

Optimum Design TEAM :metallic cock

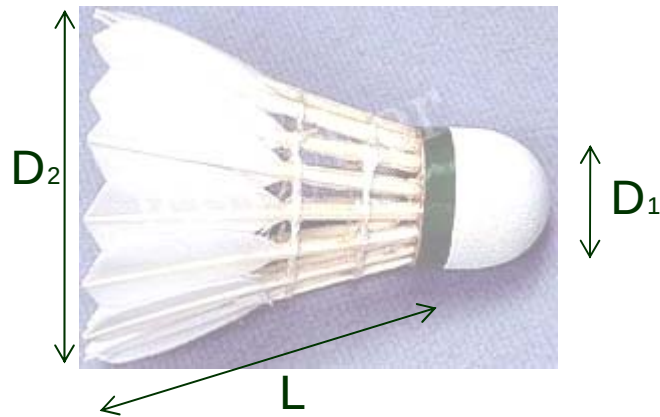
Mechanical Engineering

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김 석 희

Project / Problem statement

- ◆셔틀콕 1개 = 거위 3마리
- ◆현재의 셔틀콕은 깃털이 잘 부러짐
(배드민턴 1경기당 셔틀콕 20개 소비)
- ◆내구성 증가를 목표
(금속재료를 선택하여 경량화가 관건)
(기본적 형상과 성능 유지)

Data Collection



최대 직경(D_2): 6 cm
날개 부분 길이 : 7 cm
콕 부분 직경 : 3cm
셔틀콕의 총 중량: 5g

Data Collection

- ◆ Al 1100
- ◆ $\left\{ \begin{array}{l} \sigma_{\text{allow}} = 34 \text{ Mpa} \\ \rho = 2700 \text{ kg/m}^3 \end{array} \right.$
- ◆ $F_d = \frac{C_d A_p \rho V^2}{2}$

- ◆ $V_{\text{initial}} = 320 \text{ km/h}$
- ◆ $V_{\text{final}} = 60 \text{ km/h (16.6 m/s)}$
- ◆ $V_{\text{average}} = 100 \text{ km/h}$



Data Collection

◆ Determine applied force (F)

Momentum Eq.

$$mv_f + F \Delta t = mv_i$$

Contact time

golf = 0.0005 sec

baseball = 0.0012 sec

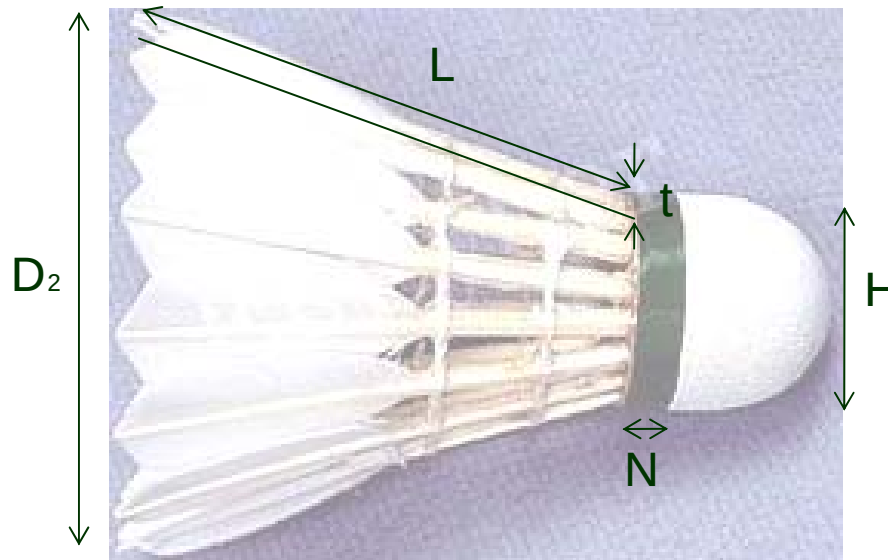
badminton = 0.001 sec

Assumption

- ◆재료는 Homogeneous함
- ◆Buckling 고려하지 않음
- ◆Cock은 symmetric, 회전운동 무시
- ◆Cock의 중앙에 정확히 하중을 받음
- ◆Cock의 초기속도(80m/s)고정 (최악치 설계)
- ◆Thickness $\ll D1$
- ◆Cock의 응력해석시 평형방정식 이용(순간적으로)

