Structural Design Optimization of Gyro Drop

자이로드롭의 최적설계

CRAZY DESIGN

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Contents

Project/Problem Statement

- Design a support column and seats of maximum profit for Gyro Drop
- The column must be safe with respect to yield strength
- The total stress must not exceed buckling load

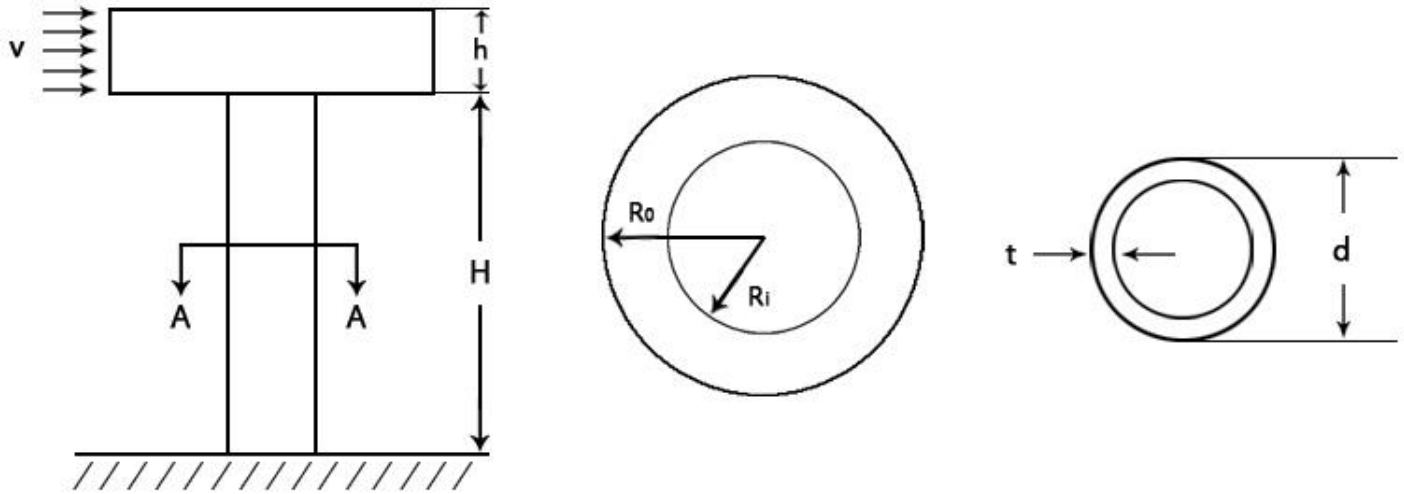
Project/Problem Statement

- Assumption

1. Column : A hollow circular bar → A truncated cone
2. Wind pressure : Acting on the side of seats → Acting on the whole structure
3. The column is a fixed-free column.
4. The column is supporting seats.
5. The seats are hanging on the top and fixed.
6. Whole structure is made my steel.

Project/Problem Statement

- Drawing of Gyro Drop (Before)



