Optimum Design

Project 2

철도 레일 설계 최적화

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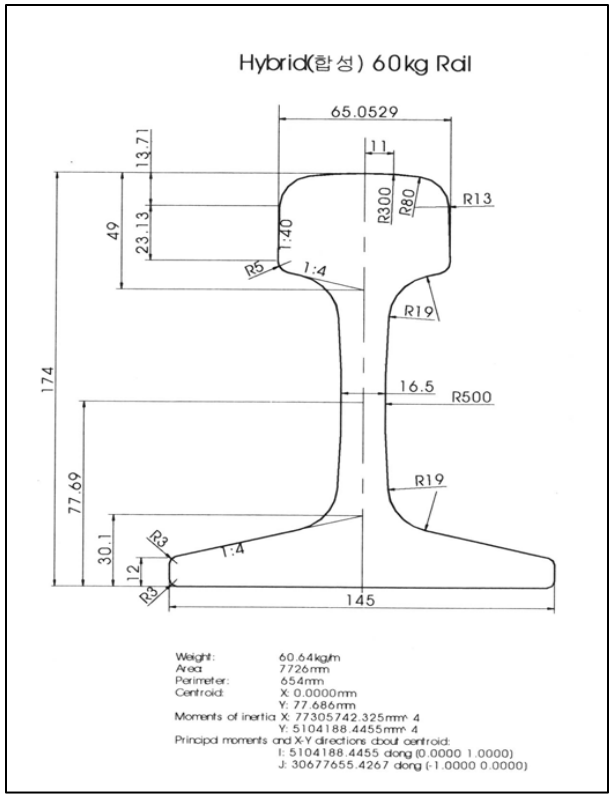
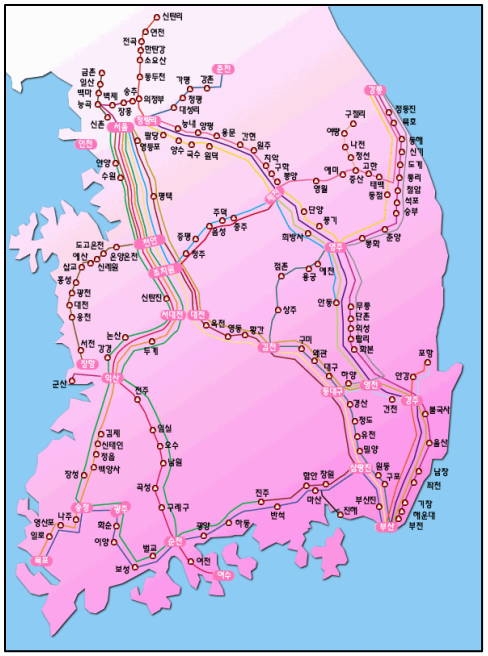
Problem

- 철도 레일 설계 최적화



Formulation

- **Step 1. Project/Problem Statement**



3380 km (2004년 기준)

열차는 전세계 어느 곳에서나 찾아볼 수 있는 가장 효율적인 운송수단이다.

레일의 올바른 설계를 위해서는 실험에 의하여 결정되는 것이 대부분이나 최적화 기법을 사용하여 레일의 단면을 설계하고 기존 설계와 얼마나 일치하는지 비교해 본다.