Design variable

- ◆ Outer diameter
- ◆ Thickness
- ◆ Radius of head



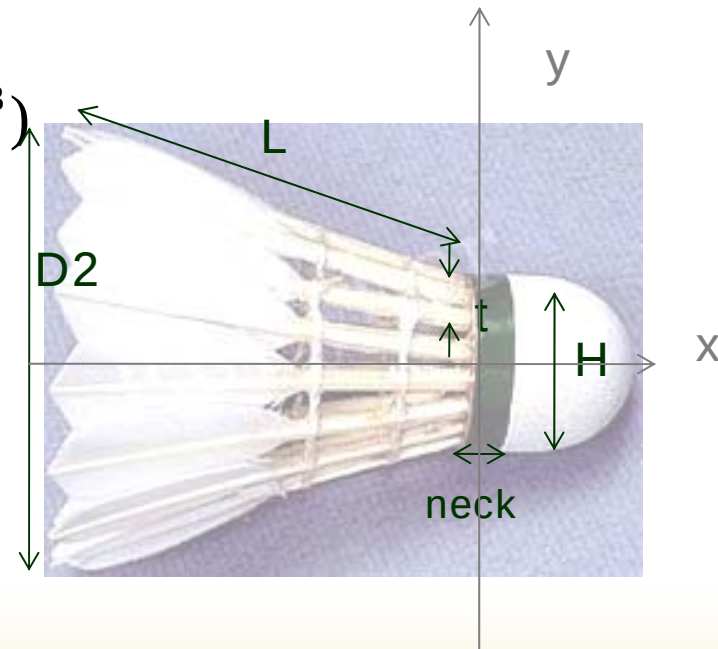
Objective function

◆ Minimize mass

$$= \text{Density} \times (\text{Total volume})$$

$$= \rho \left(\pi \int (y - t)^2 dx + \pi \frac{H^2}{4} l_{neck} + \frac{2}{3} \pi \left(\frac{H}{2} \right)^3 \right)$$

y : equation of line L



Constraints

◆ 1. $v_{final} \leq 18 \text{ m / s}$

$$F_d = \frac{C_d A_p \rho v^2}{2} \quad C_d = 0.49, A_p = \frac{\pi D_2^2}{4}, \rho = 1.2 \text{ kg / m}^3$$

($C_d = 0.49$ (corn shape)

(determined experimentally)

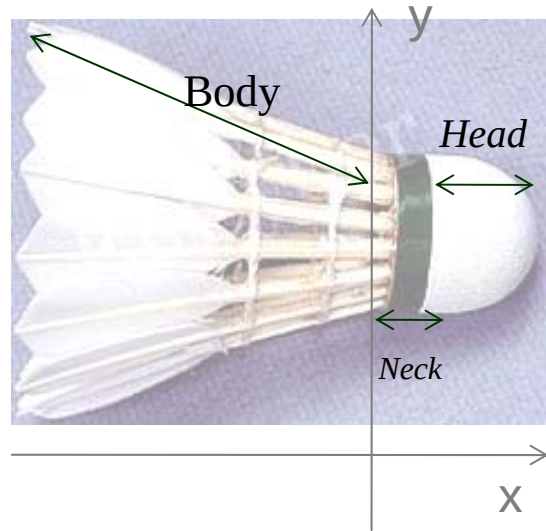
$$m \frac{dv}{dt} = -F_d$$

$$m \frac{dv}{dt} = -\frac{C_d A_p \rho v^2}{2} \rightarrow v_{i+1} = v_i - \frac{C_d A_p \rho}{2} v_i^2 \Delta t$$

(수치해석적으로 풀이)

