Optimum Design

Project 1

철도 레일 설계 최적화

峰珍魯勳

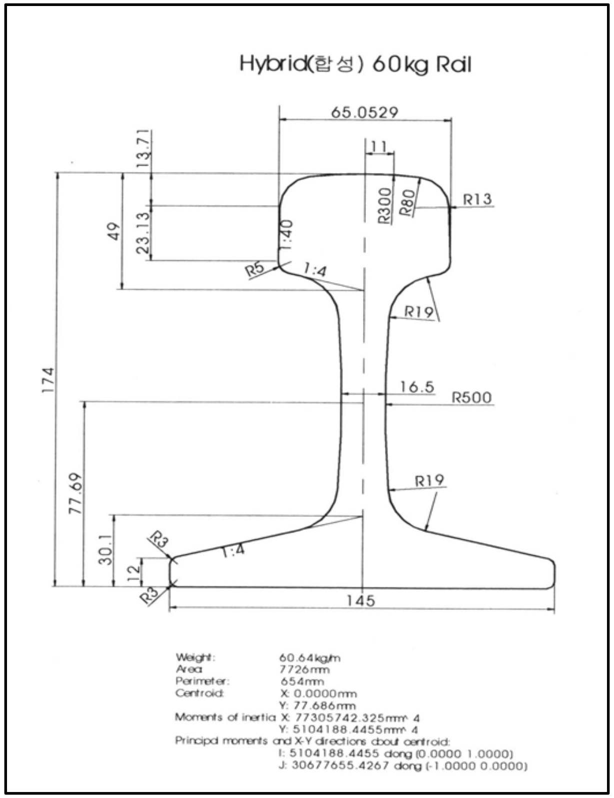
2003007709 최봉진

2004006378 이노훈

Contents

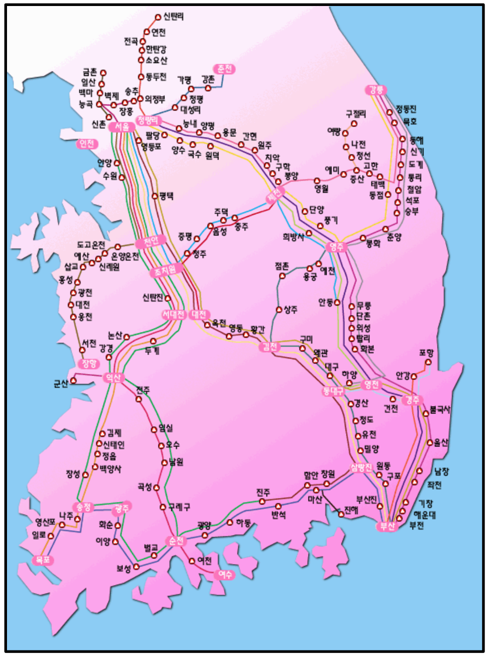
Problem

- 철도 레일 설계 최적화



Formulation

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



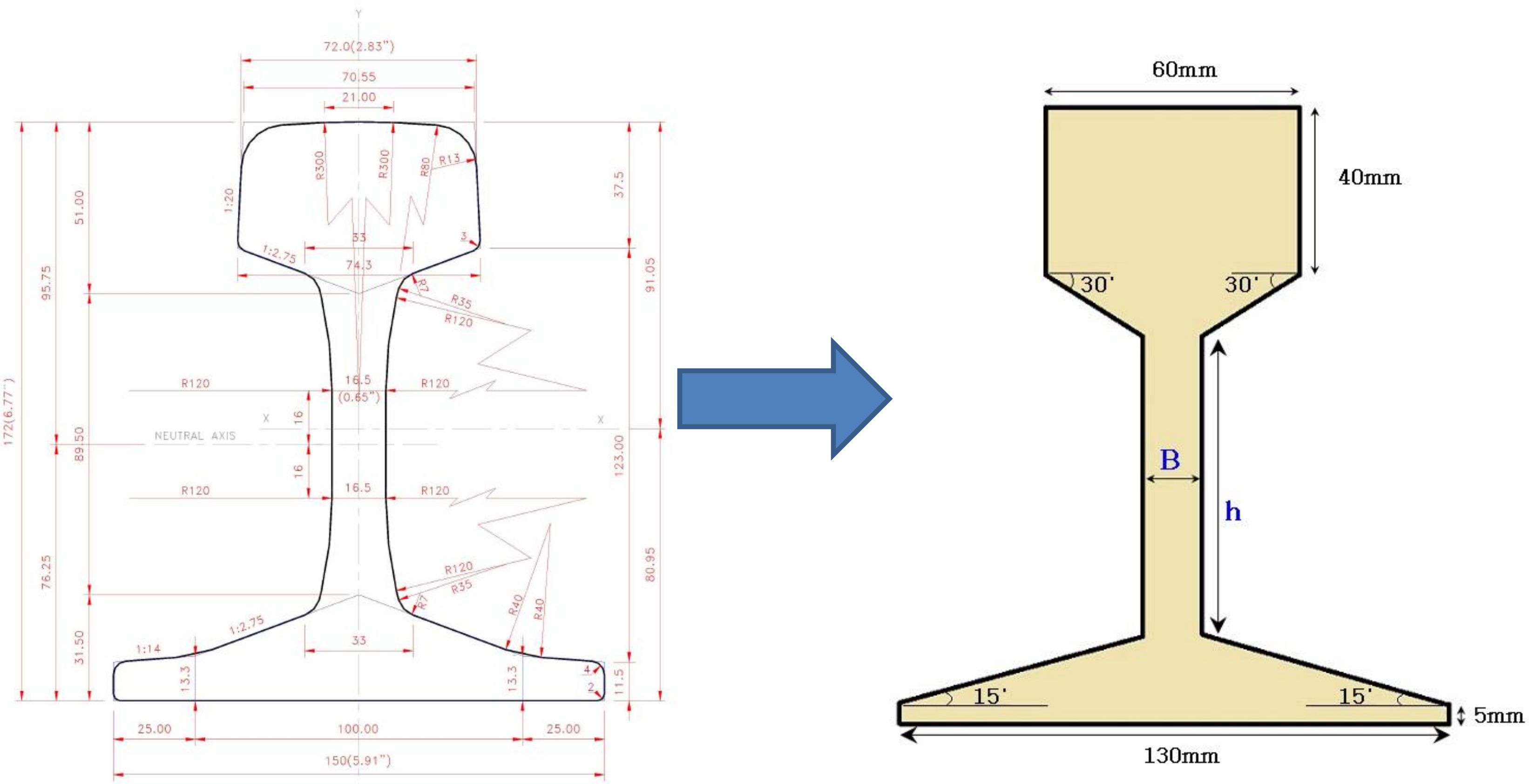
Formulation

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

KS60 Property		
Yield Strength	Tension	900 MPa
	Shear	350 MPa
Elasticity		200 GPa
Thermal Expansion Coefficient		$1.2*10^{-6}$ m/m′c
Area		7750 mm^2