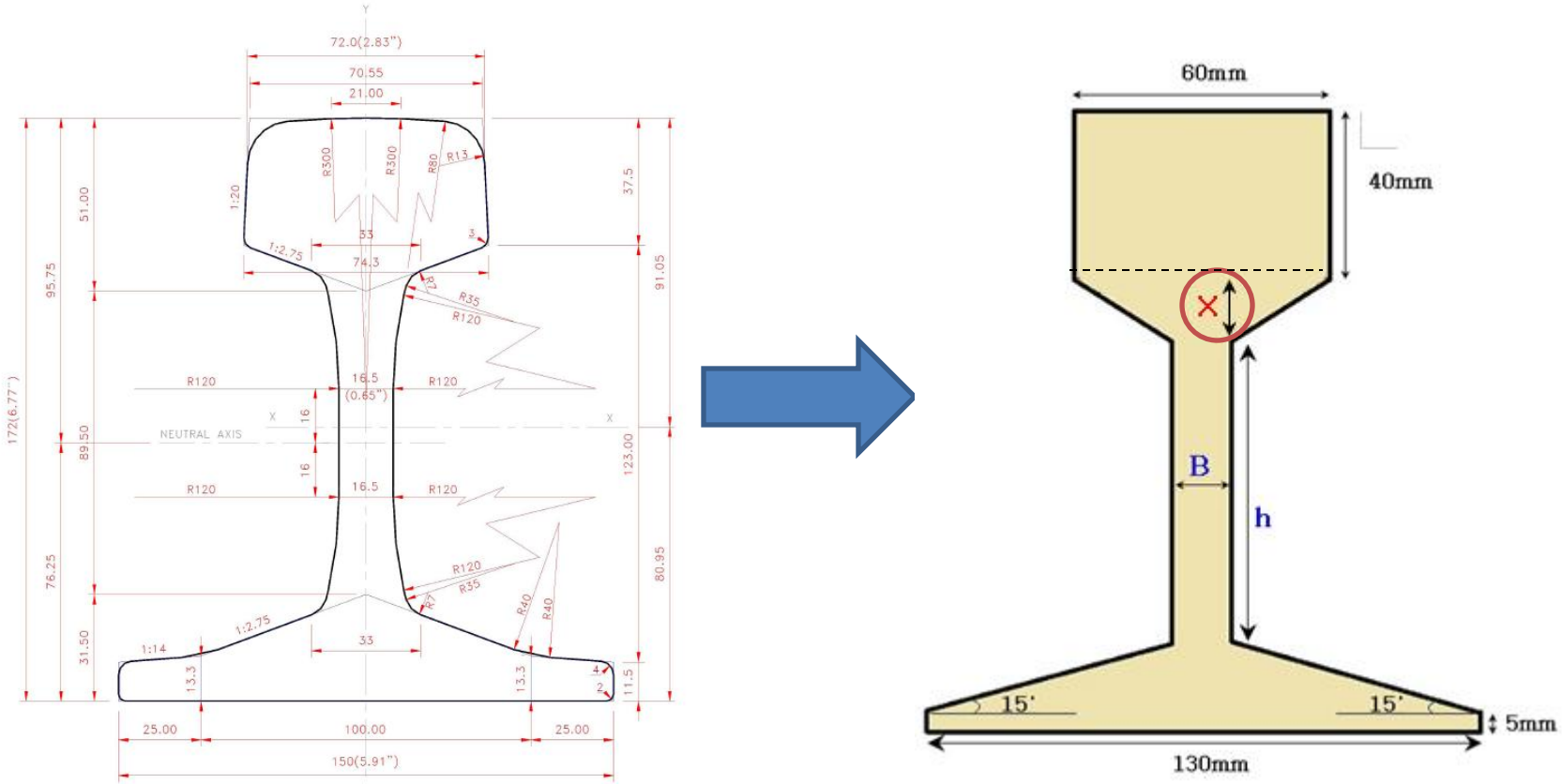
Formulation

- **Step 2. Data and Information Collection**

KS60 Property		
Yield Strength	Tension	900 MPa
	Shear	350 MPa
Elasticity		200 GPa
Thermal Expansion Coefficient		$12*10^{-6}$ m/m'c
Area		7750 mm^2

