Story by

다이빙대의 최적화

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기계공학부 김명준
양종문


INDEX
1. Project Statement
2.Data and Information
3.Design Variables
4.Criterion
5.Constraints
6.Excel & Matlab 을 통한 분석
REUTERS

1. Project Statement

1 Project Statement

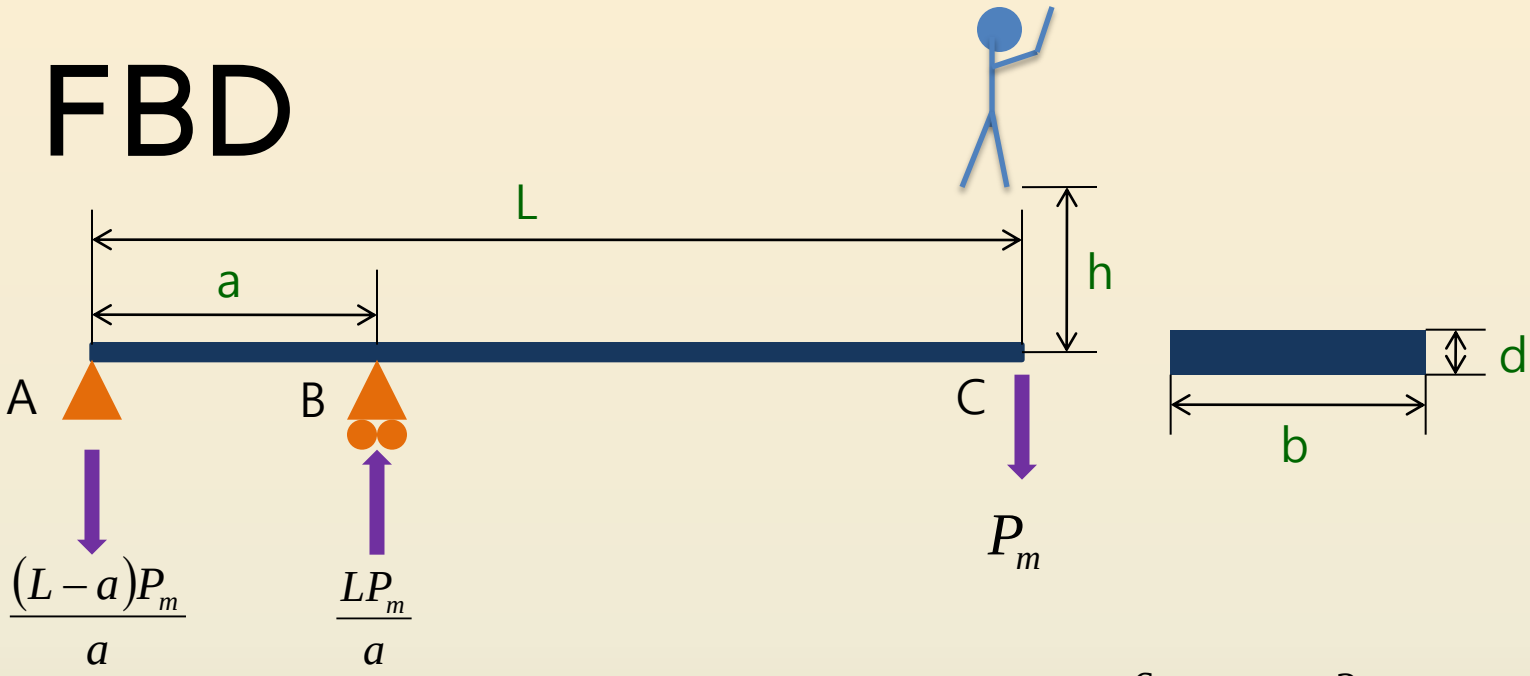
최대높이로 점프 할 수 있는 다이빙대의 최적설계

접근: 사람이 최대로 높이 뛸 수 있는 조건은 다이빙대가 눌려지는 변형량에 비례한다고 볼 수 있으므로 다이빙대의 최대 변형량을 구한다

2. Data and Information

2 Data and information

FBD



$L = 3.6576m(12\,ft)$

$E = 45\times10^9\,N/m^2$

$h = 0.5m$

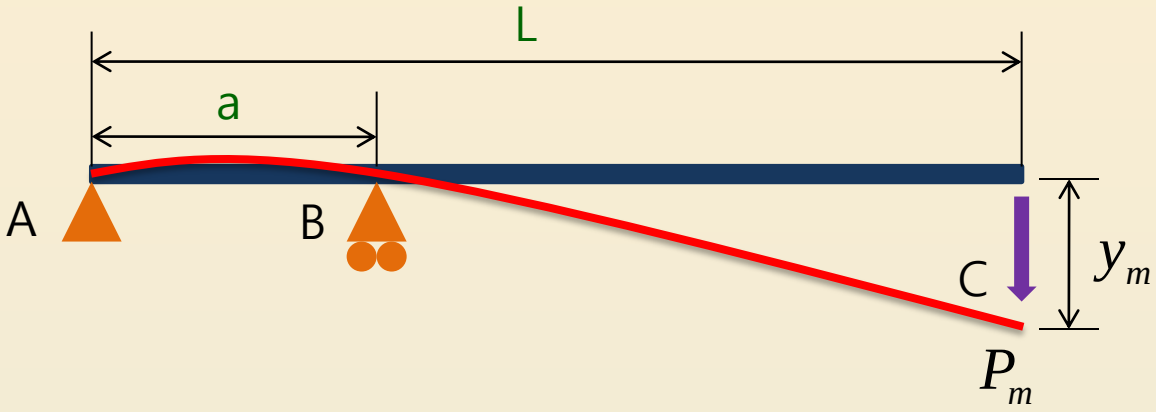
$a = 1.4m$

$\sigma_a = 50\times10^6\,N/m^2$