Constraints

◆ 2.Center of gravity ≥ 0



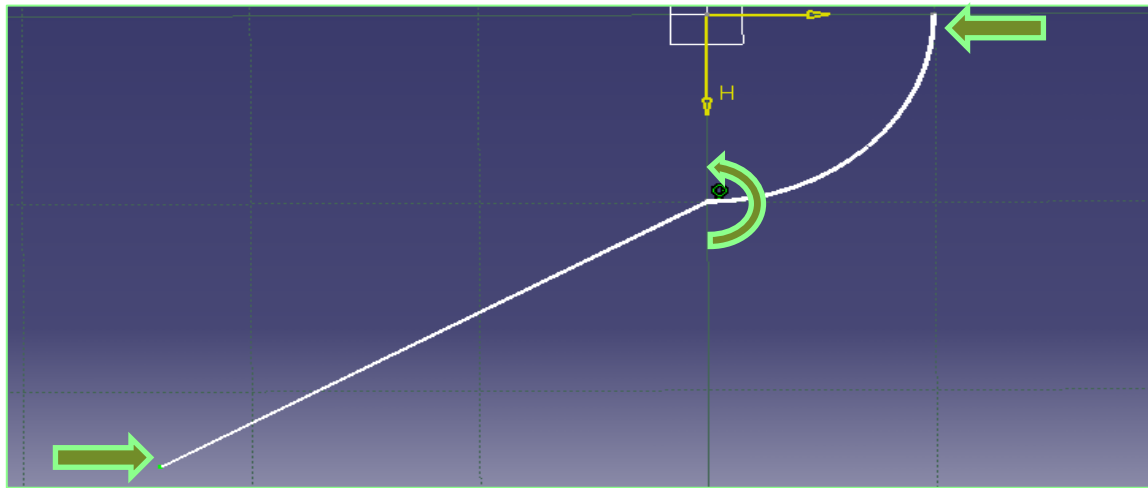
$$\text{center of gravity } \bar{x} = \frac{\int x dW}{W}$$

$$\bar{x}_{total} = \frac{\sum (\bar{x}_{b,out} W_{b,out} - \bar{x}_{b,in} W_{b,in} + \bar{x}_h W_h + \bar{x}_n W_n)}{W_{total}}$$

$$\geq 0$$

Constraints

◆ 3. $\text{Stress} \leq \sigma_{all}$



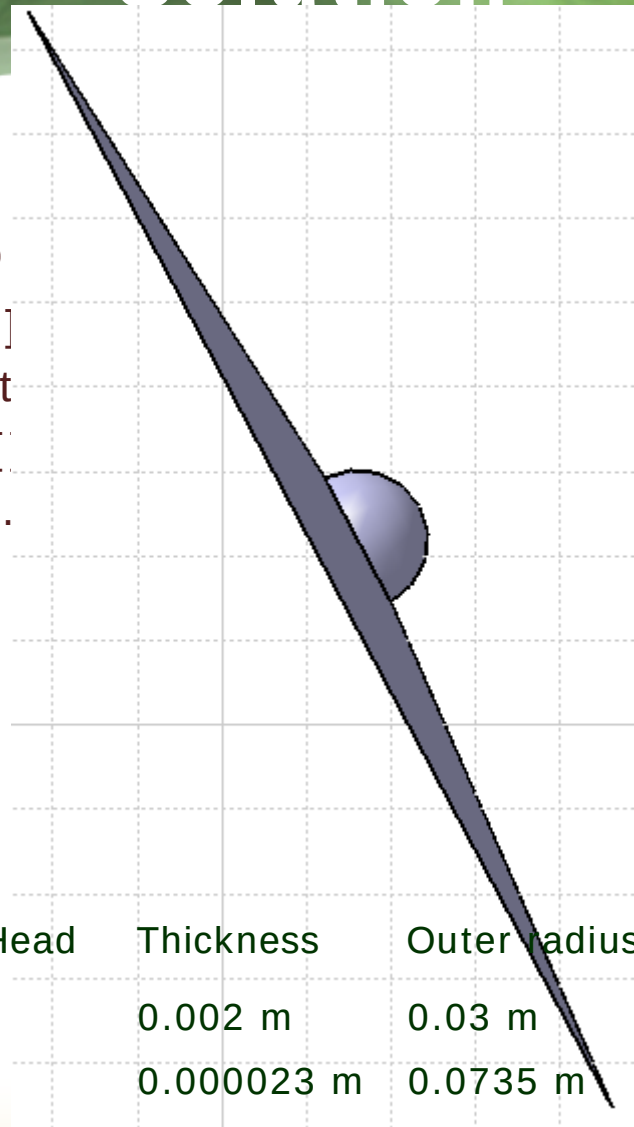
$$\sigma_{\max} = \frac{P}{A} + \frac{My}{I}$$

$$\sigma_{\max} = \frac{F}{\pi(H^2 - (H-t)^2)} + \frac{F(H - \frac{t}{2})(H-t)}{\frac{\pi}{4}(R^4 - (R-t)^4)}$$