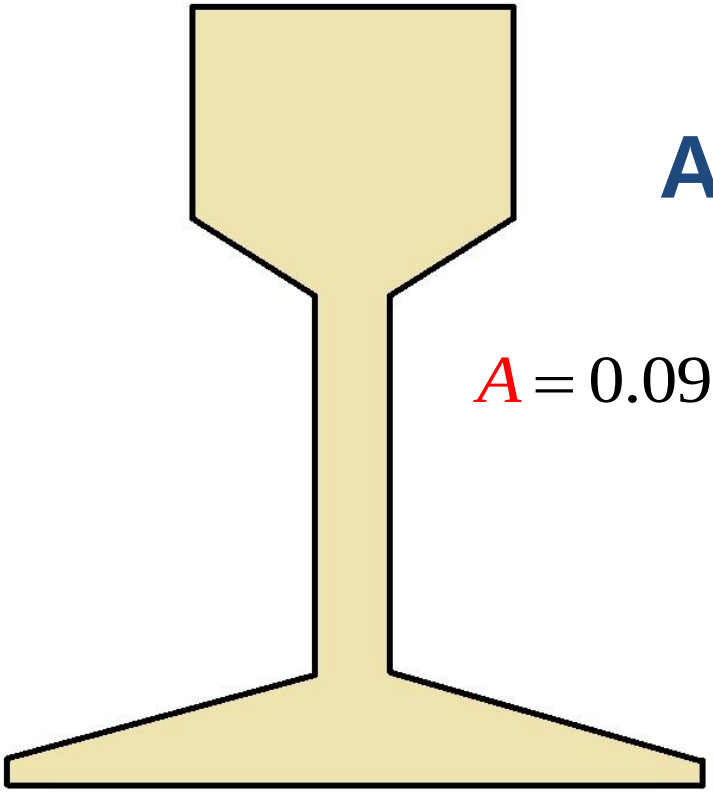
Formulation

- Step 3. Identification/Definition of Design Variables



Formulation

- **Step 4. Identification of a Criterion to be optimized**

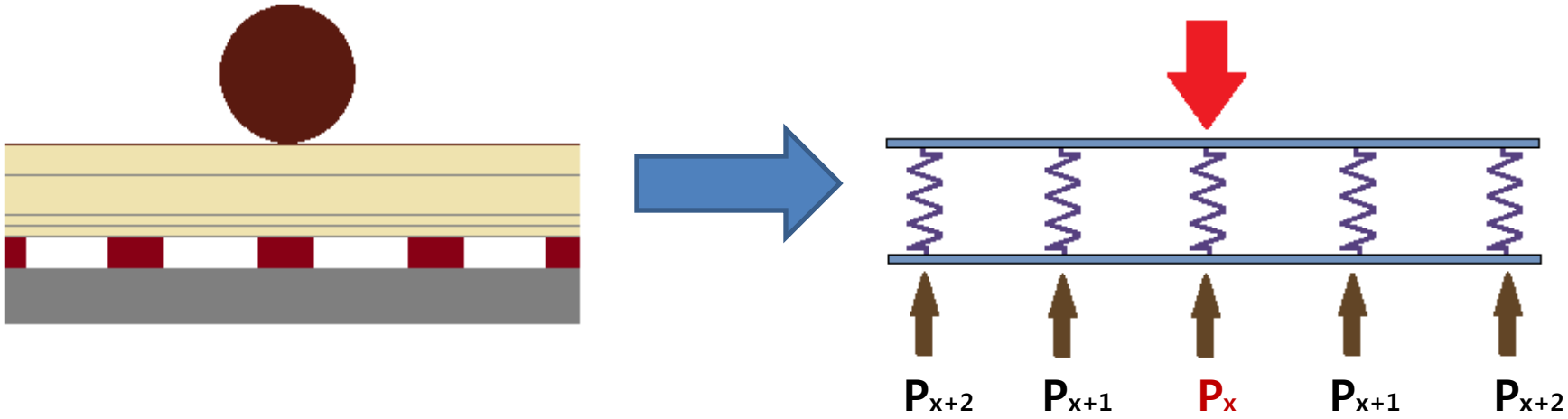


Area minimize

$$A = 0.0938b^2 + 0.0087b + bh + 0.5bx + 0.0668$$

Formulation

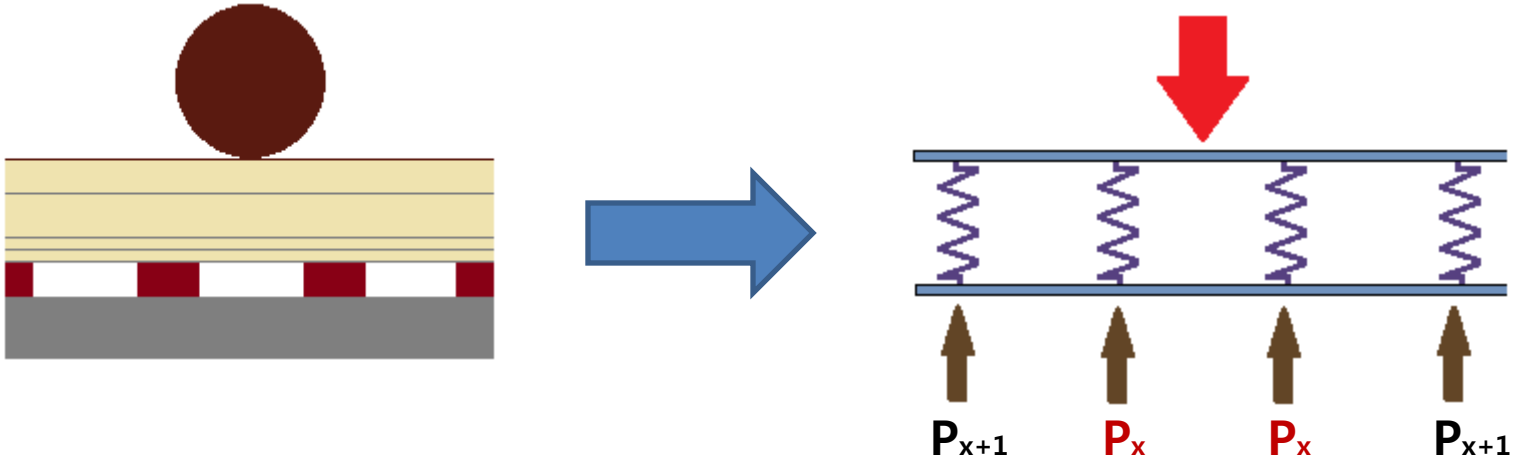
- **Step 5. Identification of Constraints**



$$P_1 = \int_0^a kydx = \frac{W}{2}[1-\phi(\beta a)] \quad \left(where \quad \phi(x) = e^{-x}\cos x \;,\; a = \text{침목간격} \;,\; \beta = \sqrt{\frac{k}{4EI_x}} \right)$$