$\theta_a = 1^\circ = 0.01745rad$

$I = \frac{bd^3}{12}$

2 Data and information



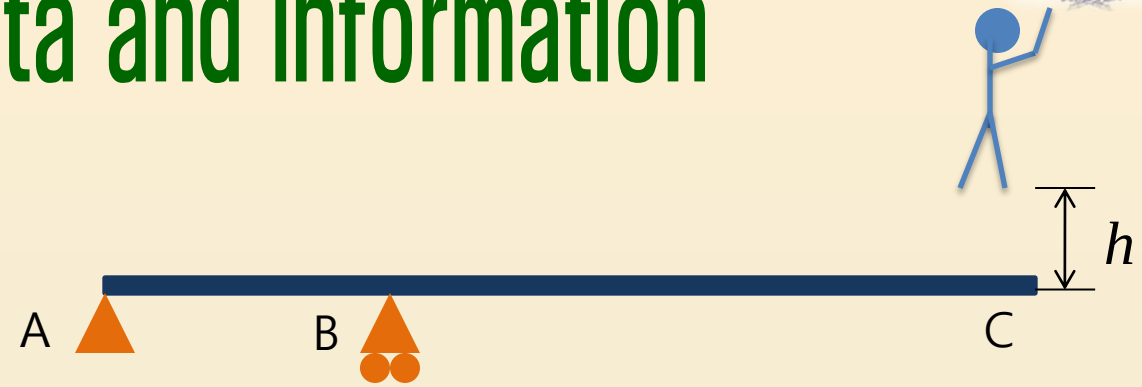
$$y_m = P_m \times \alpha$$

Where α : *Influence coefficient*

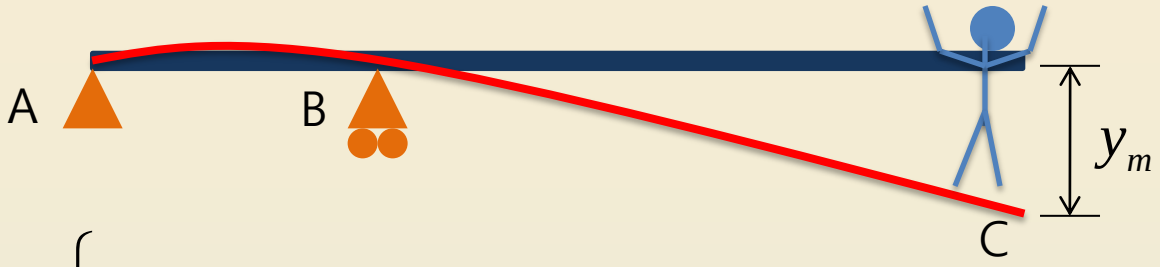
P_m : *Equivalent static load*

2 Data and information

Position 1



Position 2



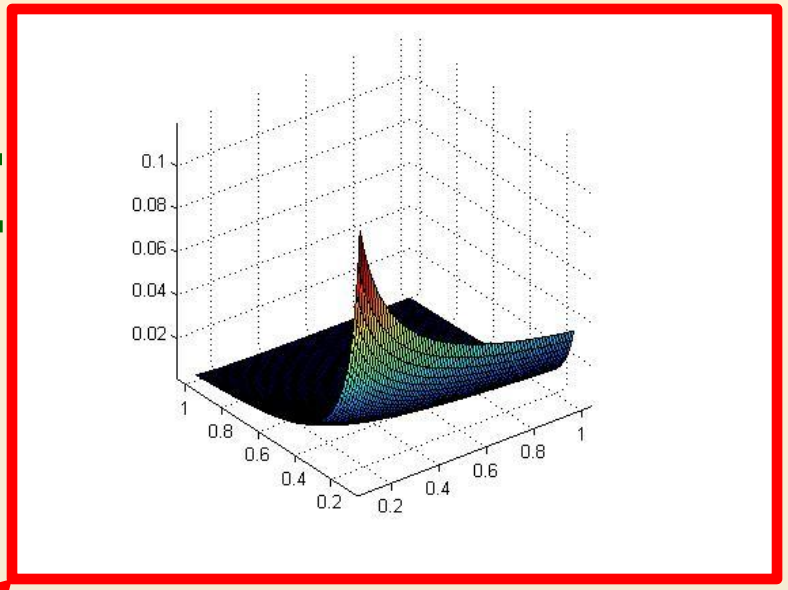
Work-Energy Method

$$work = W(h + y_m) \quad \leftarrow \quad W = 700N$$

$$U = \frac{1}{2} P_m \times y_m = \frac{1}{2} \frac{{y_m}^2}{\alpha}$$

$$work = U \quad \Rightarrow \quad \boxed{W(h + y_m) = \frac{1}{2} \frac{{y_m}^2}{\alpha}}$$

