자전거 스포크 휠의 최적화

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Contents

Abstract

- 자전거 휠 회전 관성 최소화의 중요성 :
  - 가속 및 감속에 유리
  - 에너지 소모의 최소화
  - 회전관성 감소 효과 >> 구조 경량화 효과

Introduction of Base model

- 20 Hole
- Pre-tension spoke wheel
- Spoke diameter d=2[mm]
- Spoke length ℓ=287[mm]

Problem Statement

- Necessary Condition
  - Do not exceed allowable stress

- Optimization
  - Minimize the rotational stiffness

Data and Information (1)

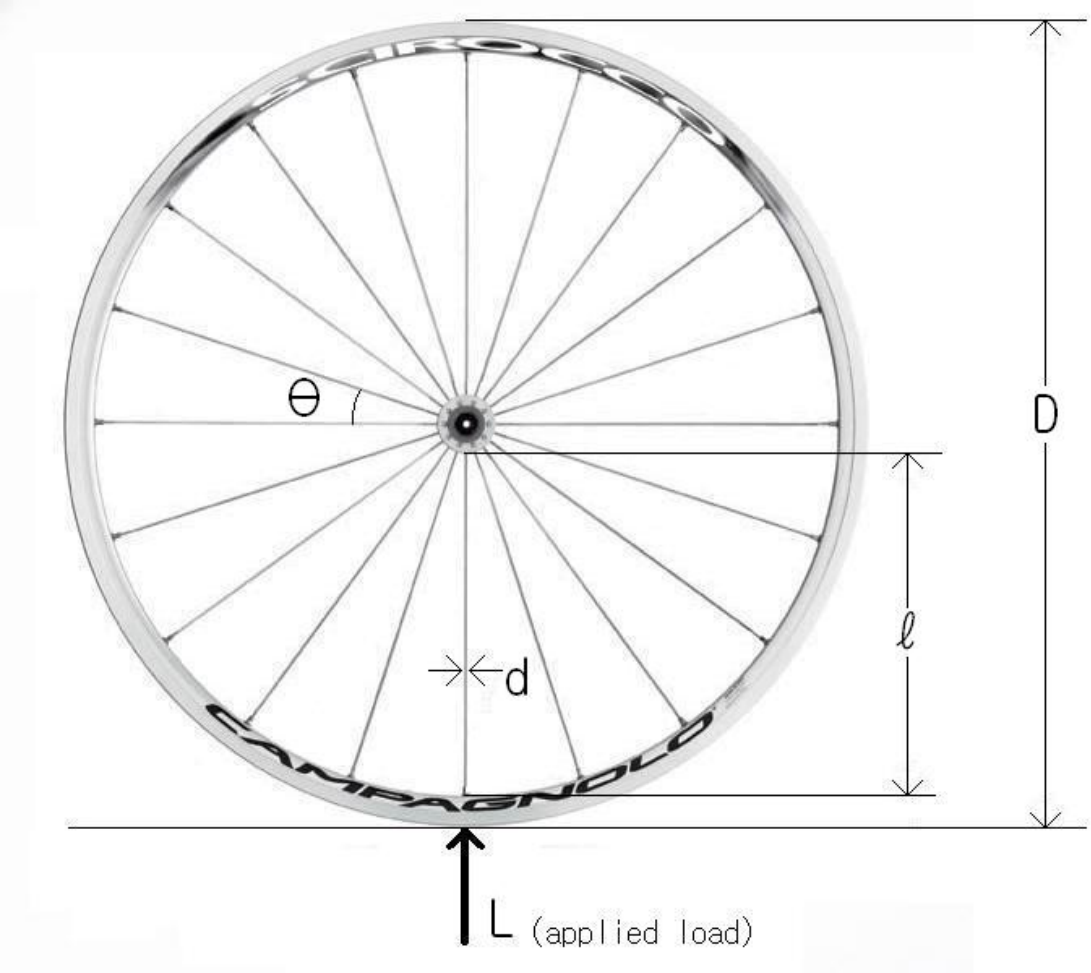
- Assumption
  - 2-D System analysis
  - Section shape of spoke is circle
  - Amount of pre-tension : 20000/n [N]
  - Maximum Load applied on wheel : 120[kgf]