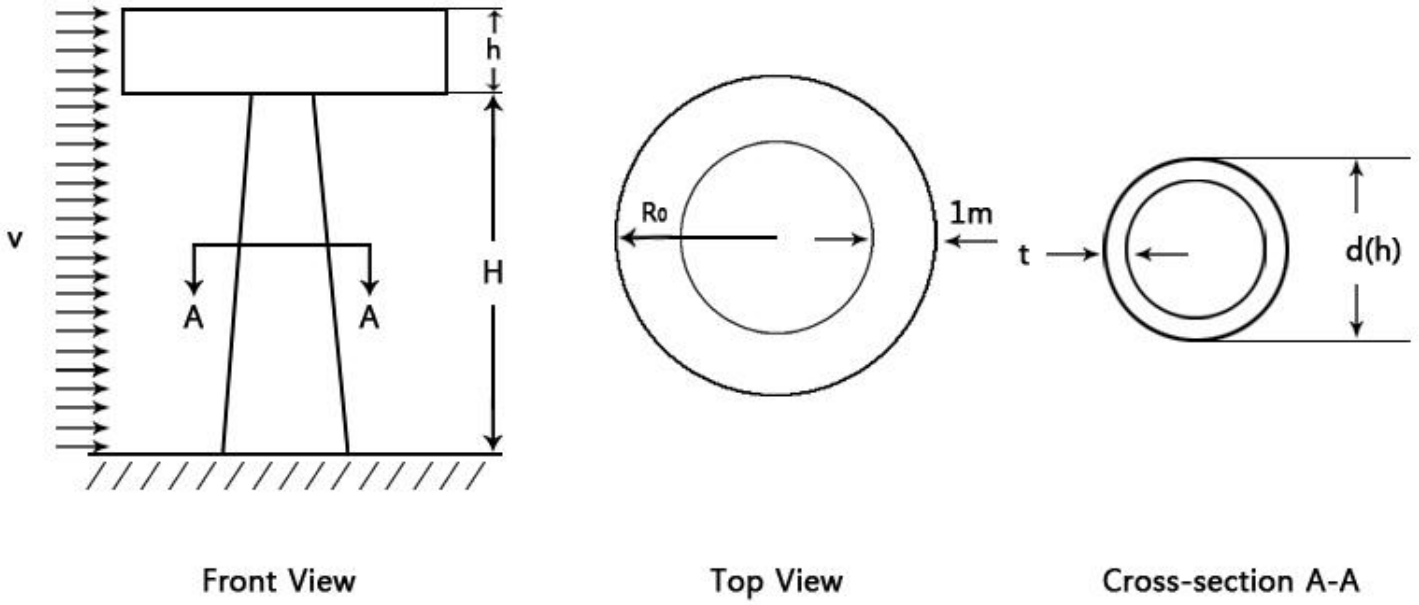
Front View

Top View

Cross-section A-A

Project/Problem Statement

- Drawing of Gyro Drop (After)



Data and Information Collection

- Not Changed

1. Height of seats: $h = 1.5\text{m}$
2. Wind velocity: $v = 40\text{m/s}$
3. Mass density of steel: $\gamma = 7860\text{kg/m}^3$
4. Radius of gyration: $r = \sqrt{\frac{I}{A}}$
5. Young's modulus (steel ASTM-A36): $E = 200\text{GPa}$
6. The buckling stress for the column: $\sigma_{cr} = \frac{\pi^2 E}{(2H/r)^2}$
7. Air density: $\rho = 1.225\text{kg/m}^3$
8. The average mass of the people: $W_p = 75\text{kg}$
9. Wind force acting on the side of seats: $F_s = \frac{1}{2} C_D 2Rh\rho v^2 \quad (C_D = 1.4)$
10. The yield stress for the column: $\sigma_a = 250\text{MPa}$

Data and Information Collection

- Added

1. A central angle per seat : $\theta = \frac{2\pi}{\mathrm{n}}$
2. Thickness of seats : $\mathrm{t} = 1\mathrm{m}$
3. A breadth of a seat : $\mathrm{b} = 0.7\mathrm{m}$
4. Wind force acting on the column : $F_c = \frac{1}{2} C_D \rho v^2 d$
5. Volume of the seats : $W_s = \pi \left[R_o^{\ 2} - (R_o - t)^2 \right] h$
6. Volume of the column : $W_c = \pi t \left[(d - t)(H - h) \right] - \frac{d}{10H} \left(H^2 - h^2 \right)$
7. Shear force at the base : $V = \frac{1}{2} C_D \rho v^2 dh - \frac{C_D \rho v^2}{20H} dh^2$
8. Maximum shear stress : $\tau_{\max} = \sqrt{\left(\frac{\sigma_{normal}}{2} \right)^2 + \left(\frac{V}{A} \right)^2}$

Data and Information Collection

- Modified

1. Height of the column : $H = 60\text{m} \rightarrow 70\text{m}$

2. Radius of seats : $R_o = 9\text{m} \rightarrow \dfrac{b}{\sin(\theta/2)}$

3. Cross-sectional area of the column :

$$A = \frac{\pi}{4}\left[d^2 - (d-2t)^2\right] \rightarrow A(h) = \frac{\pi}{4}\left[d(h)^2 - (d(h)-2t)^2\right]$$