2 Data and informat



$$W(h+y_m)=\frac{1}{2}\frac{{y_m}^2}{\alpha}$$

$${y_m}^2+(-2\alpha W)y_m+(-2\alpha Wh)=0$$

$$\therefore \quad y_m=\alpha W+\sqrt{\alpha^2W^2+2\alpha Wh}$$

* 단, y_m의 해 중에서 최대값을 원하기때문에

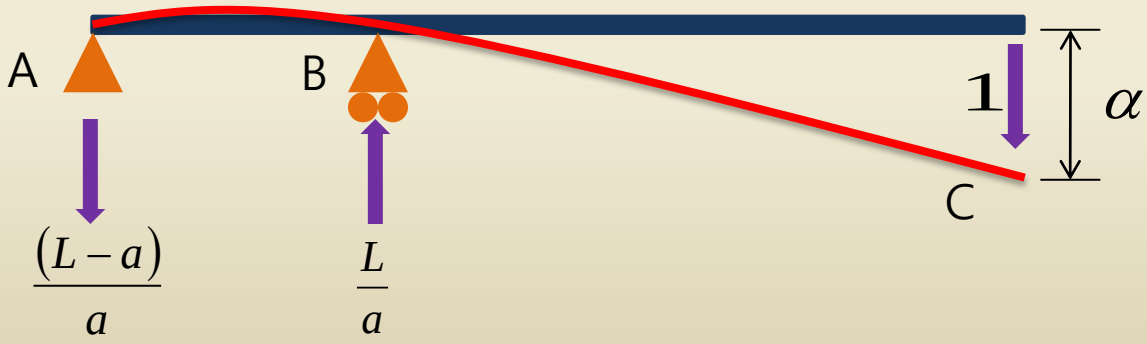
$\sqrt{}$앞의 $\pm$부호 중 $+$부호만사용

2 Data and information

Determination of Influence Coefficient α

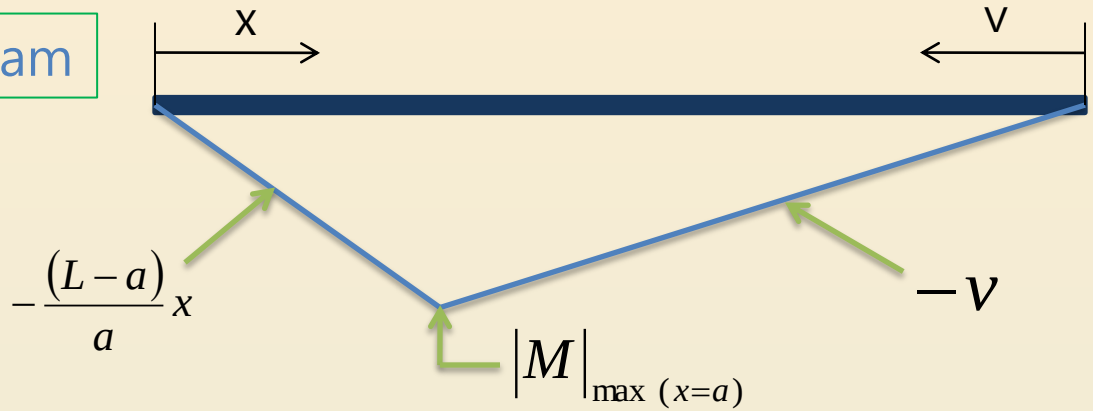
$$y_m = P_m \times \alpha$$

$$P_m = 1 \quad \Rightarrow \quad y_m = \alpha$$



2 Data and information

M-Diagram



Strain Energy in Deflection & Strain Energy in Bending

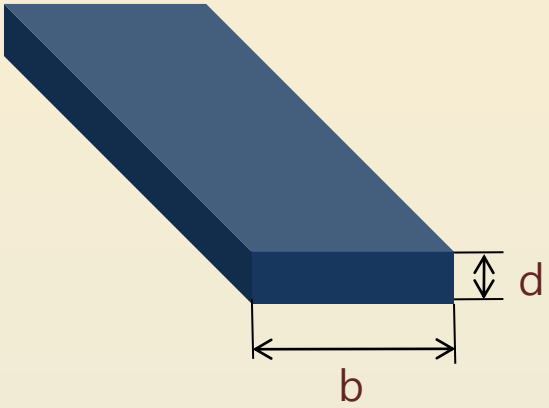
$$U = \frac{1}{2}\times 1\times \alpha = \sum\int \frac{M^2}{2EI}dx$$

$$\frac{\alpha}{2} = \frac{1}{2EI}\left[\int_0^a \left(-\frac{L-a}{a}x\right)^2 dx + \int_0^{L-a}(-v)^2 dv\right]$$

$$\alpha = \frac{1}{3EI}\left[(L-a)^2 L\right]$$

3. Design Variables

3 Design variables



b: 폭

d: 두께

4. Criterion

4 Criterion

$$y_m = \alpha W + \sqrt{\alpha^2 W^2 + 2\alpha W h}$$

y_m → 최대화

$-y_m$ → 최소화

5. Constraints

5 Constraints

$$\theta_B \le \theta_a \quad \Rightarrow \quad \frac{(L-a)WL}{3EI} \le 0.01745$$

$$\sigma \le \sigma_a \quad \Rightarrow \quad \frac{|M|_{\max} c}{I} \le 50\times 10^6$$

$$-b+6d \le 0$$

$$-b \le 0$$

$$-d \le 0$$

$$\begin{cases} |M|_{\max} = (L-a)P_m \\ \qquad\quad = (L-a)y_m/\alpha \\ I = bd^3/12 \\ c = d/2 \end{cases}$$

$$g_1 = \frac{(L-a)WL}{3EI} - 0.01745 \le 0$$

$$g_2 = \frac{|M|_{\max} c}{I} - 50\times 10^6 \le 0$$

$$g_3 = -b+6d \le 0$$

$$g_4 = -b \le 0$$

$$g_5 = -d \le 0$$

6. Excel 과 Matlab 을 통한 분석

6 Excel

$$g_1 = \frac{(L-a)WL}{3EI} - 0.01745 \le 0$$

$$g_2 = \frac{|M|_{\max} c}{I} - 50\times10^6 \le 0$$

$$g_3 = -b + 6d \le 0$$

$$g_4 = -b \le 0$$

$$g_5 = -d \le 0$$

	A	B	C
1	Given data		
2	Sig_a	5E+07	Pa
3	The_a	0.01745	rad
4	L	3.6576	m
5	w	700	N
6	E	4.5E+10	Pa
7	h	0.5	m
8	a	1.4	m

	Design Vriables	
12		
13	b	0.8
14	d	0.13333

	Constraints	
12		
13	g1	-0.01734629
14	g2	-50000024.1
15	g3	-0.8
16	g4	-0.13333333
17	g5	0

