자전거 스포크 휠의 최적화

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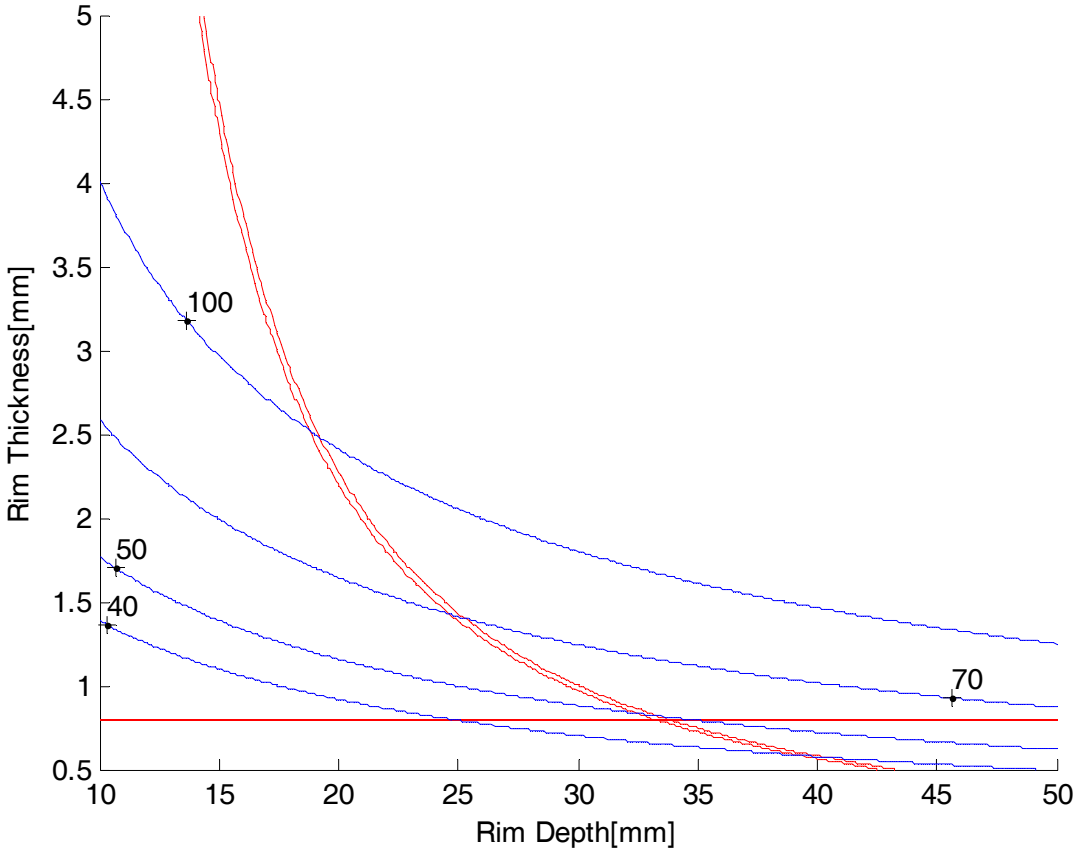
Contents

Result of previous project

- Optimized data



- Active constraint : t_min, S_allow_rim

Explanation of added variables

- Spoke Diameter d
  - $1 \leq d$
  - 커질수록 σ_spoke 감소, 질량 증가
- Number of spoke n
  - $10 \leq n \leq 32$
  - 커질수록 σ_spoke, σ_rim 감소, 질량 증가
  - 짝수만 허용하는 이산변수
  - 범위가 넓으므로 연속변수로 취급

Optimization with Excel solver

- 초기값(Feasible region)
  - Rim depth p=25
  - Rim thickness t=1.5
  - Spoke diameter d=1.5
  - Number of spoke n=20

- 초기값(Infeasible region)
  - Rim depth p=32
  - Rim thickness t=0.8 ($\sigma_{rim}<\sigma_{allow}$)
  - Spoke diameter d=1
  - Number of spoke n=24 ($\sigma_{spoke}>\sigma_{allow}$)

Optimization with Excel solver

- Solver Executed(Feasible)