Solution

MATLAB (fminco

```
>>x0=[0.03,0.001,0.01]  
>>[x,fval,exitflag,output  
    ('objfun',xo,[],[  
    x=0.0083 0.0023 0.  
    fval= 0.0033
```



	Radius of Head	Thickness	Outer radius	Weight
실제형상	0.015 m	0.002 m	0.03 m	0.005 kg
결과값	0.0083 m	0.000023 m	0.0735 m	0.0033 kg

Solution

→ 형상 보정

($0.0001 \leq t$)

MATLAB

```
>>x0=[0.0
```

```
>>[x,fval,e
```

```
('o
```

```
x=0.014
```

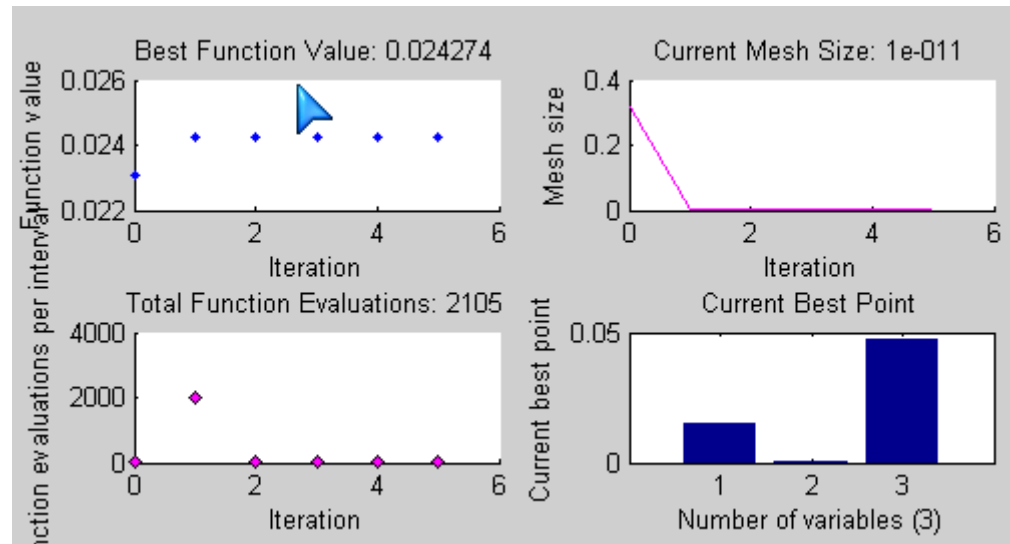
```
fval= 0.0
```

	Radius of Head	Thick	Outer radius	Weight
실제형상	0.015 m	0.002 m	0.03 m	0.005 kg
결과값	0.0147 m	0.0001 m	0.0463 m	0.0231 kg

Solution

MATLAB (patternsearch)

형상유지 -> Low Bound=[0.01,0.0001,0.02];