	Ym'
12	
13	-0.02535

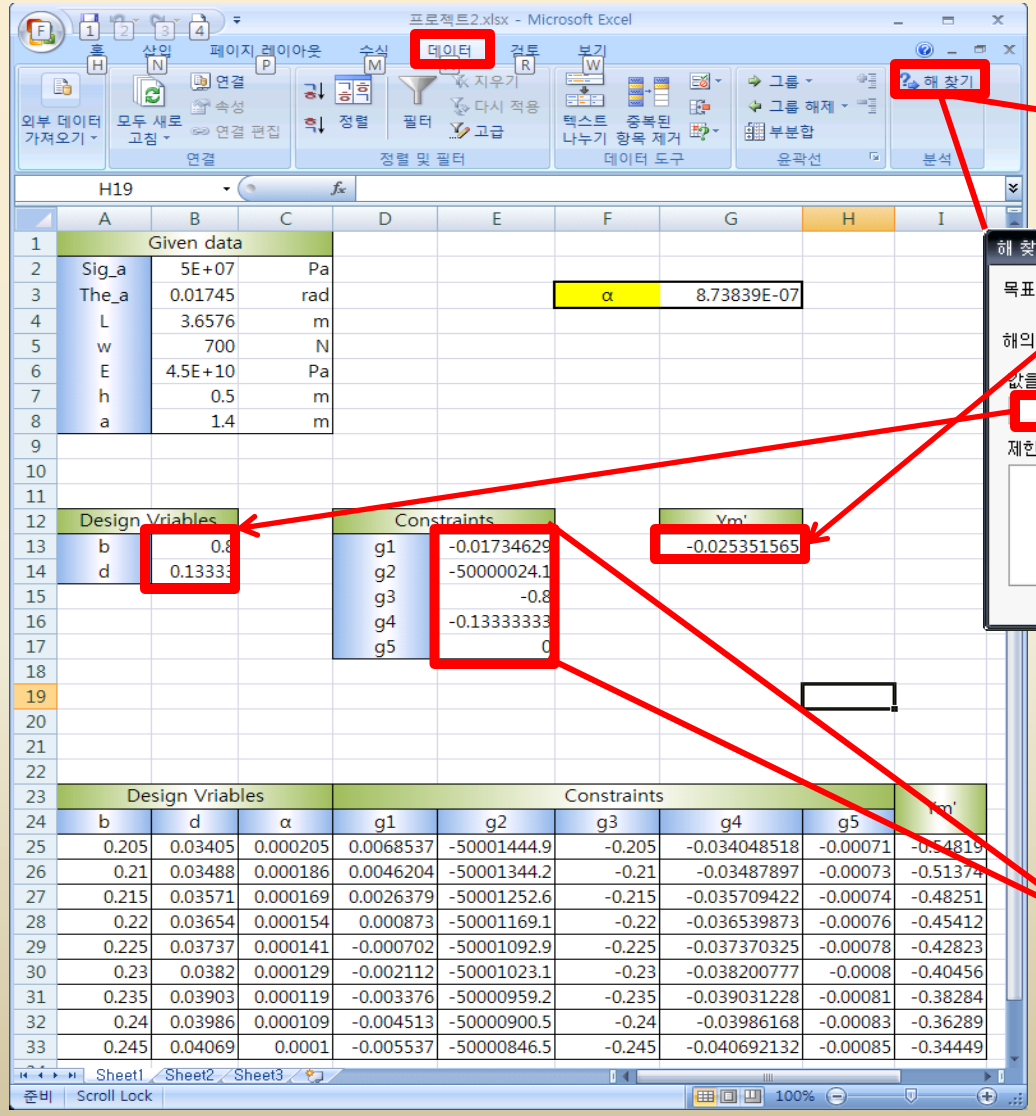
	Design Vriables			Constraints					Ym'
23									
24	b	d	α	g1	g2	g3	g4	g5	
25	0.205	0.03405	0.000205	0.0068537	-50001444.9	-0.205	-0.034048518	-0.00071	-0.54819
26	0.21	0.03488	0.000186	0.0046204	-50001344.2	-0.21	-0.03487897	-0.00073	-0.51374
27	0.215	0.03571	0.000169	0.0026379	-50001252.6	-0.215	-0.035709422	-0.00074	-0.48251
28	0.22	0.03654	0.000154	0.000873	-50001169.1	-0.22	-0.036539873	-0.00076	-0.45412
29	0.225	0.03737	0.000141	-0.000702	-50001092.9	-0.225	-0.037370325	-0.00078	-0.42823
30	0.23	0.0382	0.000129	-0.002112	-50001023.1	-0.23	-0.038200777	-0.0008	-0.40456
31	0.235	0.03903	0.000119	-0.003376	-50000959.2	-0.235	-0.039031228	-0.00081	-0.38284
32	0.24	0.03986	0.000109	-0.004513	-50000900.5	-0.24	-0.03986168	-0.00083	-0.36289
33	0.245	0.04069	0.0001	-0.005537	-50000846.5	-0.245	-0.040692132	-0.00085	-0.34449