Formulation

- **Step 5. Identification of Constraints**

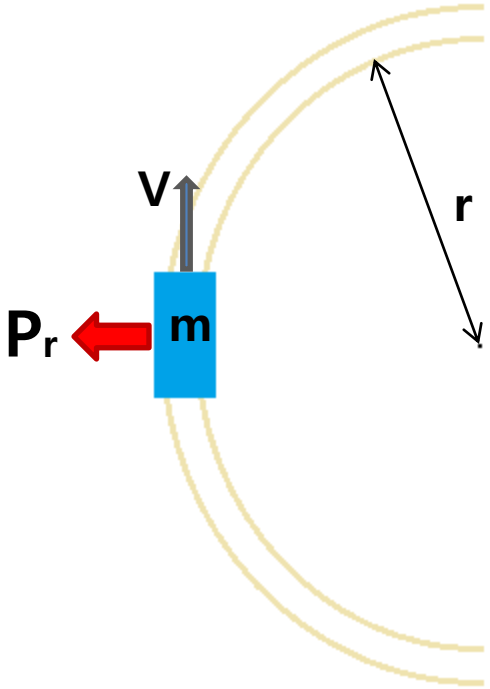


$$P_2 = 2\int_0^{\frac{a}{2}} kydx = W[1-\phi(\frac{a}{2}\beta)] \quad \left(where \quad \phi(x) = e^{-x}\cos x \;,\; \beta = \sqrt{\frac{k}{4EI_x}} \right)$$

a = 침목간격

Formulation

- **Step 5. Identification of Constraints**

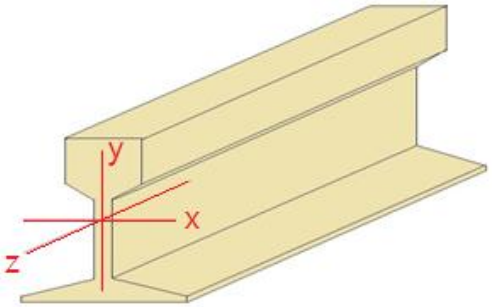


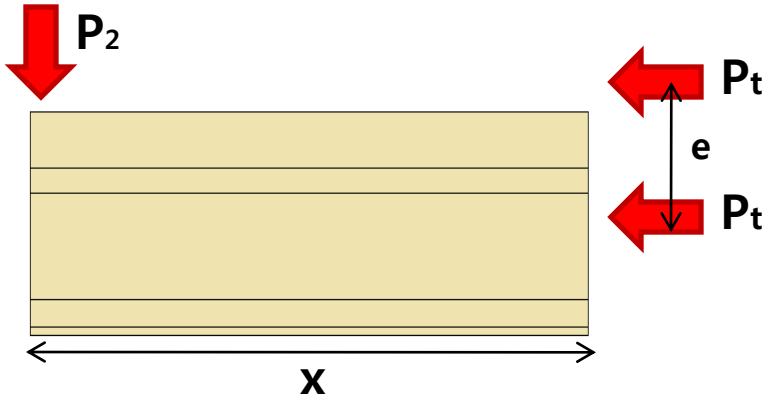
$$P_r = \frac{mV^2}{r}$$

Formulation

- **Step 5. Identification of Constraints**

1) X-axis buckling (by thermal stress & P_2)



