우산의 공학적 설계2
THE ROBUST DESIGN OF AN UMBRELLA

TEAM EEE 차은우 오세안

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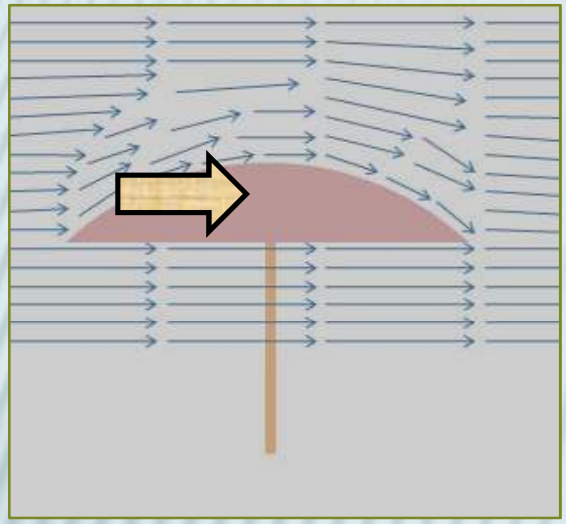
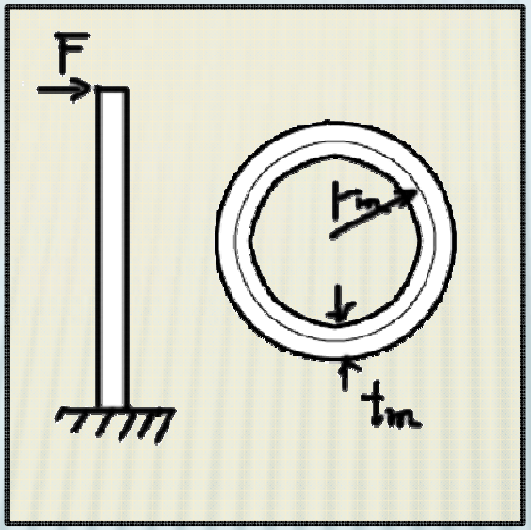
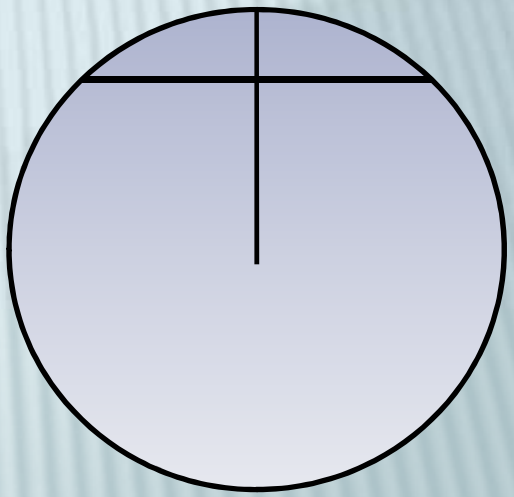
PROJECT1 REVIEW