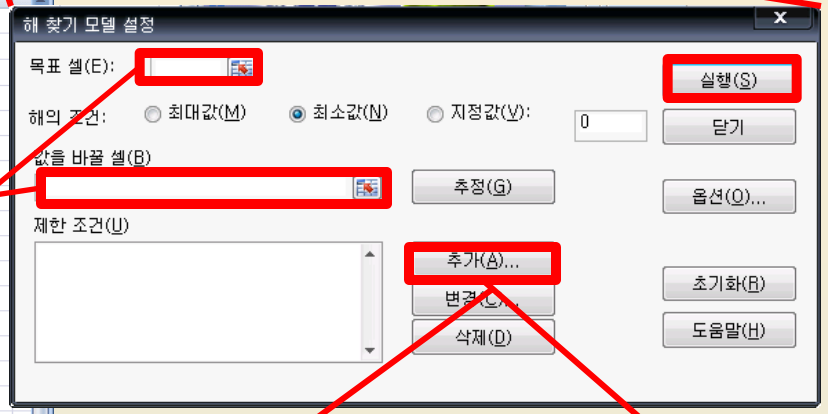
Sheet1 Sheet2 Sheet3

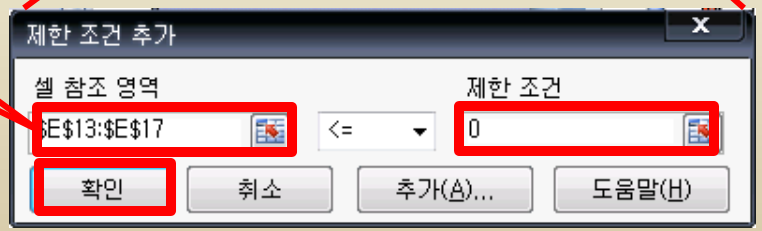
준비 Scroll Lock 100%

6 Excel

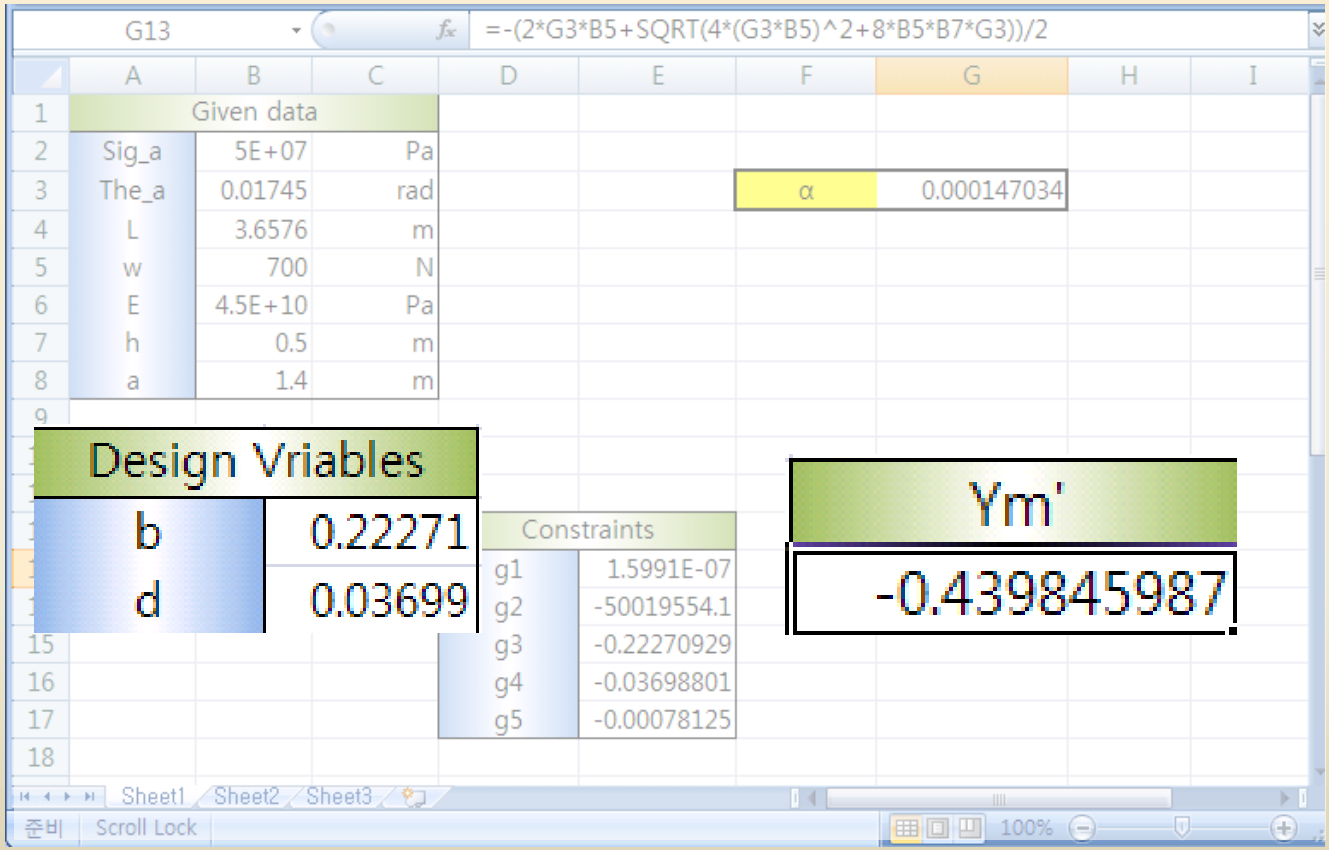
최적설계


프로젝트2.xlsx - Microsoft Excel
해 찾기
H19
Given data
Sig_a 5E+07 Pa
The_a 0.01745 rad
L 3.6576 m
w 700 N
E 4.5E+10 Pa
h 0.5 m
a 1.4 m
α 8.73839E-07
Design Vriables
b 0.8
d 0.13333
Constraints
g1 -0.01734629
g2 -50000024.1
g3 -0.8
g4 -0.13333333
g5 0
Ym'
-0.025351565
Design Vriables
Constraints
b d α g1 g2 g3 g4 g5
0.205 0.03405 0.000205 0.0068537 -50001444.9 -0.205 -0.034048518 -0.00071 -0.54819
0.21 0.03488 0.000186 0.0046204 -50001344.2 -0.21 -0.03487897 -0.00073 -0.51374
0.215 0.03571 0.000169 0.0026379 -50001252.6 -0.215 -0.035709422 -0.00074 -0.48251
0.22 0.03654 0.000154 0.000873 -50001169.1 -0.22 -0.036539873 -0.00076 -0.45412
0.225 0.03737 0.000141 -0.000702 -50001092.9 -0.225 -0.037370325 -0.00078 -0.42823
0.23 0.0382 0.000129 -0.002112 -50001023.1 -0.23 -0.038200777 -0.0008 -0.40456
0.235 0.03903 0.000119 -0.003376 -50000959.2 -0.235 -0.039031228 -0.00081 -0.38284
0.24 0.03986 0.000109 -0.004513 -50000900.5 -0.24 -0.03986168 -0.00083 -0.36289
0.245 0.04069 0.0001 -0.005537 -50000846.5 -0.245 -0.040692132 -0.00085 -0.34449
Sheet1 Sheet2 Sheet3
준비 Scroll Lock
100%