- Materials

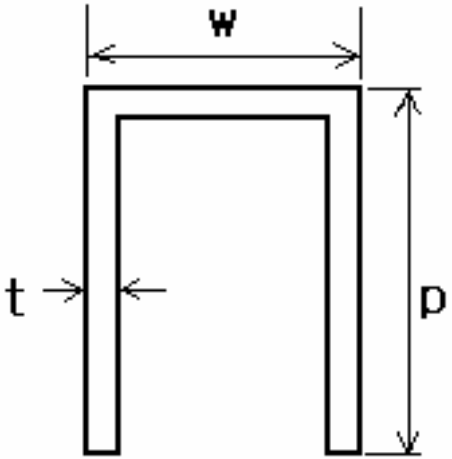
	Rim(6061-T6)	Spoke(348STS)
$\rho(kg/m^3)$	3000	8000
$\sigma_{fatigue}(MPa)$	330	1000

Data and Information (2)

❖ Wheel Dimensions



D=700[mm]
w=20[mm]



(Rim 단면 형상)

Data and Information (3)

- Spoke에 걸리는 최대 응력 계산

$$L_{\max}(n) = \frac{2gL}{D}\sin(\frac{\pi}{n}) + F_{pre}$$

$$A(d) = \frac{\pi}{4}d^2$$

$$F_{pre} = 20000/n$$

$$\sigma_{spoke\,\max} = \frac{(2gL)\sin(\pi/n) + 20000/n}{(\pi/4)Dd^2}$$

Data and Information (4)

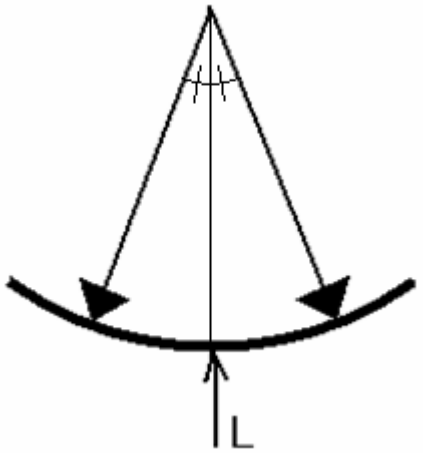
❖ Rim에 걸리는 최대 응력 계산 (Beam으로 가정)

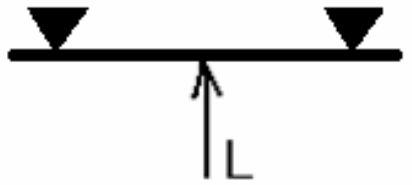
$$\bar{y} = \frac{p^2 + 0.5(w-2t)t}{2p - 2t - w}$$

$$I = \frac{tp^3}{6} + 2pt(\bar{y} - \frac{p}{2})^2 + t^2(w-2t)\{\frac{t}{12} + (\bar{y} - \frac{t}{2})^2\}$$

$$M_{\max} = \frac{DLg\pi}{2n}$$

$$\sigma_{Rim\max} = \frac{M(p-\bar{y})}{I}$$





Design Variables

- Spoke diameter : d
- Number of spoke : n
  - 스포크의 개수는 짝수만 허용하는 이산변수
- Rim depth : p
- Rim thickness: t

Constraints

- $N_{safe}\sigma_{spoke\max} \leq \sigma_{348STS\_fatigue}$
- $N_{safe}\sigma_{Rim\max} \leq \sigma_{alu\_fatigue}$
- 10 ≤ n ≤ 32 (n은 짝수)
- d ≥ 1[mm]
- t ≥ 0.8[mm]