항력

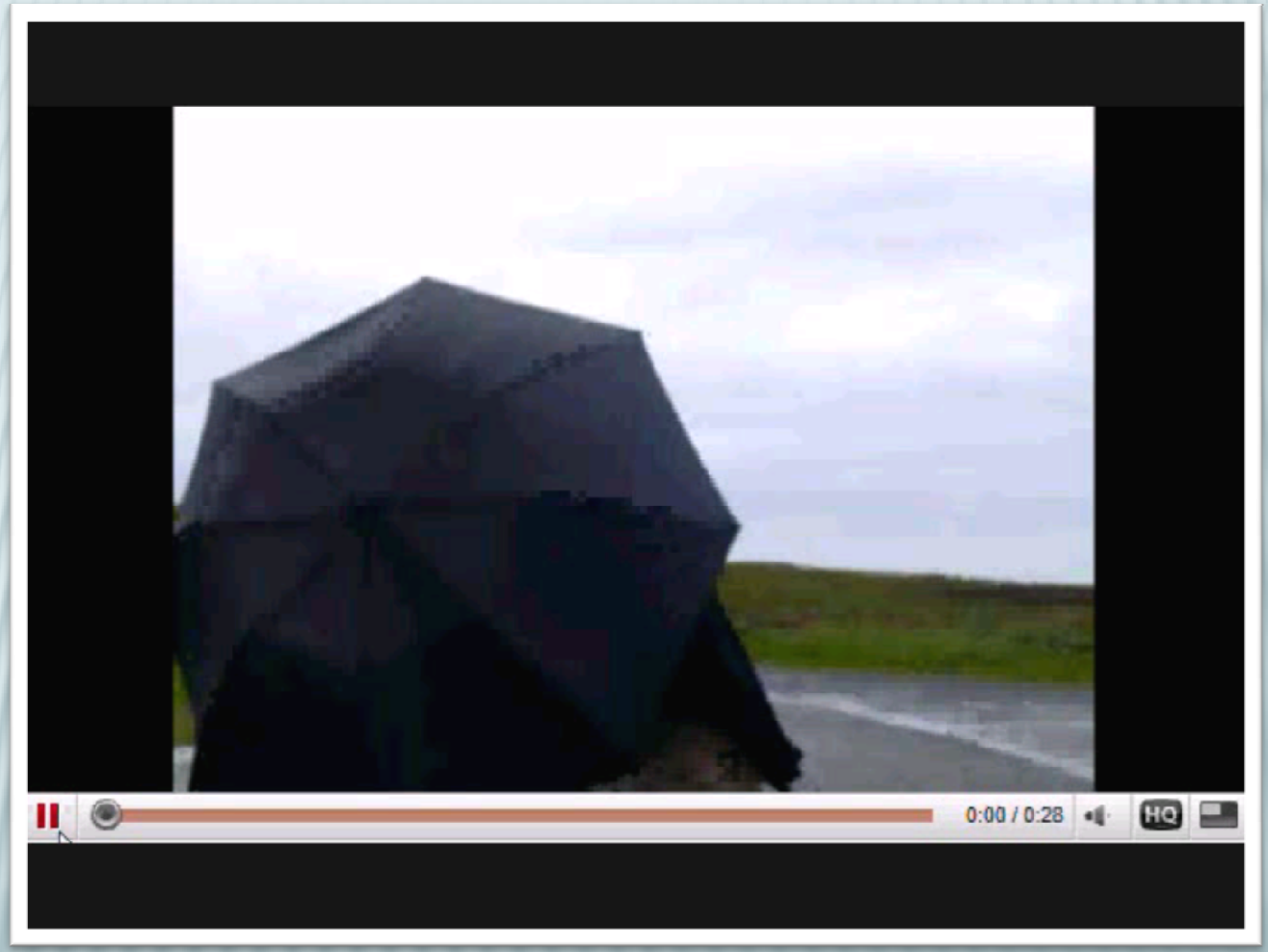


우산대



형상

동영상

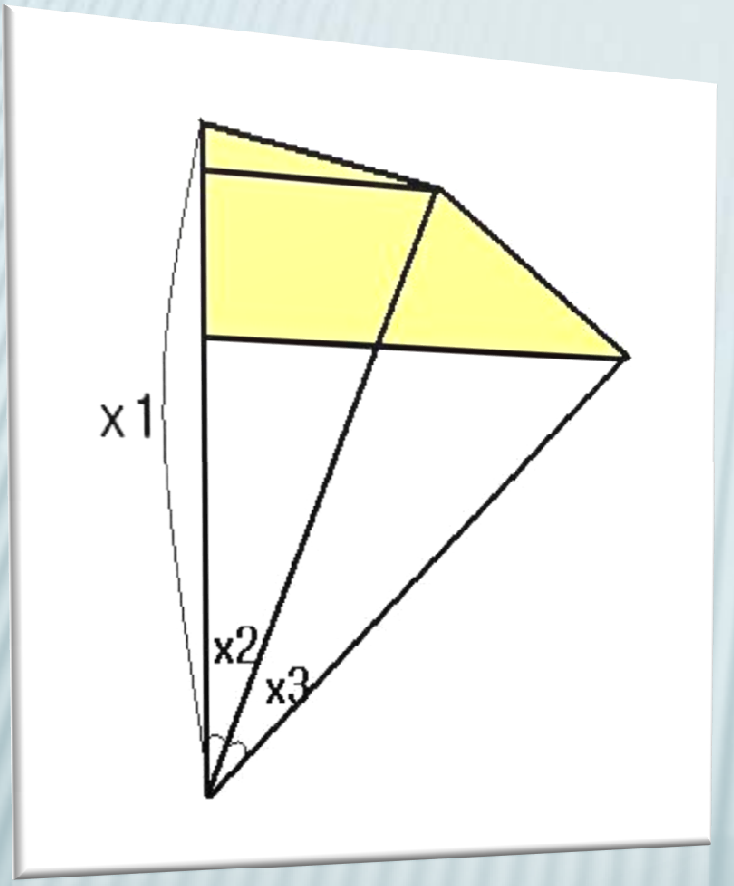


설계의 변경

Problem statement : 사람들이 자주 사용하는 2단 접이식 우산은 바람이 세게 불면 잘 뒤집혀지는 특성을 가지고 있다. 따라서 우산의 재료특성 및 모양을 유지한 채 바람이 세게 불어도 잘 뒤집혀지지 않으면서 비를 최대로 피할 수 있는 우산의 제원을 결정하는 것이 이번 설계의 목적이다.

- 뒤집어지는 순간: 우산대의 항복점 ⇒ 탄성영역내의 처짐
- 설계목표: 우산크기의 최소화 ⇒ 비를 덜 맞도록 우산표면적의 최대화
- 변수: 실제우산모양에 가깝게 설계하기 위해 변수를 추가