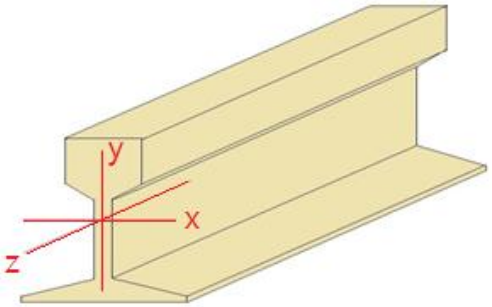


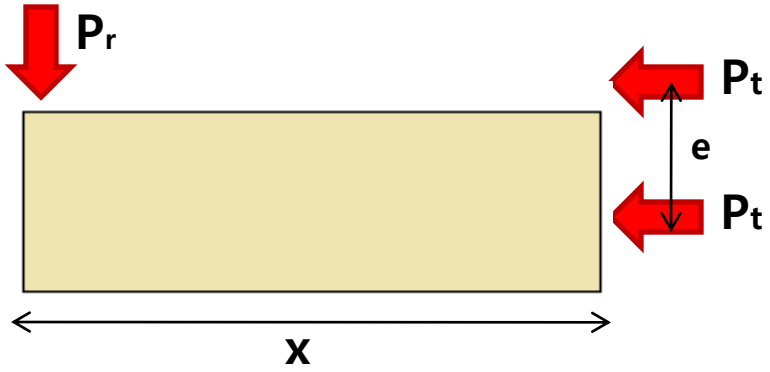
$$P_{cr} = P_t \left[1 + \frac{ce}{r^2} \sec\left(\sqrt{\frac{P_t}{EI_x}} \frac{L_e}{2} \right) \right] \quad \left(where \quad e = \frac{P_2 x}{P_t} , \quad r^2 = \frac{I_x}{A} \right)$$

Formulation

- **Step 5. Identification of Constraints**

2) Y-axis buckling (by thermal stress & P_r)



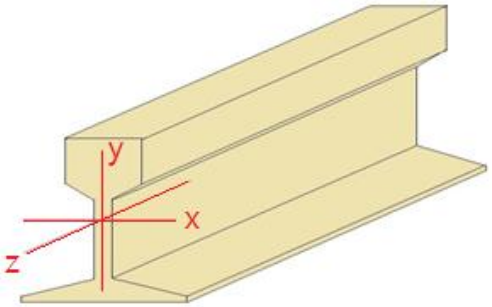


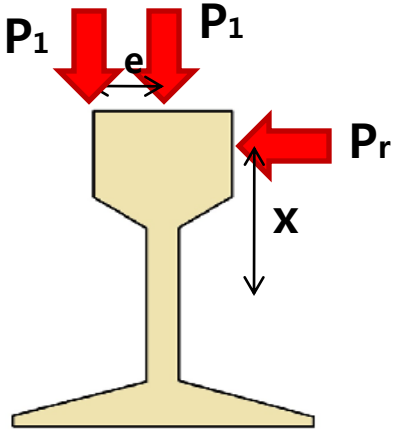
$$P_{cr} = P_t \left[1 + \frac{ce}{r^2} \sec\left(\sqrt{\frac{P_t}{EI_y}} \frac{L_e}{2} \right) \right] \quad \left(where \quad e = \frac{P_r x}{P_t} , \quad r^2 = \frac{I_y}{A} \right)$$

Formulation

- **Step 5. Identification of Constraints**

3) Z-axis buckling (by P_1 & P_r)



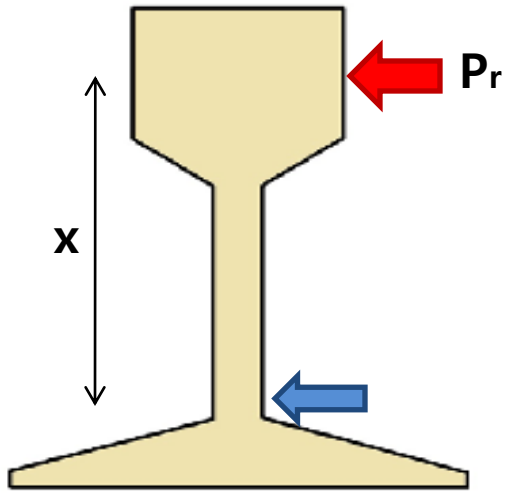


$$P_{cr} = P_t \left[1 + \frac{ce}{r^2} \sec\left(\sqrt{\frac{P_t}{EI_z}} \frac{L_e}{2} \right) \right] \quad \left(where \quad e = \frac{P_r x}{P_t} , \quad r^2 = \frac{I_z}{A} \right)$$

Formulation

- **Step 5. Identification of Constraints**

4) Maximum bending stress (by P_r)