4. Moment of inertia of the column :

$$I = \frac{\pi}{64}\left[d^4 - (d-2t)^4\right] \rightarrow I(h) = \frac{\pi}{64}\left[d(h)^4 - (d(h)-2t)^4\right]$$

Data and Information Collection

5. Deflection at center of gravity of seats:

$$\delta = \frac{F(H+0.5h)^3}{3EI} \rightarrow \delta = \frac{F_s(H+0.5h)^3}{3EI} + \frac{F_c H^4}{8EI}$$

6. Load on the column due to weight of seats:

$$P = 9.81\left[\pi\left(R_o^{\,2} - R_i^{\,2}\right)\gamma h + nw\right] \rightarrow P(h) = 9.81\left[\gamma\left(W_s + W_c\right) + nW_p\right]$$

7. Moment at the base: $M = F(H+0.5h) + P\delta$

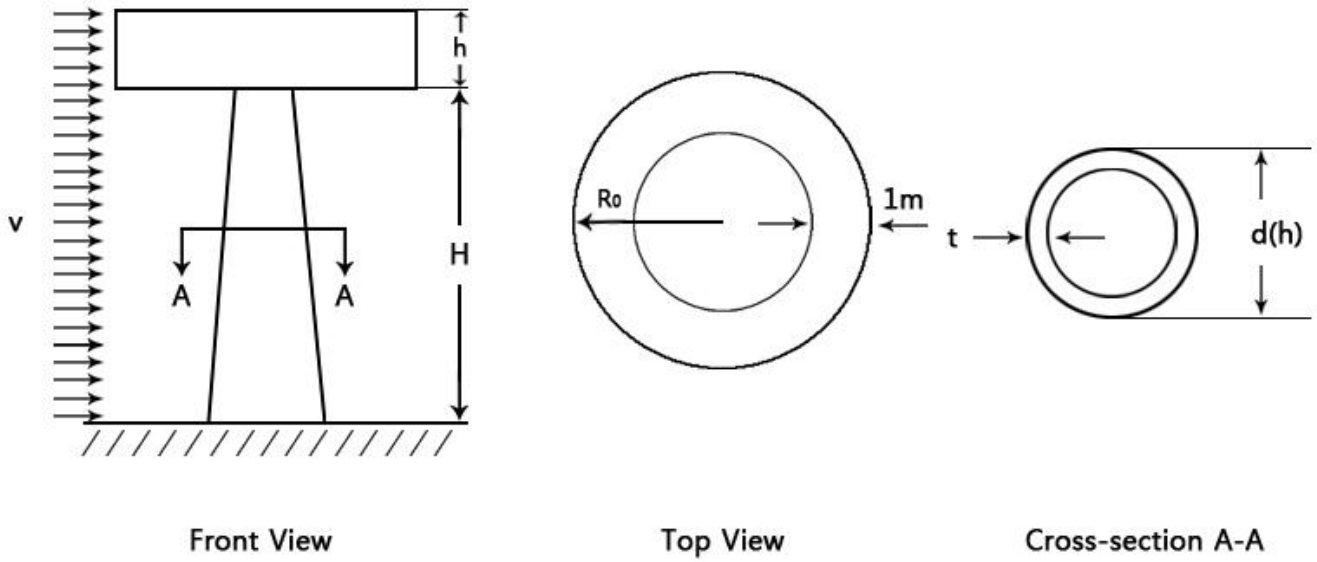
$$\rightarrow M(h) = \frac{1}{4}C_D\rho v^2 dh^2 - \frac{1}{60}C_D\rho v^2 dh^2 + \frac{1}{2}C_D 2R_o h\rho v^2 (H+0.5h)$$

8. Total stress acting on the column:

$$\sigma_{total} = \frac{P}{A} + \frac{0.5Md}{I} \rightarrow \sigma_{normal}(h) = \frac{P(h)}{A(h)} + \frac{M(h)}{2I(h)}d(h)$$