목적함수와 변수의 설정1



minimize $f = -x_1 \cos x_2 (\sin x_2 \cos x_3 + \cos x_2 \sin x_3)$

subject to

$$g_1 = \frac{P x_1^3}{3EI} - 0.1 \le 0$$

$$g_2 = \frac{PQ}{It} - \tau_{all} \le 0$$

$$g_3 = x_2 + x_3 - \frac{\pi}{2} \le 0$$

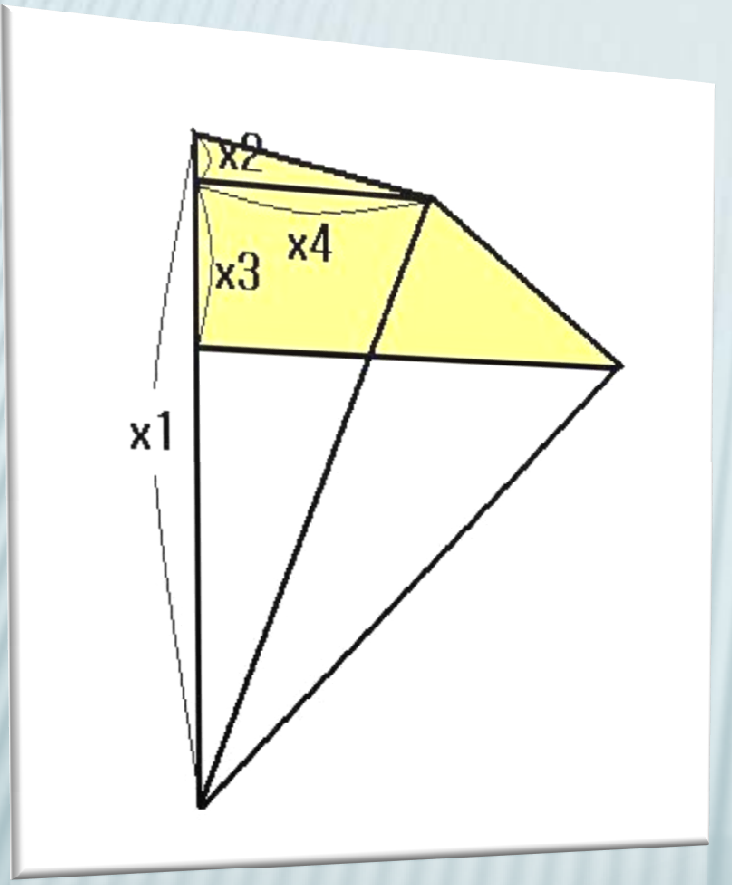
$x_i \ge 0, where\ \ i = 1\ to\ 3$

$$P = C_D \frac{1}{2} \rho A V^2$$

$$A = x_1 \cos^3 x_2 \sin x_2 + \frac{1}{2}\left[x_1 - x_1 \cos^2 x_2 - x_1 \cos x_2 \cos x_3\right]$$

$$\times \left[2x_1 \cos x_2 (\sin x_2 \cos x_3 + \cos x_2 \sin x_3) + 2x_1 \cos x_2 \sin x_2\right]$$

목적함수와 변수의 설정2



minimize $f = -\pi x_4 \sqrt{x_2^2 + x_4^2}$

$$-\pi\left(\sqrt{x_1^2 - (x_1 - x_2 - x_3)^2} + x_4\right)\sqrt{\left(\sqrt{x_1^2 - (x_1 - x_2 - x_3)^2} - x_4\right)^2 + x_3^2}$$

subject to

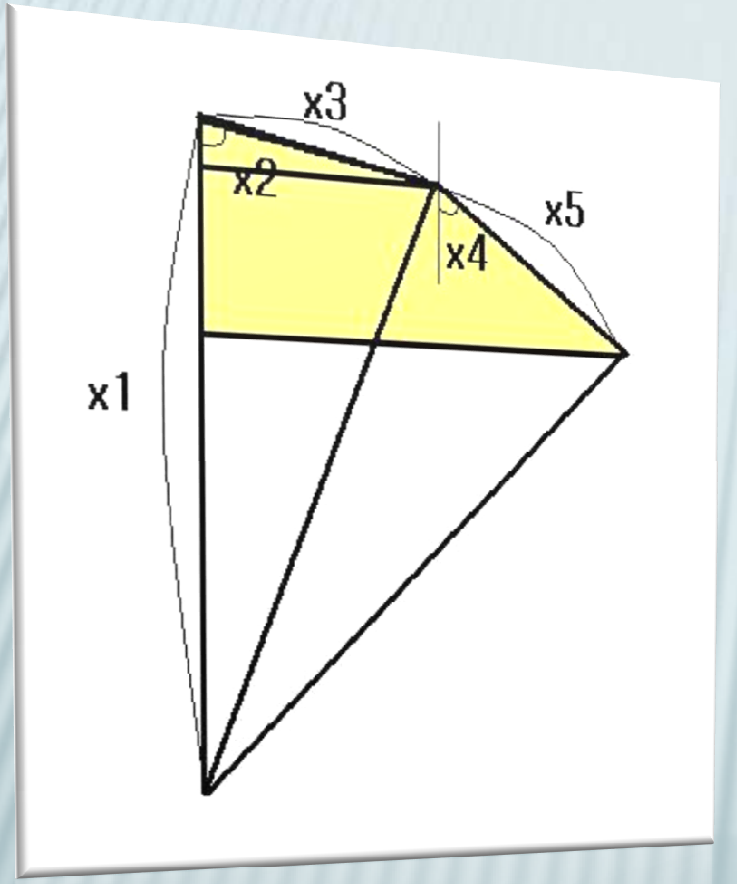
$$g_1 = 1.48213\, x_1^2\left(x_2 x_4 + x_3\sqrt{x_4 + (x_1^2 - (x_1 - x_2 - x_3)^2}\right) - 0.1763 \le 0$$