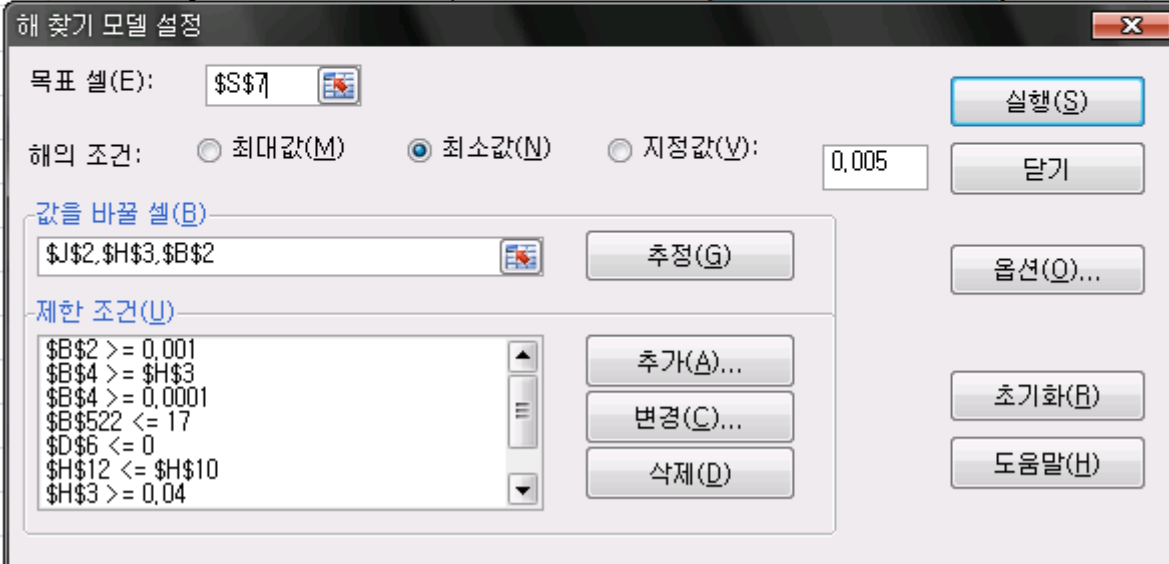


	Radius of Head	Thick	Outer radius	Weight
실제형상	0.015 m	0.002 m	0.03 m	0.005 kg
결과값	0.015 m	0.0001 m	0.04745387 m	0.024274 kg

Solution

Excel solver

	conjugate	gradient	method
		initial	solution
radius of head	0.01		0.01472
thick	0.000001		0.0001
outer radius	0.01		0.04767
mass			0.02314



The image shows the Excel Solver dialog box with the following settings:

- 해 찾기 모델 설정** (Solver Parameters)
- 목표 셀(E):** $\$S\7
- 해의 조건:** ☐ 최대값(M) ☒ 최소값(N) ☐ 지정값(V): 0.005
- 값을 바꿀 셀(B):** $\$J\$2, \$H\$3, \$B\2
- 제한 조건(U):**
 - $\$B\$2 \geq 0.001$
 - $\$B\$4 \geq \$H\3
 - $\$B\$4 \geq 0.0001$
 - $\$B\$522 \leq 17$
 - $\$D\$6 \leq 0$
 - $\$H\$12 \leq \$H\10
 - $\$H\$3 \geq 0.04$
- Buttons:** 실행(S), 닫기, 옵션(O)..., 초기화(R), 도움말(H), 추정(G), 추가(A)..., 변경(C)..., 삭제(D)