9. Mass of Gyro Drop: $m_g = \gamma\left(W_s + W_c\right)$

Identification/Definition of Design Variables



- Variable 1

d_0: diameter of the column

- Variable 2

t: thickness of the column

- New Variable

n: the number of people

Identification of a Criterion to Be Optimized

$Profit = P_i - P_t$

1. Operation time a day : $T_d = 10.5 hour$
2. Playing time : $T_o = 1/12 hour$
3. Ticket price : $C_o = 4000 won$
4. Power : $E_g = 562 kW$
5. Tax for power : $C_e = 111.3 kW / won$
6. The number of employees : $m = 3$
7. Pay per hour : $a_t = 7000 won$
8. Installation charges : $P_i = 50(\text{development costs}(\text{unit : 억})) + \frac{(2/7)m_g}{10^3}$
9. The total net profit : $P_t = \sum_{k=1}^{5} \frac{1}{i}\left(1-(1+i)^{-k}\right)\frac{P_y}{10^8}$ (k : year, i : an annual interest)
10. The net profit per year : $P_y = 365\left[n\frac{T_d}{T_o}C_o e^{-\frac{1}{40}n} - \frac{2E_g(T_d/T_o)}{T_d}C_e - ma_t T_d \right]$

Identification of Constraints

- Modified

1. $g1: \tau_{\max} - \frac{\sigma_a}{2} \le 0$
2. $g2: \sigma_{cr} - \sigma_a \le 0$

- Not changed

3. $g3: \frac{d}{t} - 92 \le 0$ (The diameter/thickness ratio)
4. $g4: \delta - 0.2 \le 0$
5. $g5: 1m \le d \le 4.0m$
6. $g6: 1cm \le t \le 10cm$

Use of Excel and MATLAB for Optimization

Conclusion

- Real Model

d: 2m

t: 0.15m

n: 40people

Profit:

11,100,000,000won

- Optimum Model

d: 1.849m

t: 0.02m

n: 23people

Profit:

3,690,000,000won

Conclusion

year	5	10	15	20
d(m)	1.849	1.985	2.021	2.033
t(m)	0.020	0.021	0.022	0.022
n(people)	23	33	36	37
Profit($10e^8$ won)	37	509	1147	1870

Gyro Drop

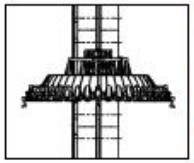
a spectacular all-round experience

Formosan Aboriginal, Culture Village, Taiwan

Kings Island, USA

Using the magnetic braking technology which is so effective in the Giant Drops, the same technology was put to use in the super-sized Gyro Drop. Combining the pleasant experience of a Panorama Tower with the white-knuckle experience of a free fall is an unusual and exciting mixture which will be guaranteed to satisfy even the most sceptical of thrill seekers. The 40-seat ring structure rises slowly up the shaft, turning as it goes to give the guests a good all-round view of their surroundings, turning slowly and gently at the top to lull the guests into a false sense of tranquility. Then CLUNK CLICK! The ring of seats weighting over 25 tons suddenly drops to the ground. Anybody who can breath in that split second has nerves of Titanium. STEEL ISN'T STRONG ENOUGH!

GYRO DROP (TURNING RING STRUCTURE)



Technical Data (approx.)

VARIATIONS – GYRO DROP

Height	68.6 m (225 ft)	79.9 m (262 ft)	91.2 m (299 ft)
Highest speed	93 km/h (58 mph)	98 km/h (61 mph)	105 km/h (65 mph)
Number of persons	40	40	40
Ride Time	56 sec.	70 sec.	138 sec.
Theoretical capacity	1360 pers.	1200 pers.	1040 pers.

RING DROP

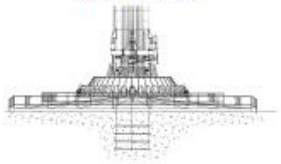
A variation on a theme in the new Freefalls. With the passengers sitting around the tower they are all pulled up to the top of the tower together and after a brief pause the whole lot comes shooting down.

Technical Data (approx.)