$$g_2 = x_2 + x_3 - x_1 \le 0$$

$$g_3 = x_4 - \sqrt{x_4 + (x_1^2 - (x_1 - x_2 - x_3)^2} \le 0$$

$$x_i \ge 0 \;\; i = 1 \;\; to \;\; 4$$

목적함수와 변수의 설정3



minimize $f = -x_3^2 \sin x_2 - 2x_5(x_3 \sin x_2 + x_5 \sin x_4)$

subject to

$$g_1 = \frac{Px_1^3}{3EI} - \frac{3}{54.5}x_1 \le 0$$

$$g_2 = x_3 \cos x_2 + x_5 \cos x_4 - x_1 \le 0$$

$$g_3 = 0.3 - x_1 + x_3 \cos x_2 + x_5 \cos x_4 \le 0$$

$$g_4 = x_2 - \frac{\pi}{2.2} \le 0$$

$$g_5 = x_4 - \frac{\pi}{6} \le 0$$

$$g_6 = x_3 - 0.3 \le 0$$

$$g_7 = x_5 - 0.3 \le 0$$

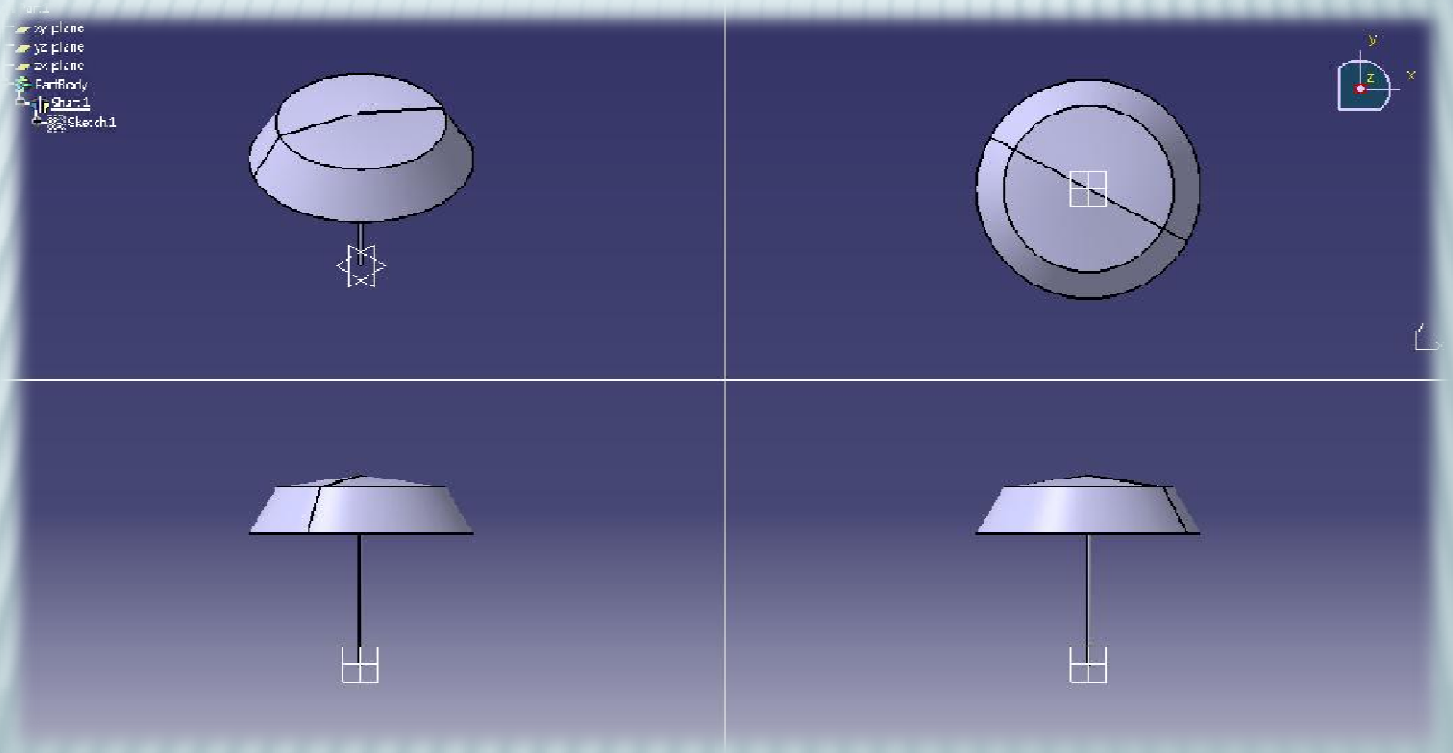
$x_i \ge 0$, *where* $i = 1$ *to* 5

$$P = C_D \frac{1}{2}\rho A V^2$$

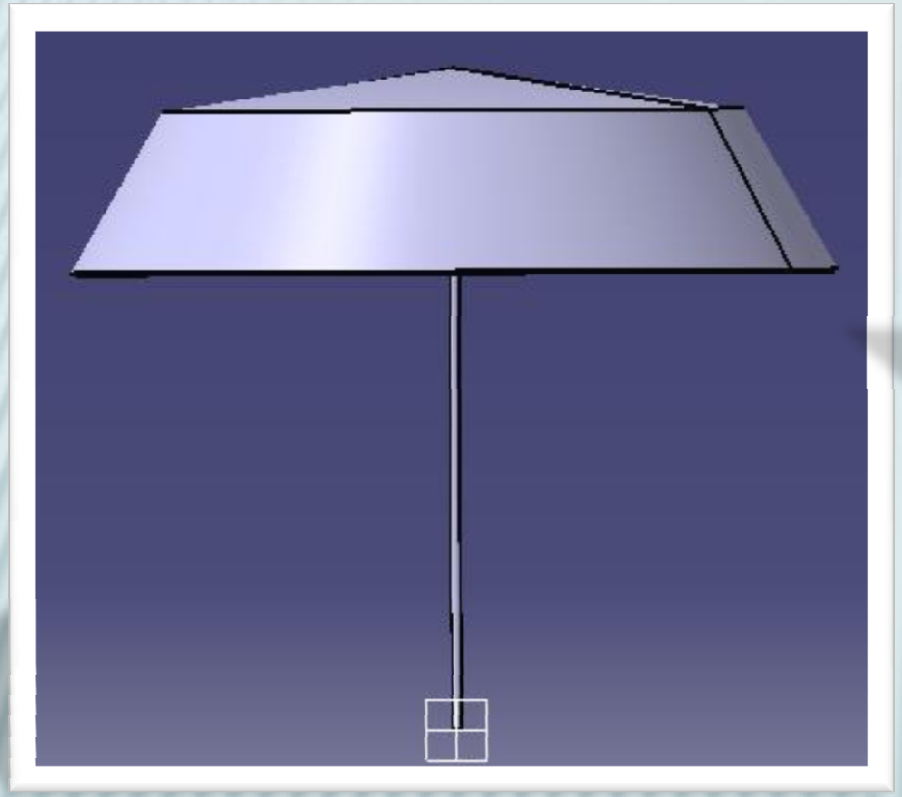
$$A = \frac{1}{2}x_3^2 \sin 2x_2 + \frac{1}{2}x_5^2 \sin 2x_4 + x_3 x_5 \sin x_2 \cos x_4$$

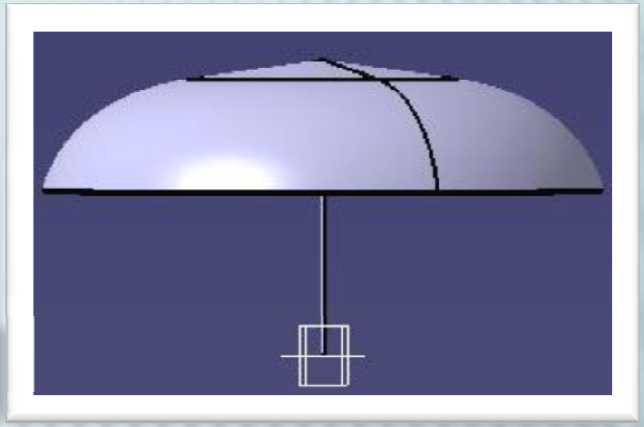
최적값

	x1	x2	x3	x4	x5	f
fmincon	0.6884	1.428	0.3	0.5236	0.1929	-0.2222
pattern	0.904172	1.427965	0.25064	0.523599	0.133971	-0.13763
Excel	0.967727	1.427997	0.3	0.523599	0.3	-0.00307