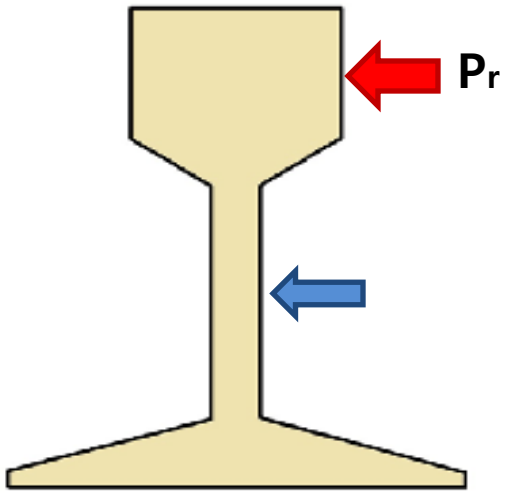
$$\sigma_{\max} = k\frac{Mc}{I_z}$$

$$\left(where \quad c = \frac{b}{2} \quad , \quad k = 1.6\,(intensity \;\; factor) \right)$$

Formulation

- **Step 5. Identification of Constraints**

5) Maximum Shear stress (by P_r)

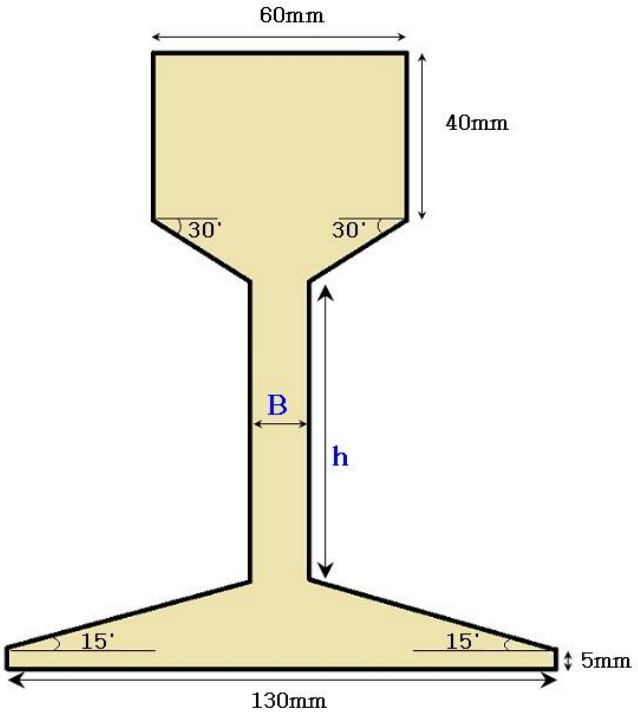


$$\tau_{\max} = \frac{3}{2}\frac{V}{A}$$

Formulation

- **Step 5. Identification of Constraints**

6) Geometric Shape



$$b \leq \frac{h}{5}$$

Optimization

- Constraints

1)X-axis buckling

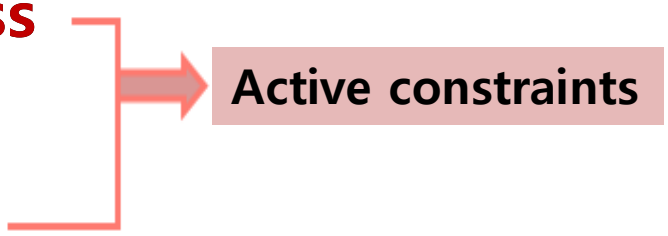
2)Y-axis buckling

3)Z-axis buckling

4)Max bending stress

5)Max shear stress

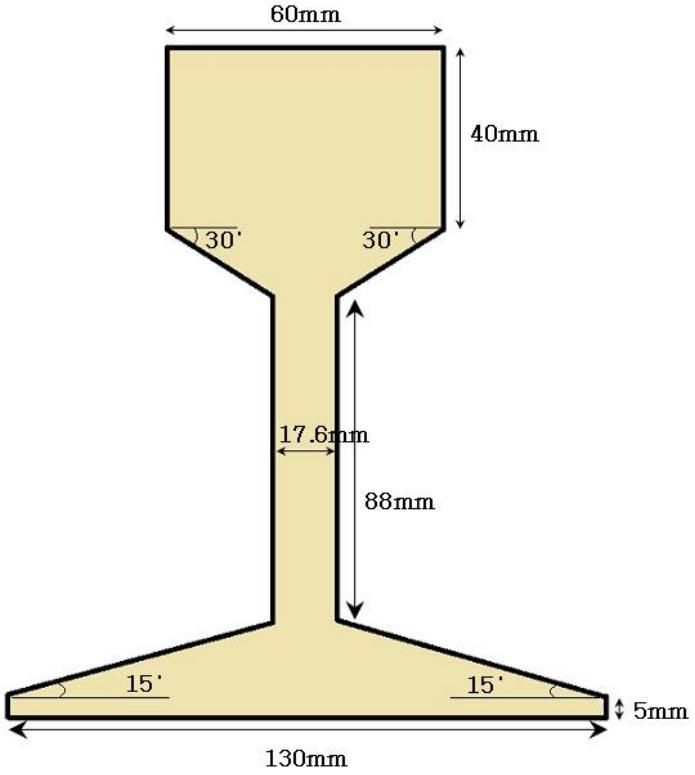
6)Geometric shape

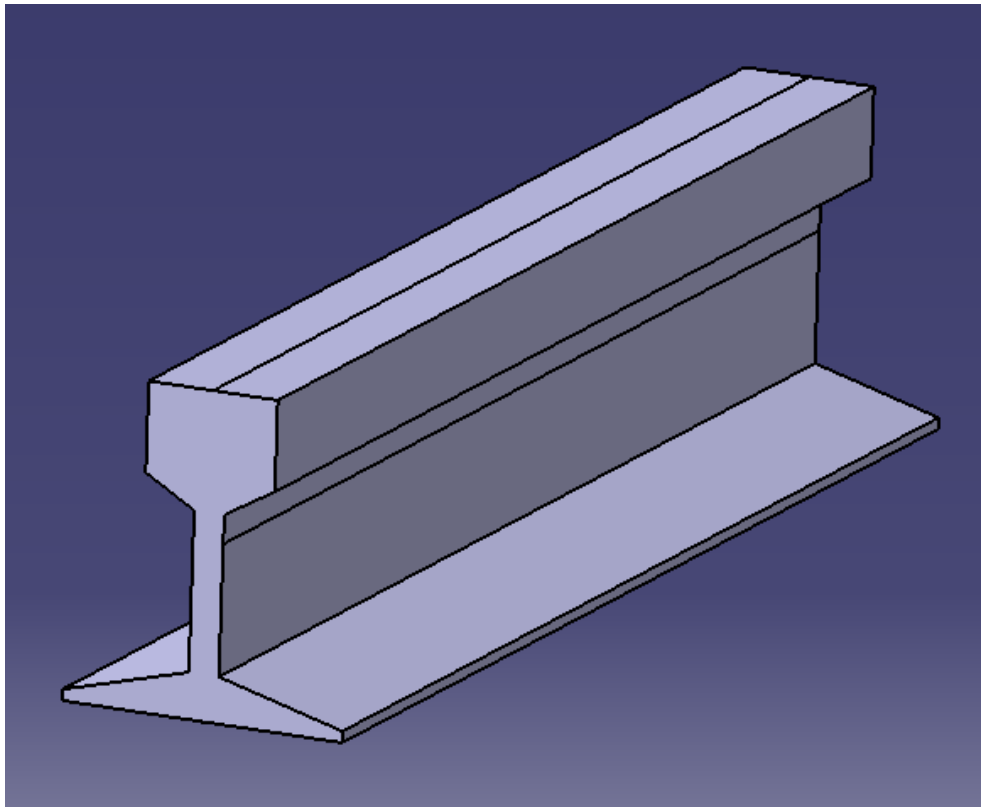


Graphical optimization

b=17.6 mm h=88 mm

A= 5635.7 mm^2 (<7750 mm^2)