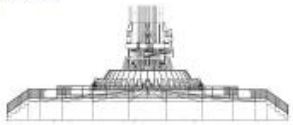
VARIATIONS – RING DROP (Non turning ring structure)

Height	54 m (177 ft)	54 m (177 ft)	65.3 m (214 ft)	65.3 m (214 ft)
Highest speed	85 km/h (53 mph)	85 km/h (53 mph)	93 km/h (58 mph)	93 km/h (58 mph)
Number of persons	12 pers.	20 pers.	12 pers.	20 pers.
Ride Time	45 sec.	45 sec.	52 sec.	52 sec.
Theoretical capacity	492 pers.	820 pers.	420 pers.	700 pers.

EMBEDDED VERSION



STARFOOT VERSION



RIDE TRADE

The Art of Thrill

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RIDE TRADE

The Art of Thrill

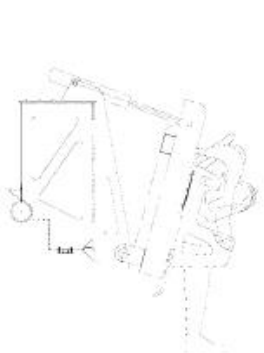
Printed in Switzerland, 01/01

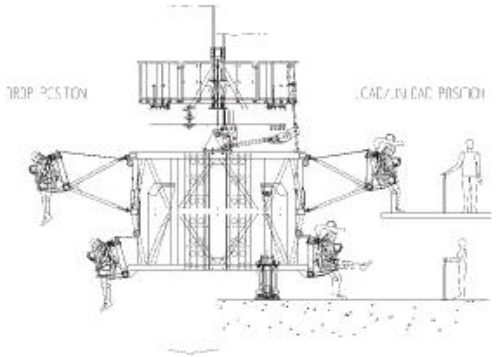
Floorless tilting Gyro Drop

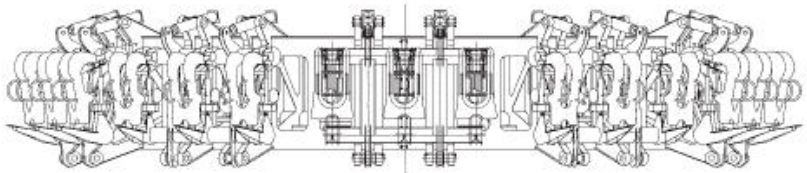
The tilting madness

Six Flags over Georgia, Atlanta, USA

Using the magnetic braking technology which is so effective in the Giant Drops, the same technology was put to use in the Gyro Drop Floorless Stand-Up & Tilt and the Double-Decker Gyro Drop Floorless Stand-Up & Tilt. Combining the pleasant experience of a Panorama Tower with the white-knuckle experience of a free fall is an unusual and exciting mixture which guarantees to satisfy even the most sceptical of thrill seekers. The 30-seat ring structure rises slowly up the shaft, turning as it goes to give the guests a good all-round view of their surroundings (please note: The Double-Decker Gyro Drop Floorless & Tilt does not rotate), turning slowly and gently at the top to lull the guests into a false sense of tranquillity. Then CLUNK CLICK! The ring of seats weighing over 25 tons suddenly drops to the ground. Anybody who can breath in that split second has nerves of titanium. STEEL ISN'T STRONG ENOUGH!







Technical Data (approx.)

FLOORLESS TILTING GYRO DROP
(rotating ring structure)

Height	60.9 m (200 ft)	68.6 m (225 ft)	79.9 m (262 ft)	91.2 m (299 ft)
Highest speed	93 km/h (58 mph)	100 km/h (62 mph)	105 km/h (65 mph)	120 km/h (74 mph)
Ride Time	60 sec.	65 sec.	75 sec.	85 sec.
Theoretical capacity	960 pers./h	900 pers./h	840 pers./h	750 pers./h
Number of persons	30	30	30	30

Technical Data (approx.)

DOUBLE-DECKER VERSION
(non rotating structure)

Height	99.1 m (325 ft)
Highest speed	106 km/h (66 mph)
Ride Time	85 sec.
Theoretical capacity	1300 pers./h
Number of persons	60

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