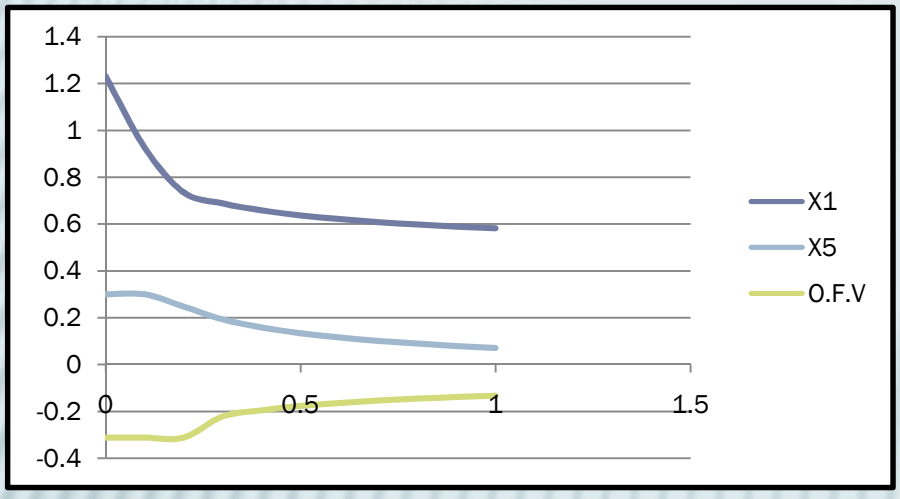


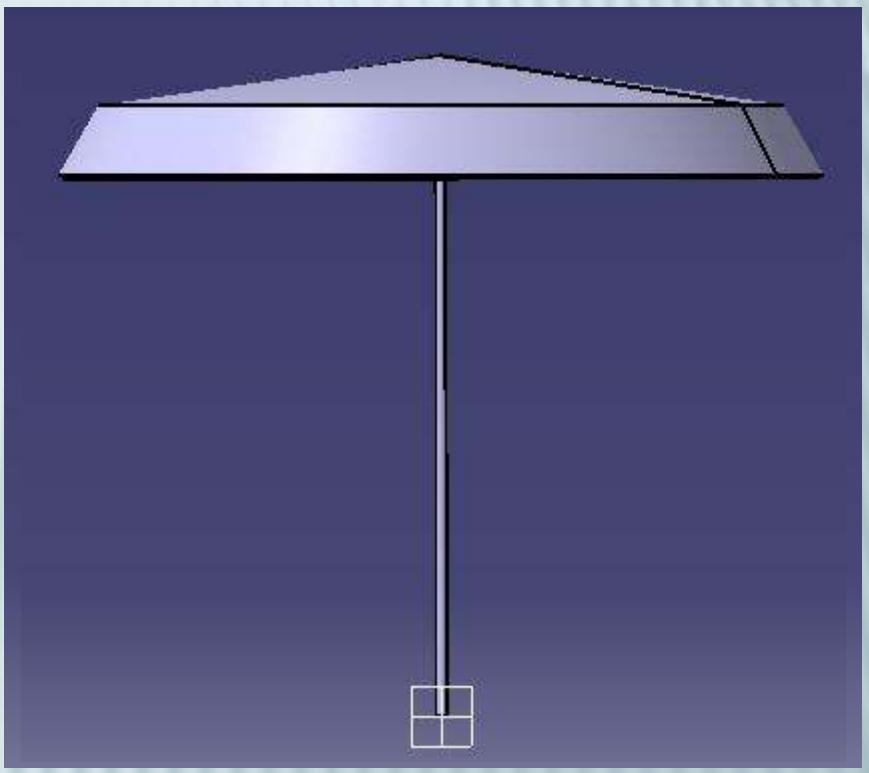
실제 우산과의 비교





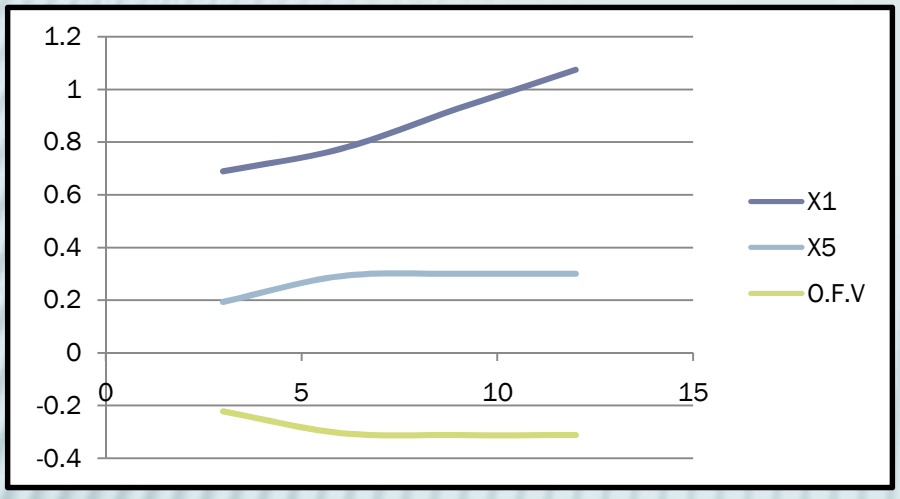
민감도 해석 - 항력계수의 영향



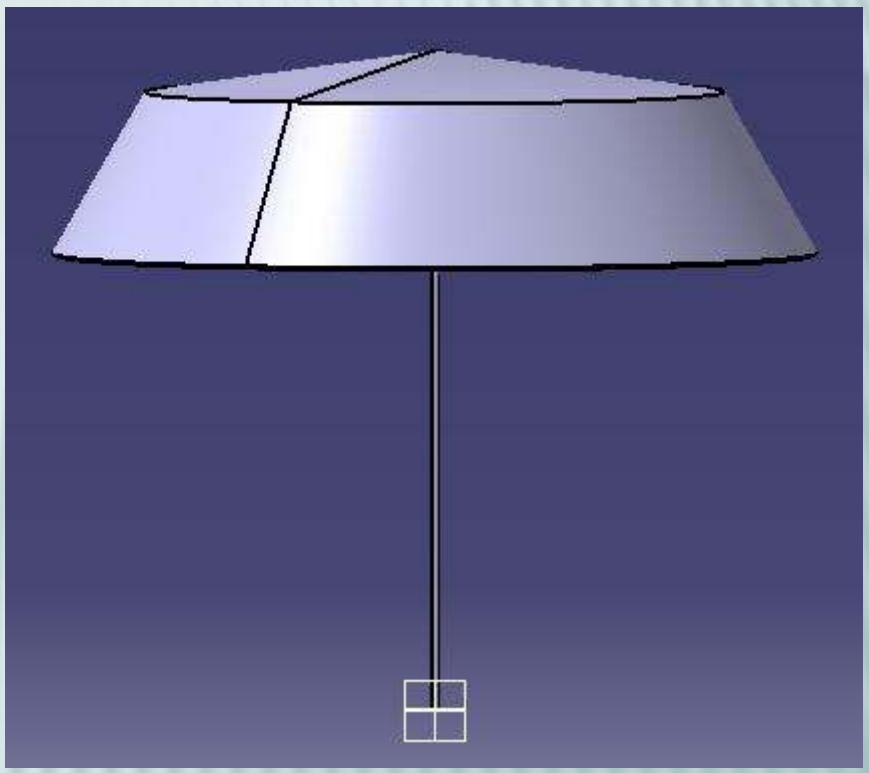


C_d	X1	X2	X3	X4	X5	O.F.V
0	1.230545	1.427997	0.3	0.523599	0.3	-0.31225
0.1	0.926992	1.427997	0.3	0.523599	0.3	-0.31225
0.2	0.735785	1.427997	0.3	0.523599	0.247611	-0.31225
0.3	0.688366	1.427997	0.3	0.523599	0.192857	-0.22222
0.4	0.658457	1.427997	0.3	0.523599	0.158321	-0.19564
0.5	0.637289	1.427997	0.3	0.523599	0.133878	-0.17756
0.6	0.621265	1.427997	0.3	0.523599	0.115375	-0.16426