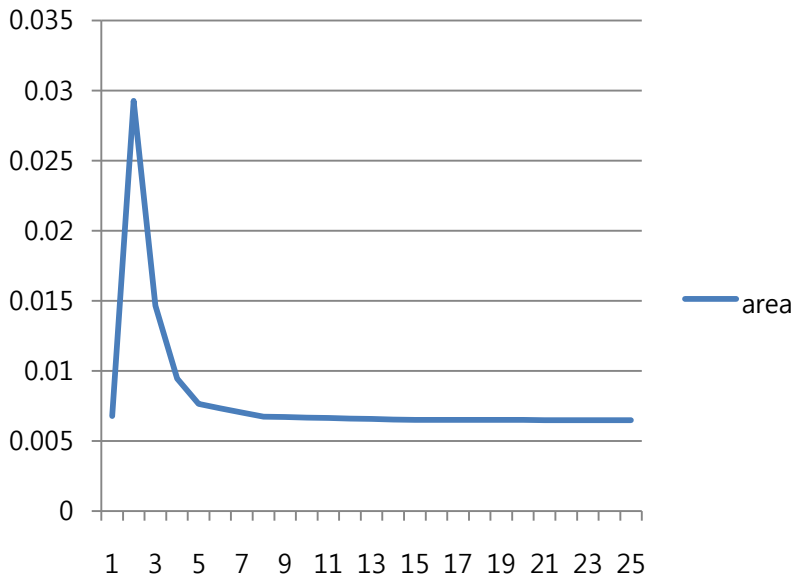




Conjugate gradient method

Initial Value	
x (m)	0.02
h (m)	0.09
b (m)	0.02
area (m^2)	0.00678

Optimized Value	
x (m)	0.00927
h (m)	0.02068
b (m)	0.09338
area (m^2)	0.006495

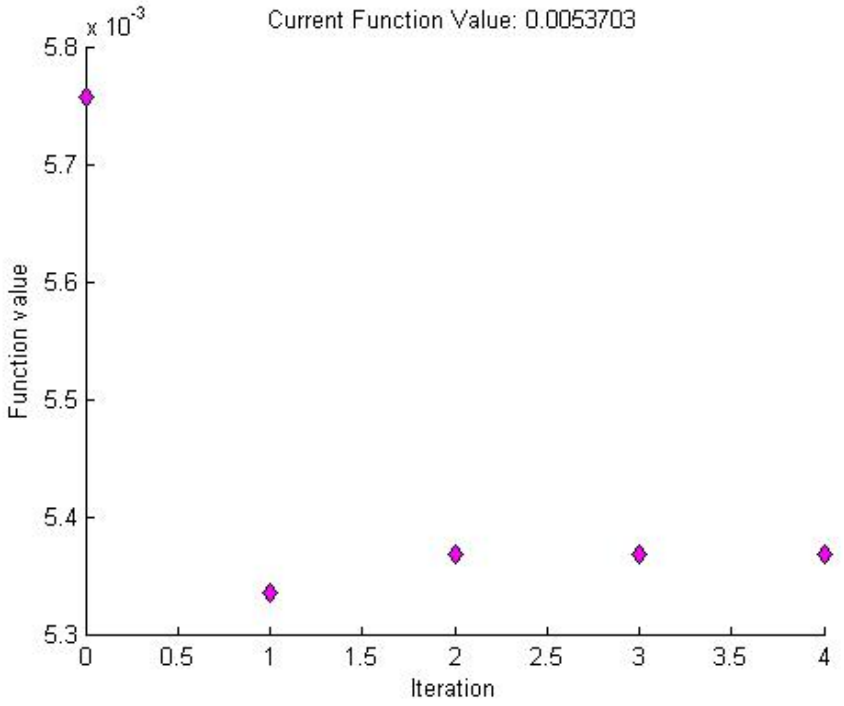


Iteration : 25

Optimized by fmincon

Initial Value	
x (m)	0.01241
h (m)	0.088
b (m)	0.017
area (m^2)	0.005636

Optimized Value	
x (m)	0
h (m)	0.089
b (m)	0.018
area (m^2)	0.00537

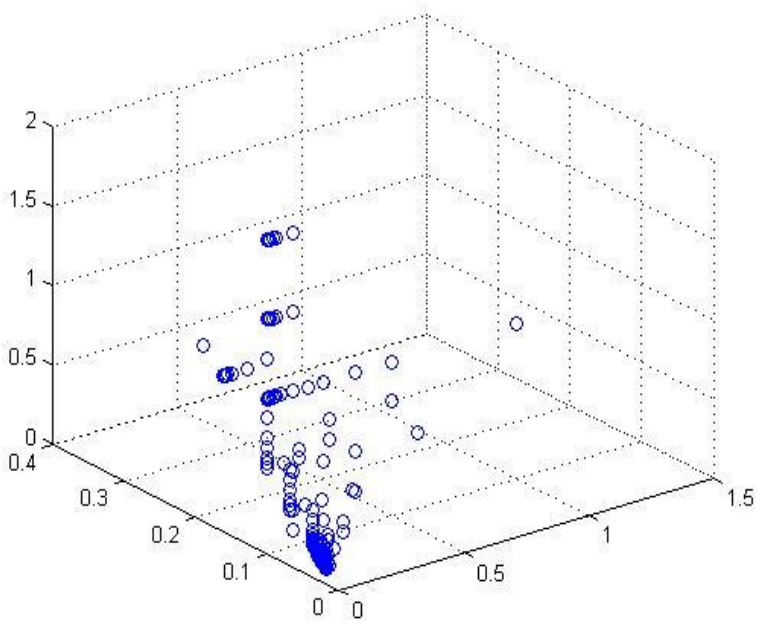


Iteration : 4

Optimized by Pattern search

Initial Value	
x (m)	0.1
h (m)	0.1
b (m)	0.1
area (m^2)	0.0228

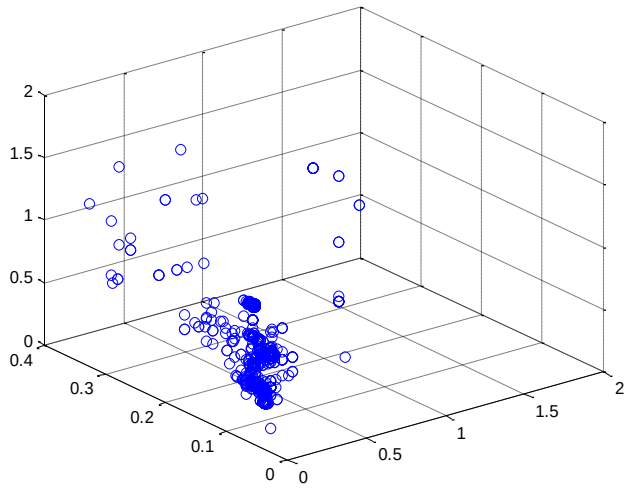
Optimized Value	
x (m)	0
h (m)	0.09
b (m)	0.018
area (m^2)	0.00539