해 찾기 모델 설정
목표 셀(E):
해의 조건: 최대값(M) 최소값(N) 지정값(V): 0
값을 바꿀 셀(B)
추정(G)
제한 조건(U)
추가(A)...
변경(C)...
삭제(D)
실행(S)
닫기
옵션(O)...
초기화(R)
도움말(H)


제한 조건 추가
셀 참조 영역
$E$13:$E$17
<=
제한 조건
0
확인
취소
추가(A)...
도움말(H)

6 Excel



G13 =-(2*G3*B5+SQRT(4*(G3*B5)^2+8*B5*B7*G3))/2

	A	B	C
1	Given data		
2	Sig_a	5E+07	Pa
3	The_a	0.01745	rad
4	L	3.6576	m
5	w	700	N
6	E	4.5E+10	Pa
7	h	0.5	m
8	a	1.4	m

α	0.000147034

Design Vriables	
b	0.22271
d	0.03699

Constraints	
g1	1.5991E-07
g2	-50019554.1
g3	-0.22270929
g4	-0.03698801
g5	-0.00078125

Ym'
-0.439845987

Sheet1 Sheet2 Sheet3

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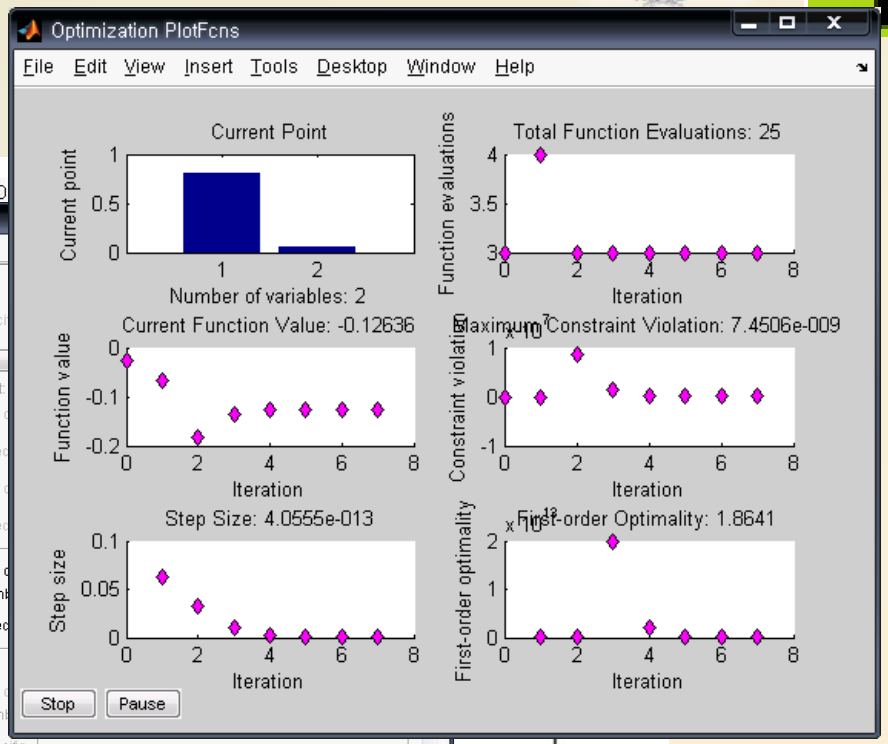
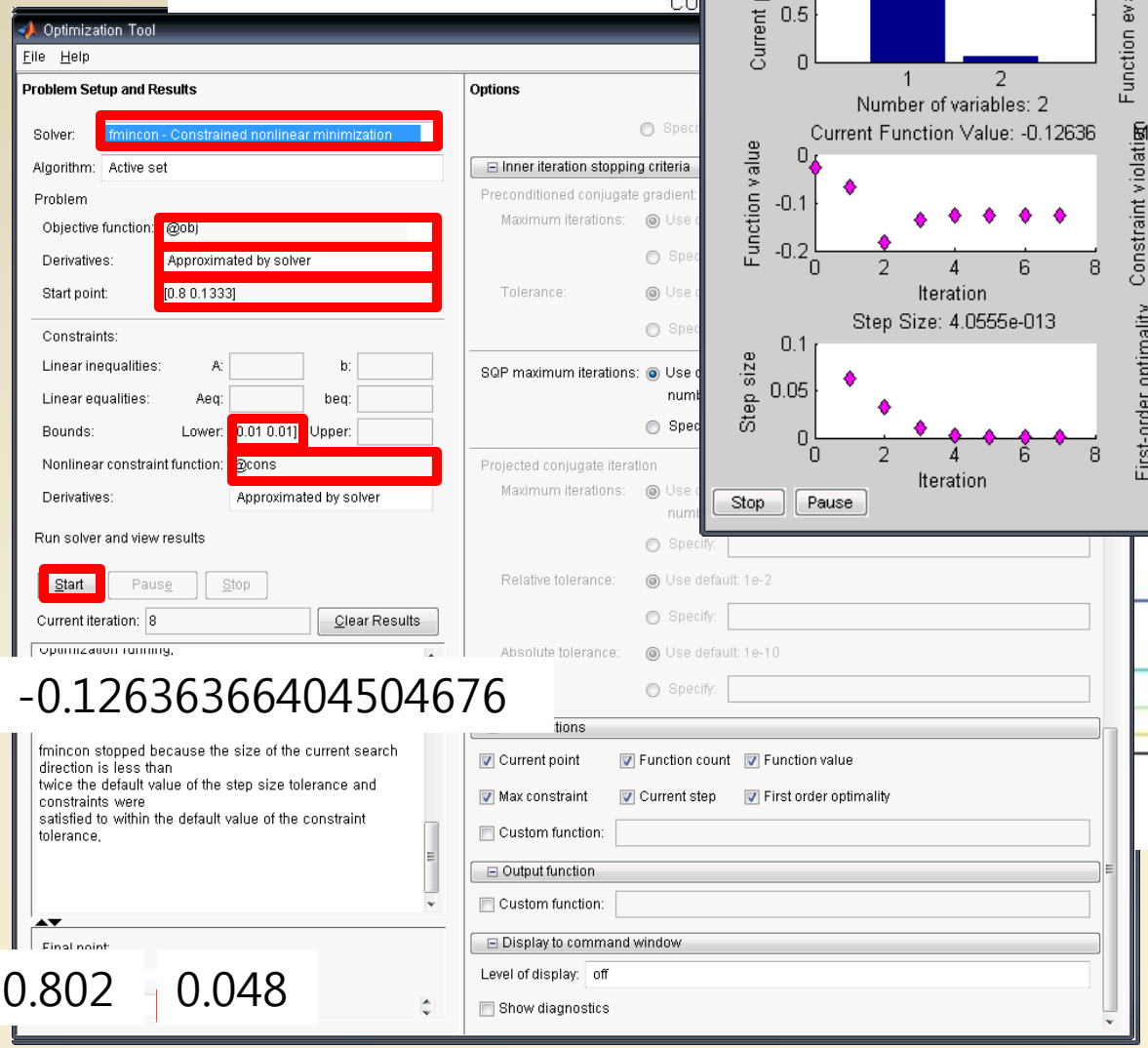
6 Matlab (fmincon)