0.7	0.608582	1.427997	0.3	0.523599	0.10073	-0.15398
0.8	0.598222	1.427997	0.3	0.523599	0.088767	-0.14574
0.9	0.589555	1.427997	0.3	0.523599	0.078759	-0.13896
1	0.582169	1.427997	0.3	0.523599	0.070231	-0.13326

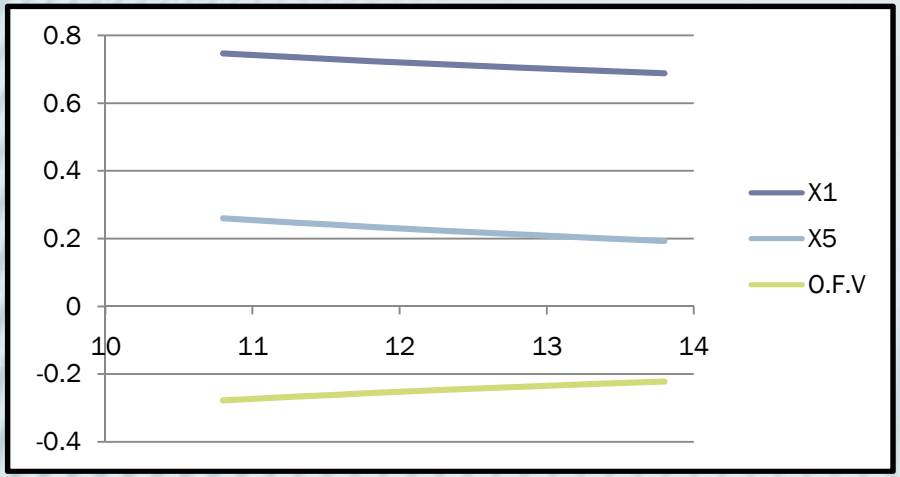
민감도 해석 - 풍속의 영향



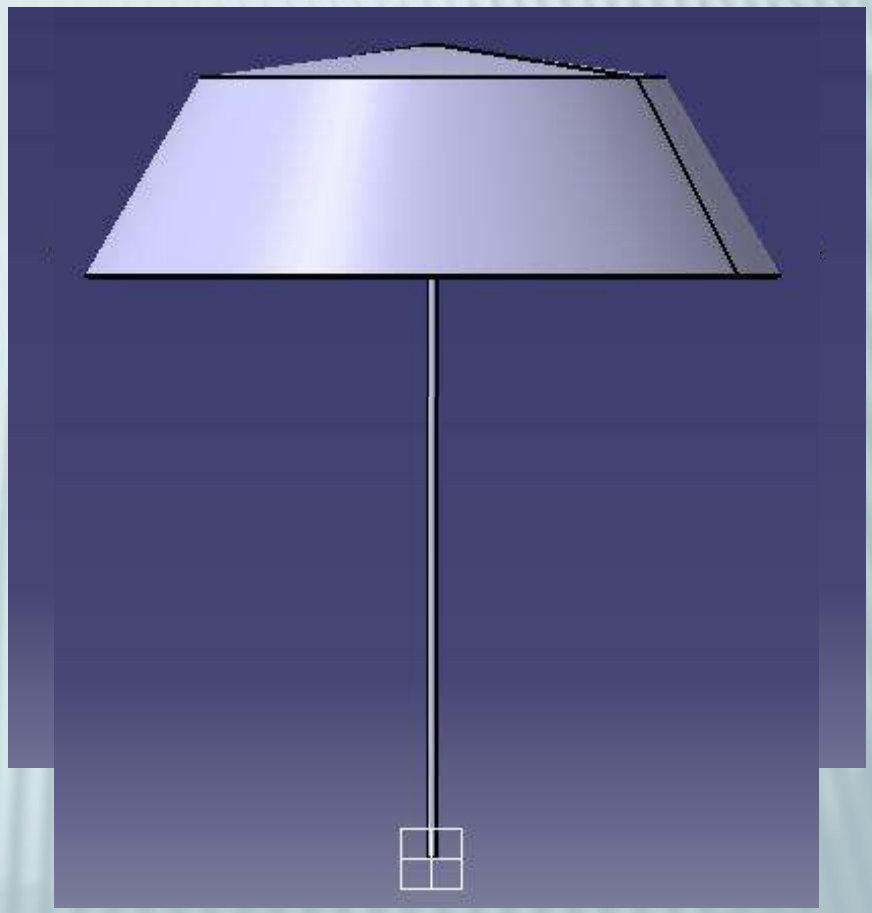
V	X1	X2	X3	X4	X5	O.F.V
10.8	0.746513	1.427997	0.3	0.523599	0.259999	-0.2773
11.8	0.724427	1.427997	0.3	0.523599	0.234497	-0.25584
12.8	0.705225	1.427997	0.3	0.523599	0.212323	-0.23772
13.8	0.688366	1.427997	0.3	0.523599	0.192857	-0.22222