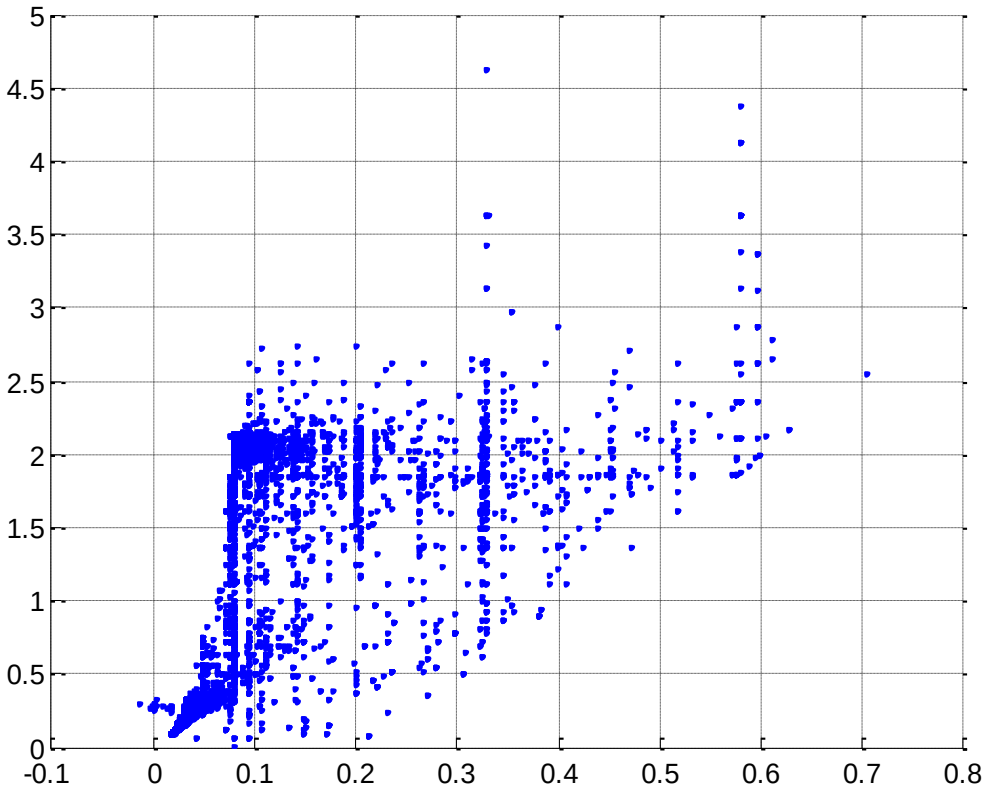


Iteration : 3

Optimized by G.A

Optimized Value	
x (m)	0
h (m)	0.089
b (m)	0.018
area (m^2)	0.00537





Result

Graphical	
x (m)	0.01241
h (m)	0.088
b (m)	0.017
area (m^2)	0.005636

Conjugate gradient	
x (m)	0.00927
h (m)	0.02068
b (m)	0.09338
area (m^2)	0.006495

fmincon	
x (m)	0
h (m)	0.089
b (m)	0.018
area (m^2)	0.00537

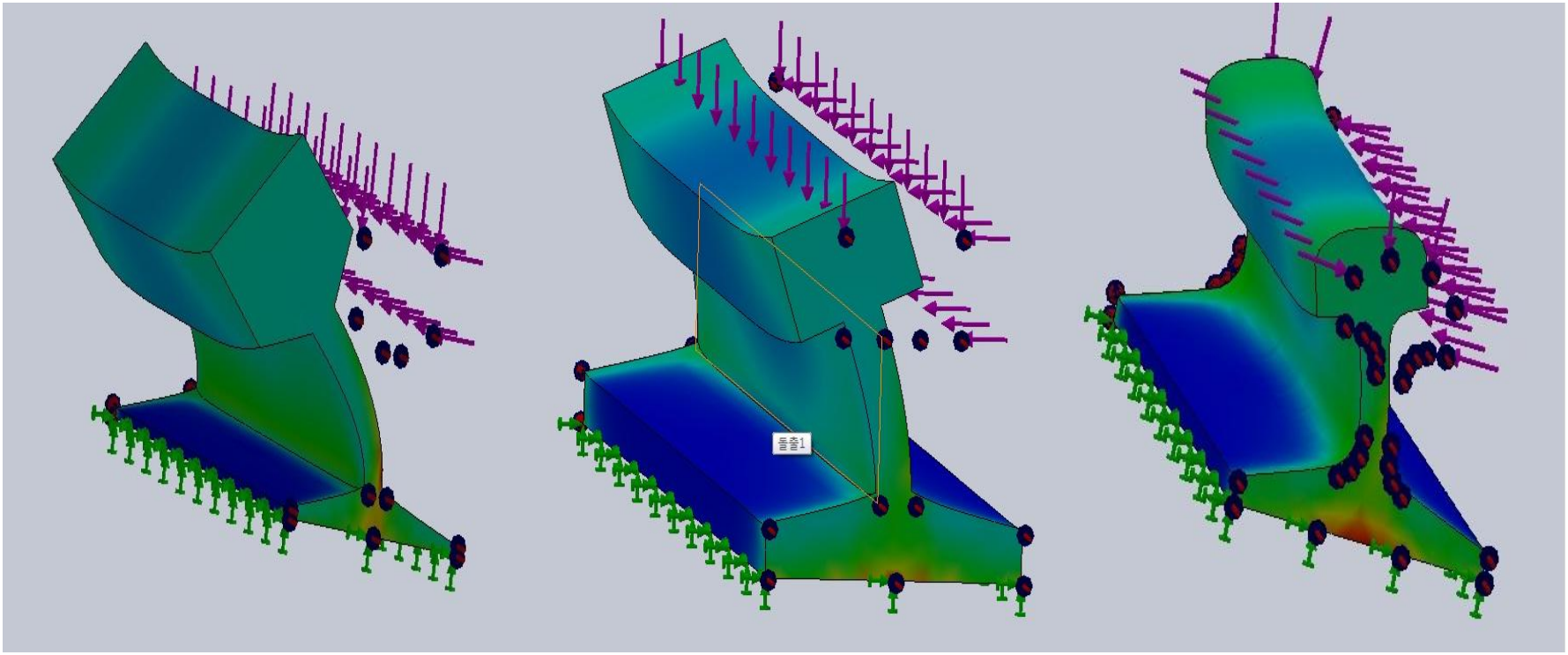
Genetic algorithm	
x (m)	0
h (m)	0.089
b (m)	0.018
area (m^2)	0.00537

Pattern search	
x (m)	0
h (m)	0.09
b (m)	0.018
area (m^2)	0.00539

Simulation

100배의 하중을 주었을 때

Project 1 | Project 2 | Standard



Comments

1. Simulation 결과 기존의 레일에 비해 좋은 결과를 얻지 못함

2. 다양한 최적화 방법을 이용하여 최적해 도출

3. 최적화 과정에서 초기값의 영향을 크게 받음

   - 초기값이 조금만 변해도 발산

   - G.A를 통한 대략적인 경향성 판단 후 적절한 초기값 선정

Reference

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2. 재료역학 / 임장근 외 3명 저 / 병진

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4. Introduction of optimum design
   / Jasbir S. Arora저/ ELSEVIER

5. 한국 철도 기술 연구원 http://www.krri.re.kr/

Q n A