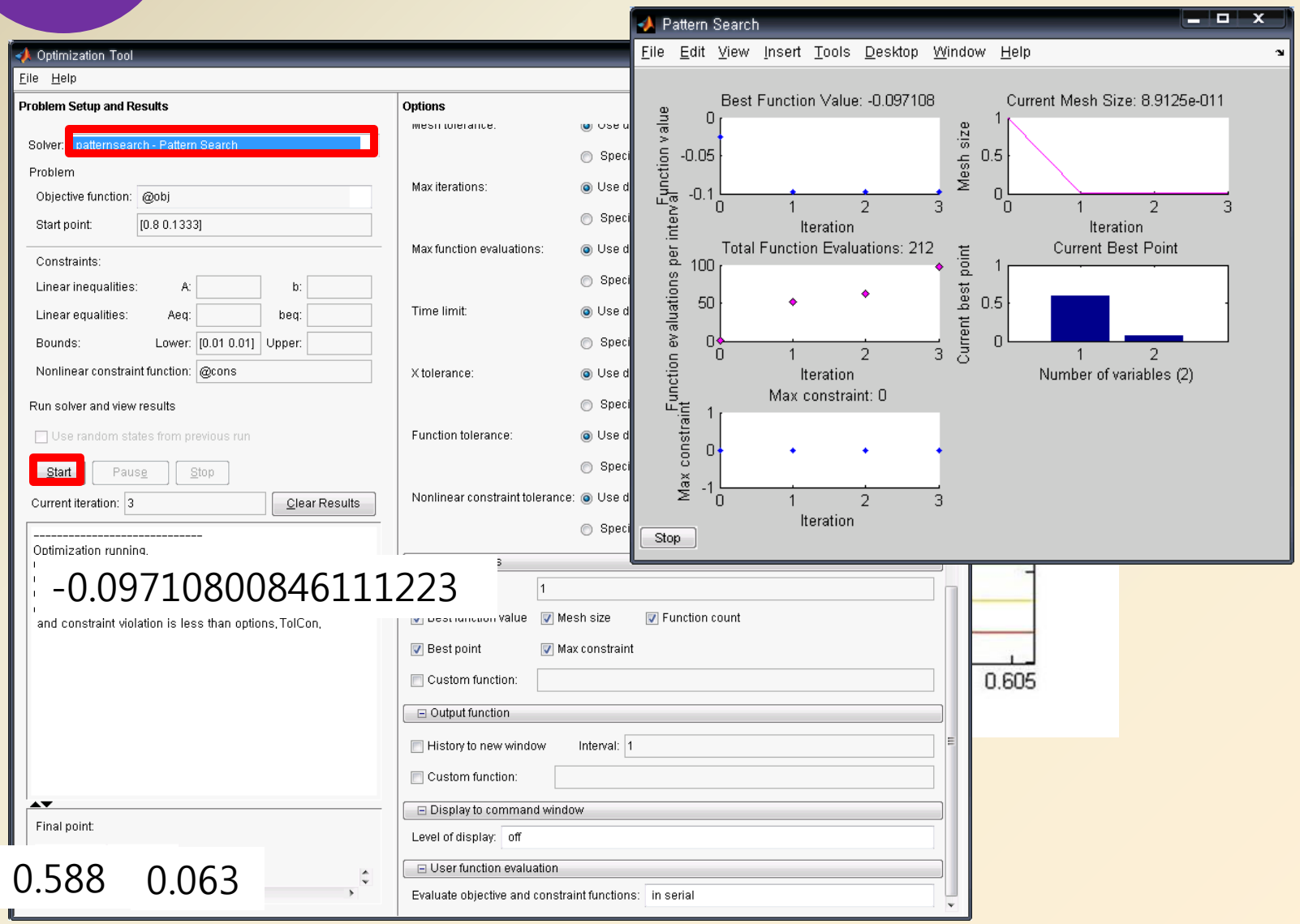


-0.1263636640450467 6

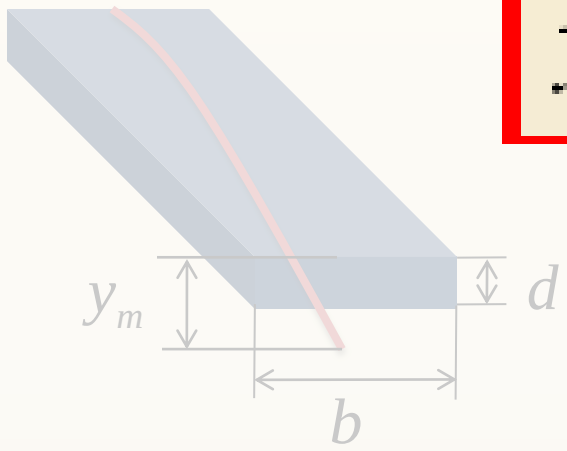
0.802 0.048

0.83

6 Matlab (Pattern Search)



7 결론



엑셀-해찾기

$b = 22.271cm, \quad d = 3.699cm$

$$y_m = 43.9846cm$$

매트랩-fmincon

$b = 80.2cm, \quad d = 4.8cm$

$y_m = 12.636cm$

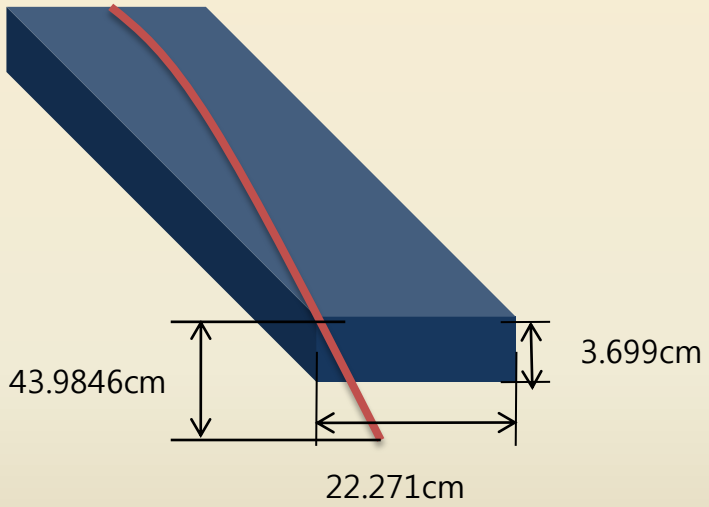
매트랩-patternsearch