민감도 해석 - 굽힘 임계점의 영향



Deflection	X1	X2	X3	X4	X5	O.F.V
3	0.6884	1.428	0.3	0.5236	0.1929	-0.2222
6	0.773377	1.427997	0.3	0.523599	0.291019	-0.30426
9	0.926992	1.427997	0.3	0.523599	0.3	-0.31225
12	1.073832	1.427997	0.3	0.523599	0.3	-0.31225



참고자료

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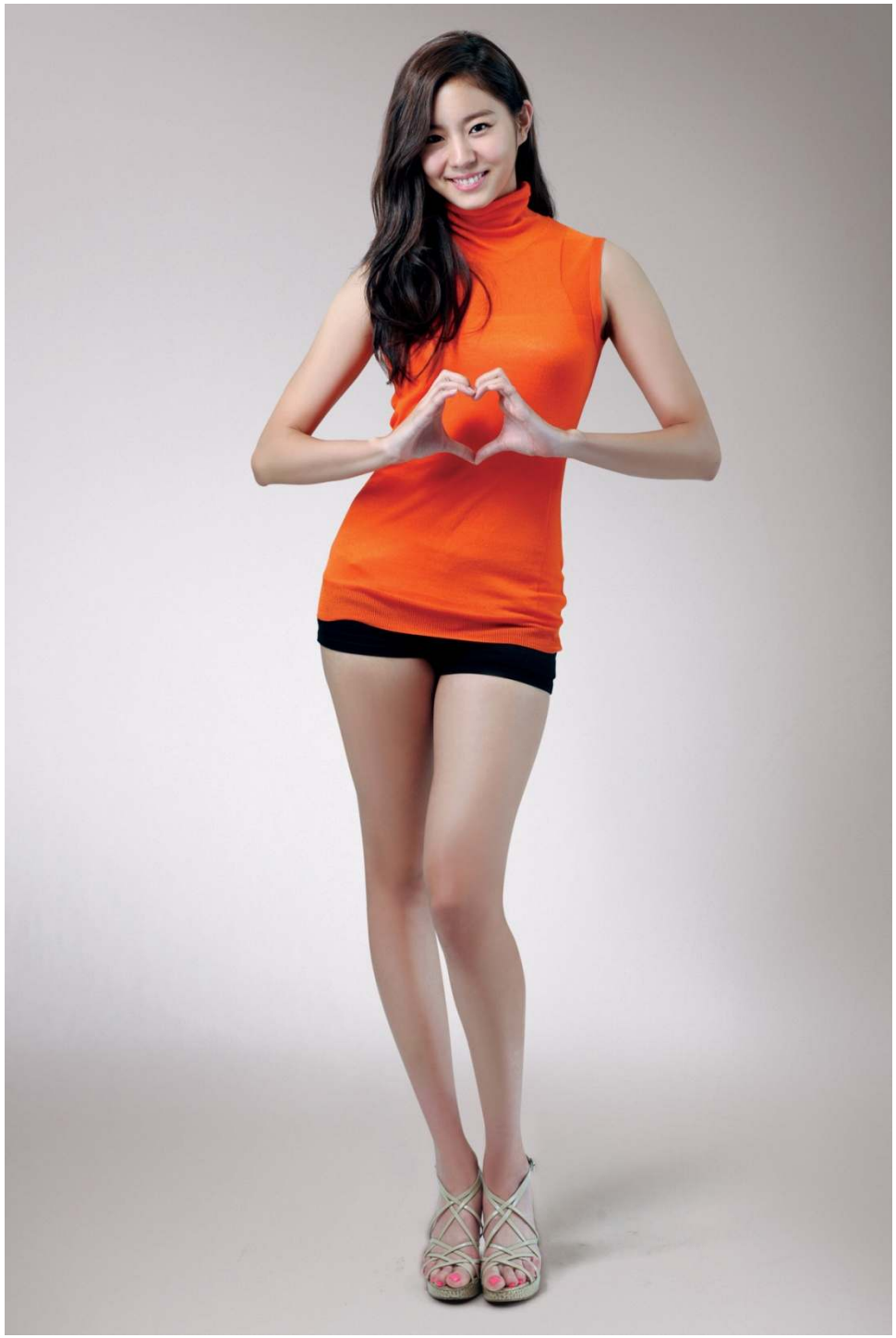
- http://www.solver.com
- http://cdl.hanyang.ac.kr



한 학기 동안 수고하셨습니다.
감사합니다.

TEAM EEE