Additional solution

◆ 메탈코크 : 형상과 성능은 비슷하나 무게가 많이 나감

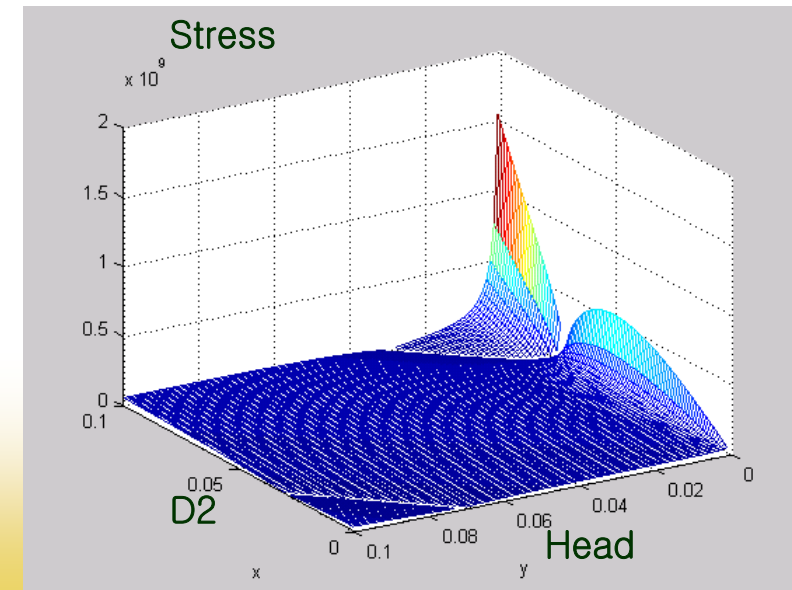
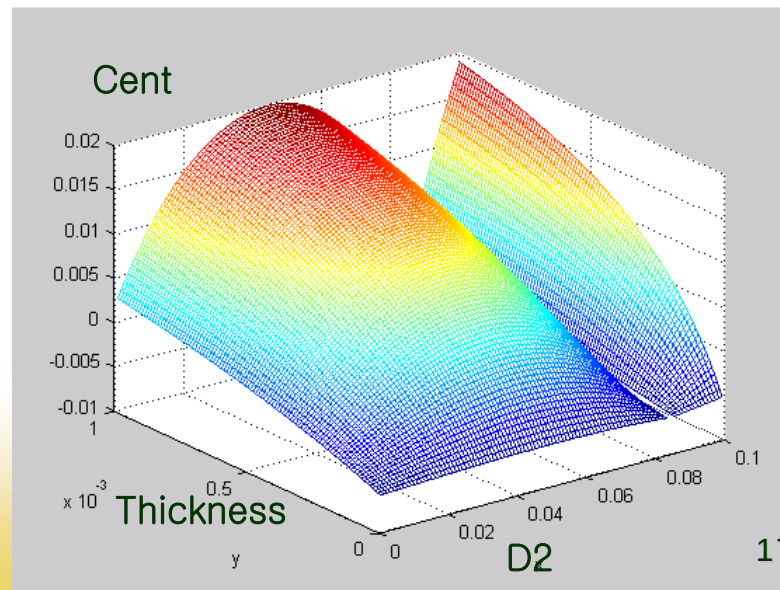
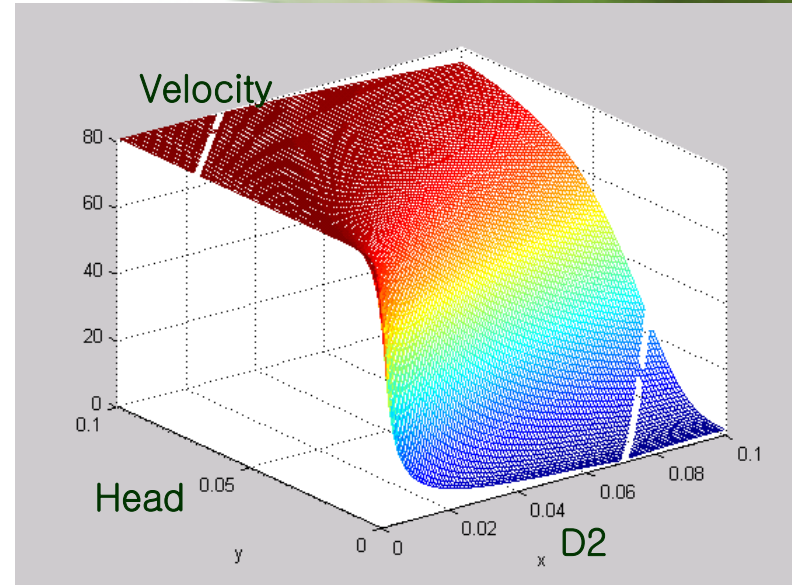
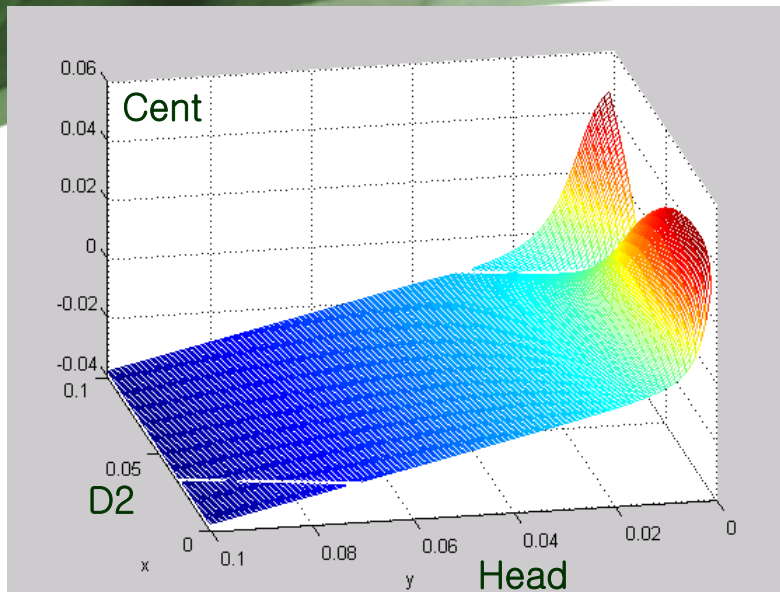
→ 밀도가 낮은 플라스틱재료 선정