Identification of a Criterion to be Optimized

Minimize the rotational stiffness :

$$m_{spoke}(n,l,d) = \rho_{348STS}(\frac{\pi}{4})d^2 l$$

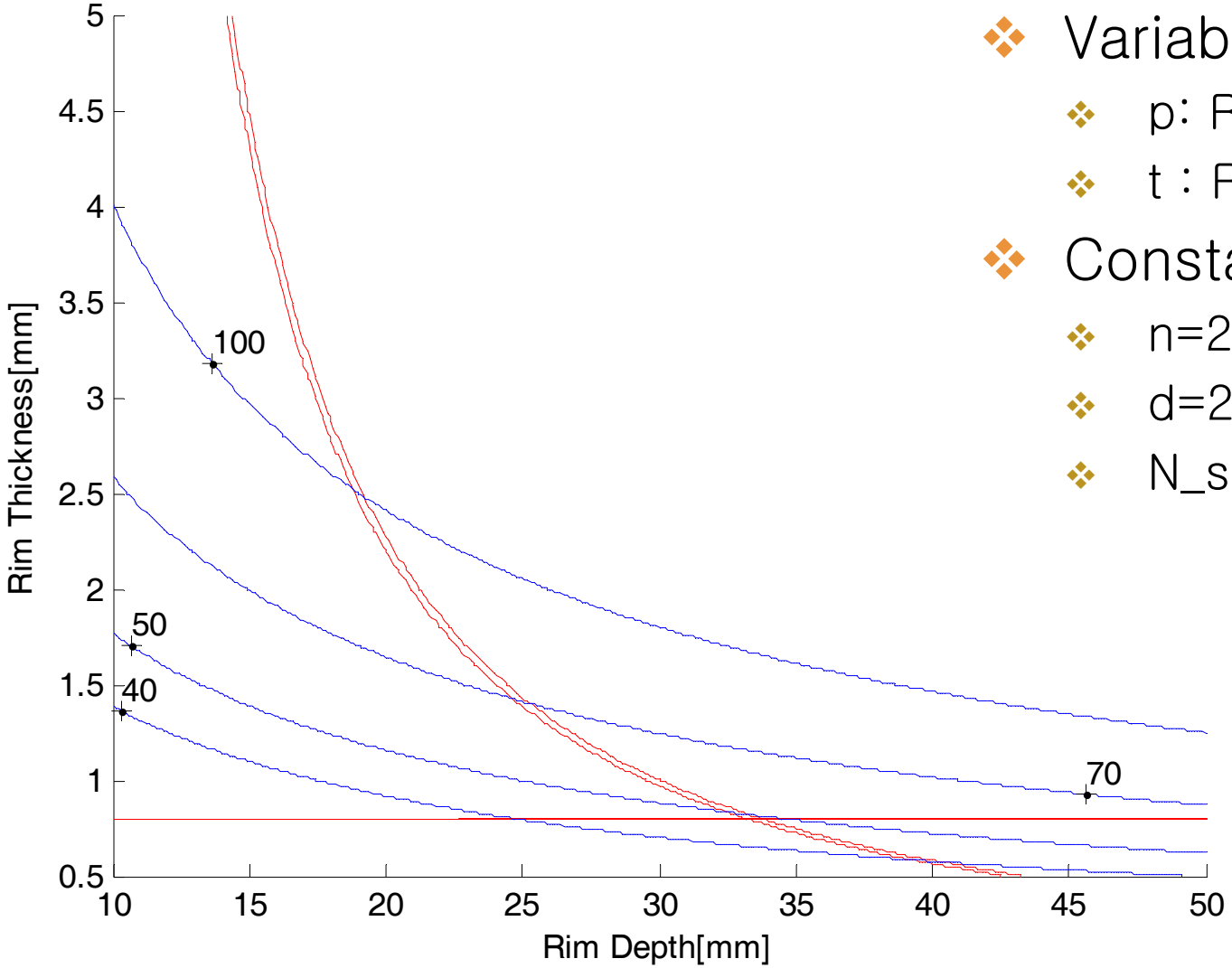
$$J_{spoke}(n,l,d) = m_{spoke} l^2 / 3$$

$$m_{Rim}(t,\ p) = \rho_{alu}\{2wt + (w-2t)t\}(l + \bar{y})$$

$$J_{Rim}(t,\ p) = m_{Rim}(\frac{D}{2} - p + \bar{y})^2$$

$$J_{total}(n,d,t,\ p) = n \times J_{spoke} + J_{Rim}$$

Graphical Solution



- Variables
  - p: Rim depth
  - t : Rim thickness
- Constants
  - n=20
  - d=2mm
  - N_safe = 2

진행방향

- Spoke의 개수와 지름도 변수로 두어 총 4개의 변수로 최적화