$b = 58.8cm, \quad d = 6.3cm$

$y_m = 9.7108cm$

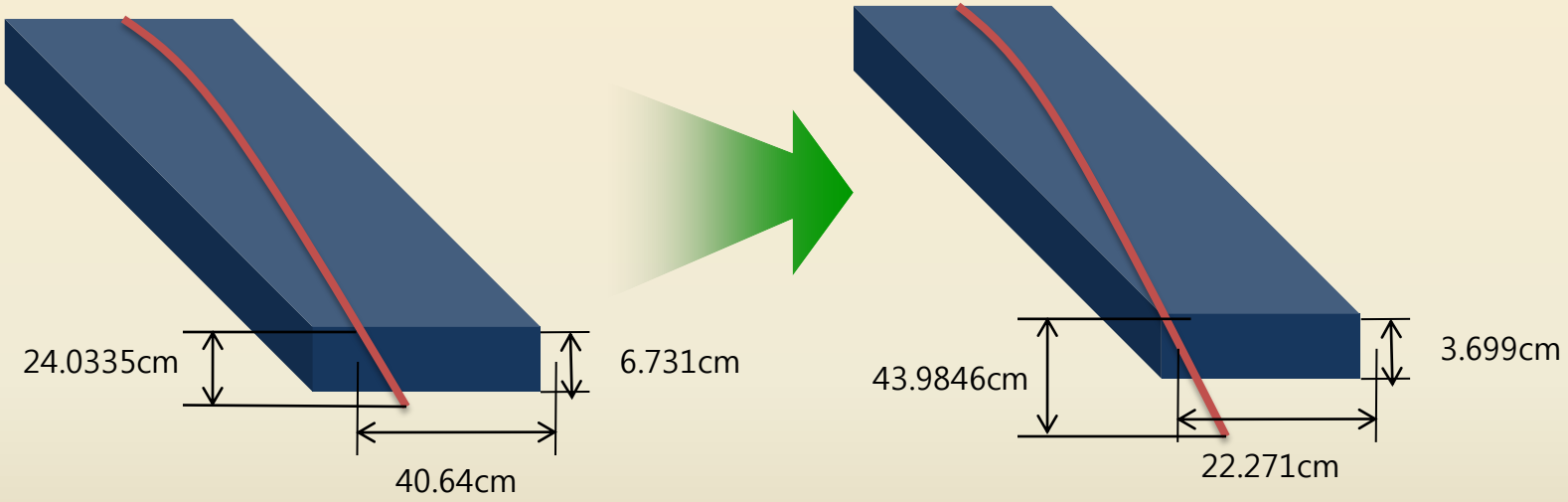
7 결론

최대 점프를 하기 위한 조건 b=22.271cm, d=3.699cm 의 단면 치수로 최대 처짐량 43.9846cm 를 얻을 수 있었고 이 설계로 최대의 점프를 낼 수 있다.



7 결론

기존다이빙대와의 비교



<기존 다이빙대>

<최적화된 다이빙대>

최적프로젝트를 마치며..

선천성설계증후군 조

The End

감사합니다.

Reference

재료역학 병진출판사
Mechanics of Materials - Beer
두산백과사전 Encyber

Thank you.