

◆ Pattern Search(MATLAB)-2









- ✓ **Fmincon 알고리즘과 동일한 결과**
- ✓ **Iteration 감소**
- ✓ **Total function evaluations 증가**

3. Optimization

◆ Genetic Algorithm

No.	Ro [m]	b [m]
1	0.1170	0.020
2	0.1190	0.030
3	0.1130	0.034
4	0.1150	0.033
5	0.1160	0.038
6	0.1170	0.029
7	0.1080	0.041
8	0.1050	0.049
9	0.1070	0.044
10	0.1170	0.029
Average	0.1134	0.0347

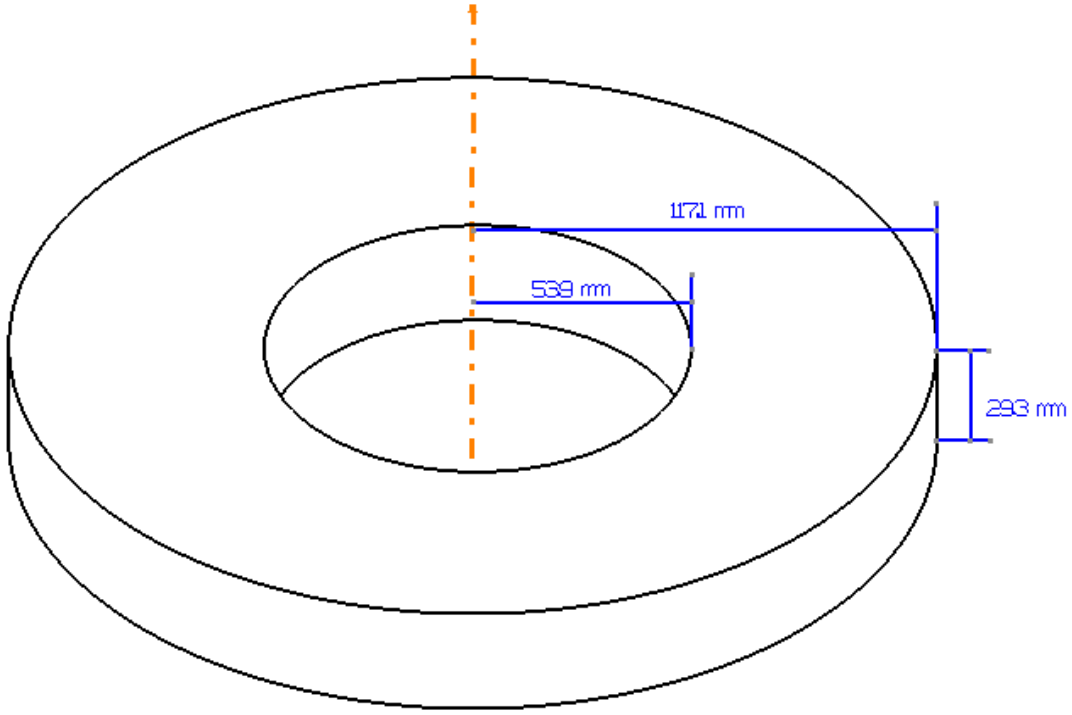
4. Conclusion & Comment

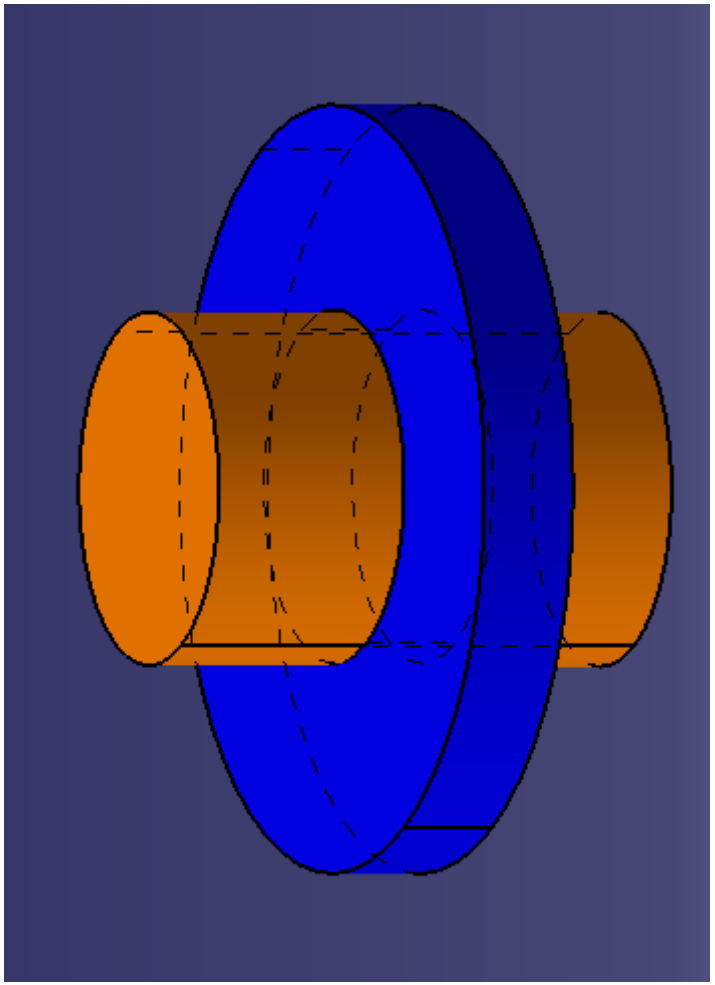
- Fmincon&Pattern Search&Excel Solver 의 결과 일치

	Ro [mm]	b [mm]	Mass [kg]
Origin Value	131.75	57	8.8
Previous Optimum Value	116.04	29.01	9.66
Fmincon	117.1	29.3	7.819
Excel solver	117.1	29.3	7.819
Pattern Search	117.1	29.3	7.819
Genetic Algorithm	113.4	34.7	8.535

4. Conclusion & Comment t

- **Rout : 117.1mm , b = 29.3mm**





Q & A