	A	B	C	D	E	F	G	H
1	spk	Spk number	spk dia.	spk length	wheel dia.	spk area	rho_steel	Load
2		19.999765	1.493743	325.0028	700	1.752433	0.008	1176
3	rim	S_allow_spk	S_allow_rim	rim_depth	rim_thick	rim_width	rho_alu	
4		1000	160	24.99718	1.431214	20	0.003	
5	Stress	S_spoke	S_rim					
6		870.57585	160					
7	Rim	Y_bar	I_1	I_2	I	A_1	A_3	c
8		9.4906053	1862.928	4.186793	6266.083	35.7763	24.52753	15.50657
9	mass	rim	spoke	hub	sum			
10		633.87375	91.12624	150	875			
11		J_rim	J_spoke	J_sum				
12		70921506	3208459	74129965				
13								

- Remained at local minima

Optimization with Excel solver

- Solver Executed(Infeasible)

	A	B	C	D	E	F	G	H
1	spk	Spk number	spk dia,	spk length	wheel dia,	spk area	rho_steel	Load
2		32	1,300986	323,8472	700	1,329338	0,008	1176
3	rim	S_allow_spk	S_allow_rim	rim_depth	rim_thick	rim_width	rho_alu	
4		1000	160	26,15282	0,8	20	0,003	
5	Stress	S_spoke	S_rim					
6		1000	160					
7	Rim	Y_bar	I_1	I_2	I	A_1	A_3	c
8		9,7775774	1192,516	0,785067	4135,642	20,92225	14,72	16,37524
9	mass	rim	spoke	hub	sum			
10		373,17554	110,2086	150	633,3841			
11		J_rim	J_spoke	J_sum				
12		41536483	3852781	45389264				
13								

- Found optimum point
- Spoke constraint 가 더 영향을 미침.
- 초기값에 의해 영향을 받음.

Optimization with MATLAB

Function fmincon

- 21 times Iteration (function count : 182)
- Active Constraint
  - g1 [σ_rim<σ_allow]
  - g2 [σ_spoke<σ_alow]
  - g4 [t>t_min]
  - g6 [n<n_max]

p [mm]	t [mm]	d [mm]	n
26.153	0.8	1.301	32

- Optimized Value
  - 4.539 * 10^7 [kg · ㎟]

Result and Result analysis

	A	B	C	D	E	F	G	H
1	spk	Spk number	spk dia,	spk length	wheel dia,	spk area	rho_steel	Load
2		32	1,300986	323,8472	700	1,329338	0,008	1176
3	rim	S_allow_spk	S_allow_rim	rim_depth	rim_thick	rim_width	rho_alu	
4		1000	160	26,15282	0,8	20	0,003	
5	Stress	S_spoke	S_rim					
6		1000	160					
7	Rim	Y_bar	I_1	I_2	I	A_1	A_3	c
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9	mass	rim	spoke	hub	sum			
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11		J_rim	J_spoke	J_sum				
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13								

- Analysis
  - J_rim≫J_spoke
  - Spoke의 개수가 늘어날수록 σ_rim 의 값이 감소
  - σ_rim이 줄어들면서 minimize, J_rim 최소화

Result and Result analysis

- Postoptimallity Analysis
  - Change material to 6Al-4V Titanium
  - Change Constraint and Objective function
  - σ_allow=827MPa, ρ=0.0045kg/㎣
- Pridected Result
  - Replace rim -> p decrease, m_rim increase
  - Replace spoke -> d, n increase, m_spk decrease
  - Replace both -> p,d,n can decrese?

Result and Result analysis

- Changed rim material

p [mm]	t [mm]	d [mm]	n
15	0.8	1.4271	18
f	4.713E7		

- Changed spoke material

p [mm]	t [mm]	d [mm]	n
26.15	0.8	1.431	32
f	4.418E7		

- Changed both

p [mm]	t [mm]	d [mm]	n
15	0.8	1.57	18
f	4.621E7		

Conclusion

- 기존 설계보다 경량화에 성공
  - 약 40%정도의 감량
  - Spoke 재질을 바꿀 경우 조금 더 경량화 가능
  - 기존 설계는 공기저항을 고려한 설계