(Nylon type 6/6 : ρ :1140 kg/m³

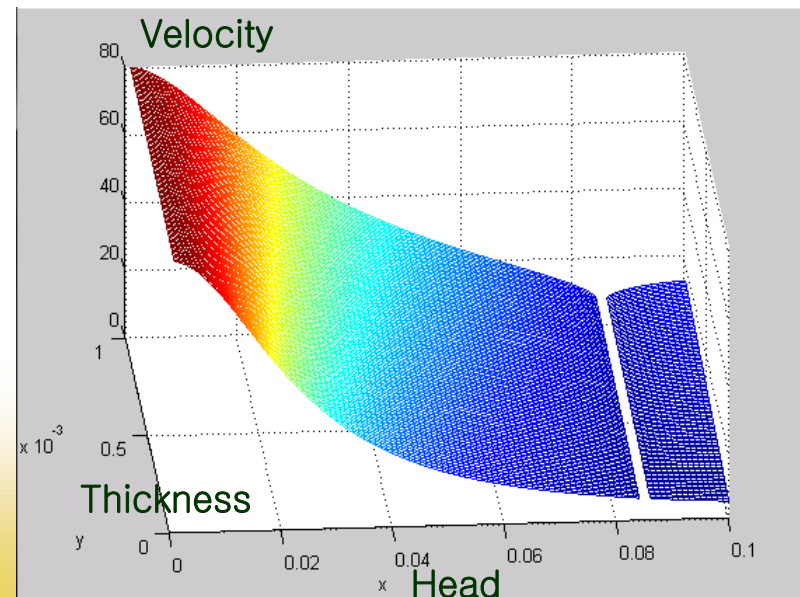
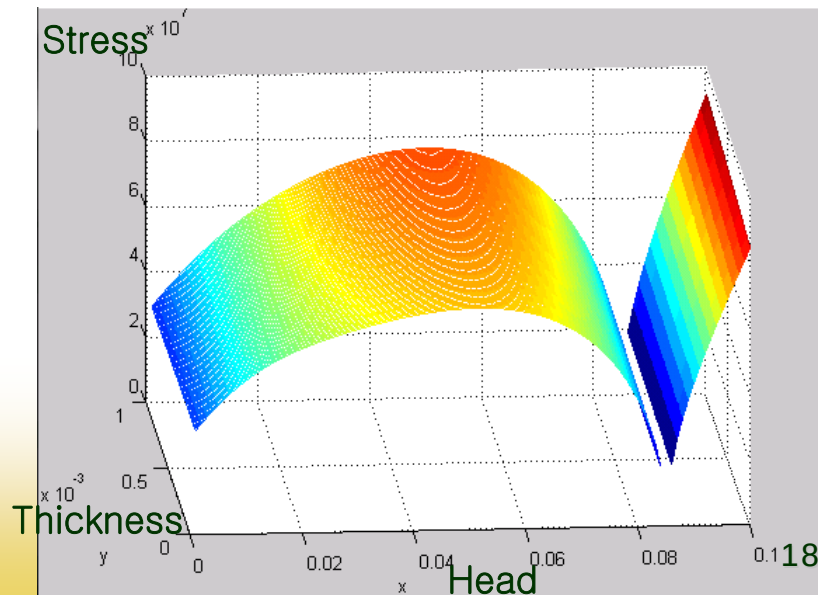
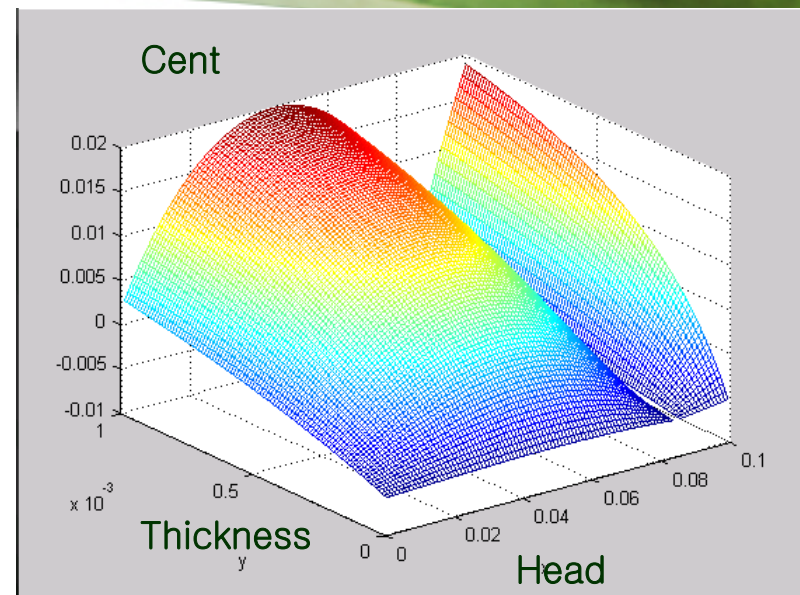
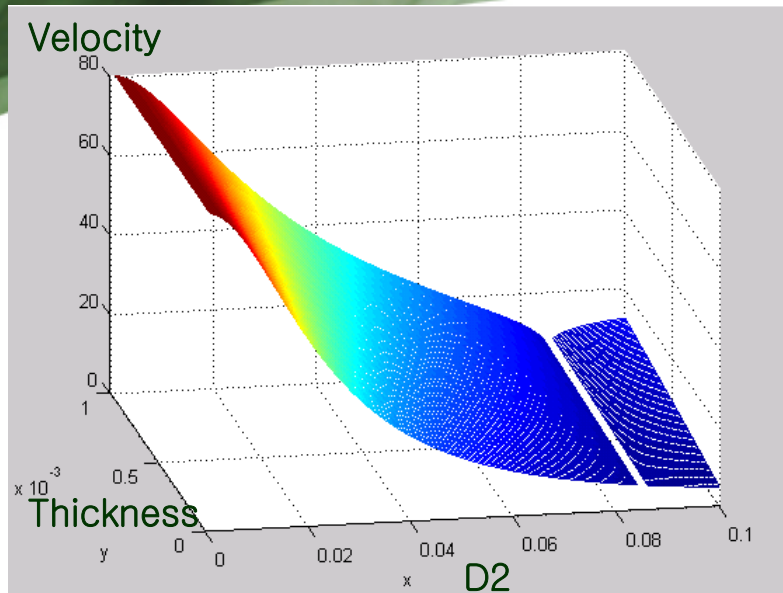
σ_{all} = 95 Mpa)

	Radius of head	thickness	Outer diameter	Mass
Real Value	0.015 m	0.002 m	0.03 m	0.005 kg
Excel solver (conjugate)	0.0145 m	0.0001 m	0.04 m	0.00939 kg
Fmincon	0.0137 m	0.0001 m	0.0269 m	<u>0.0078 kg</u>
patternsearch	0.015 m	0.0001 m	0.02 m	0.009736 kg

Analysis



Analysis



Analysis

- ◆ 제약조건에 적분식을 포함한 복잡한 식과 목적함수 값이 포함되어 식이 난해함
- ◆ 설계변수를 5개 까지 증가시켜봤으나 목적함수는 작아지나 형상이 솥뚜껑모양으로 나옴
- ◆ 형상, 무게 유지를 위해서는 밀도가 낮은 재료를 사용 해야 함 -> 플라스틱, 신소재

References

- ◆ Principles of fluid mechanics
 - Andreas N.Alexandrou
- ◆ 변형 및 파괴역학
 - 이동녕, 김정수, 이성근 공역
- ◆ Mechanical engineer' s handbook
 - Myer Kutz
- ◆ Vector mechanics for engineers
 - Ferdinand P.Beer