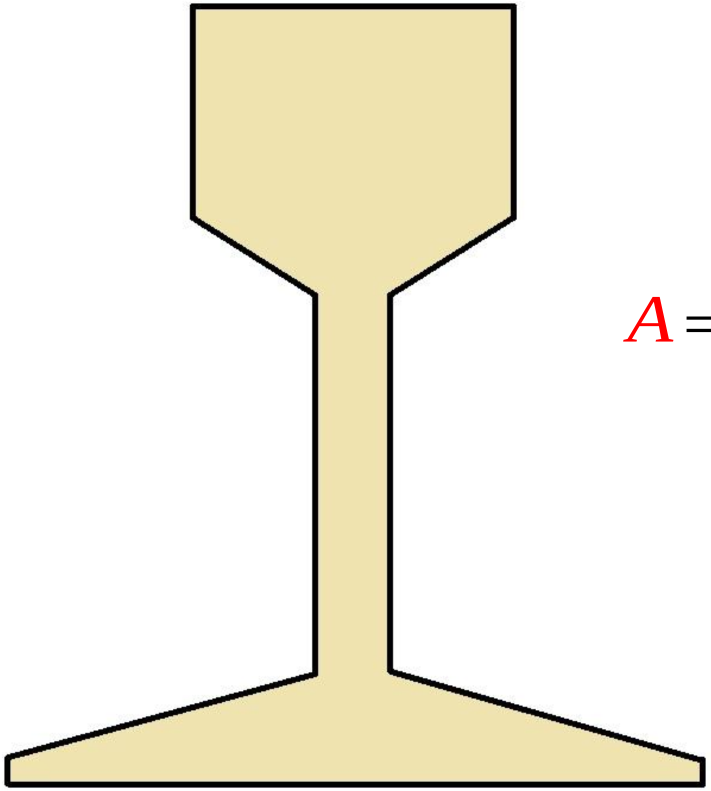
Formulation

- **Step 3. Identification/Definition of Design Variables**



Formulation

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

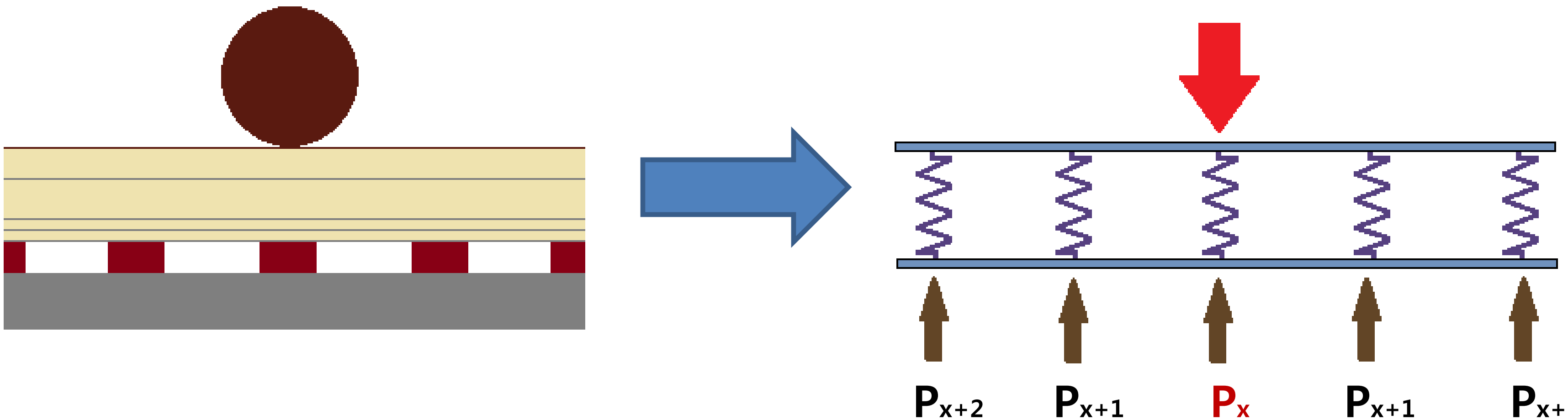


Area minimize

$$A = -0.317b^2 + 0.0174b + bh + 0.0097$$

Formulation

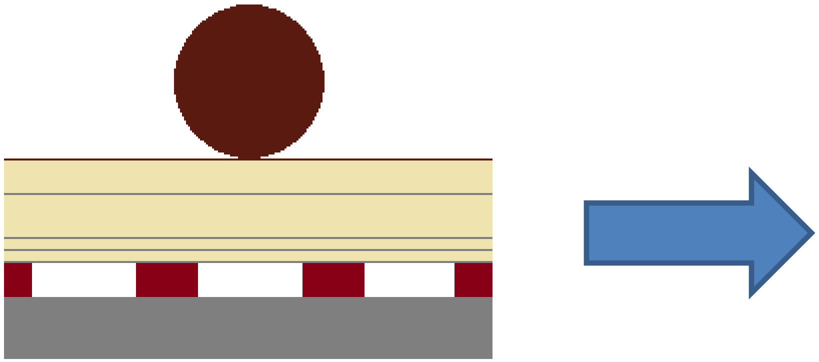
- **Step 5. Identification of Constraints**

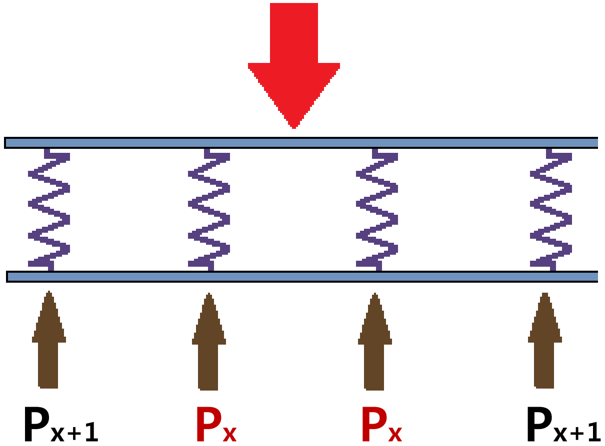


$$P_1 = \int_0^a ky\,dx = \frac{W}{2}\left[1-\phi(\beta a)\right] \quad \left(where \quad \begin{matrix} \phi(x) = e^{-x}\cos x \\ a = 침목간격 \end{matrix} \;,\quad \beta = \sqrt{\frac{k}{4EI_x}} \right)$$

Formulation

- **Step 5. Identification of Constraints**

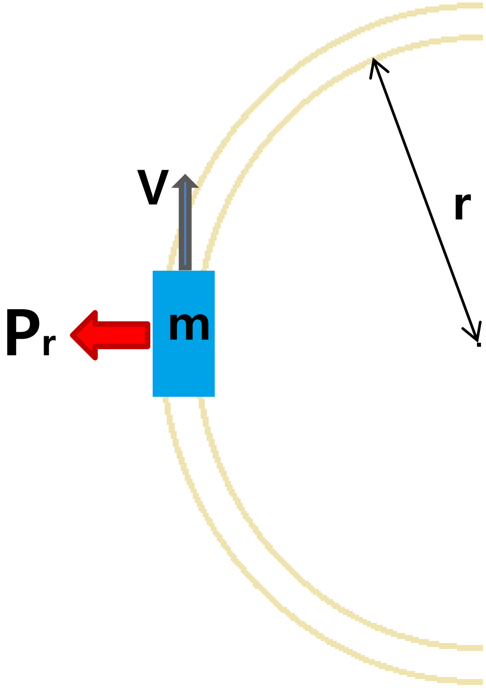




$$P_2 = 2\int_0^{\frac{a}{2}} ky\,dx = W[1-\phi(\frac{a}{2}\beta)] \quad \left(\begin{matrix} where & \begin{matrix} \phi(x) = e^{-x}\cos x \\ a = \text{침목간격} \end{matrix} & , & \beta = \sqrt{\dfrac{k}{4EI_x}} \end{matrix} \right)$$

Formulation

- **Step 5. Identification of Constraints**

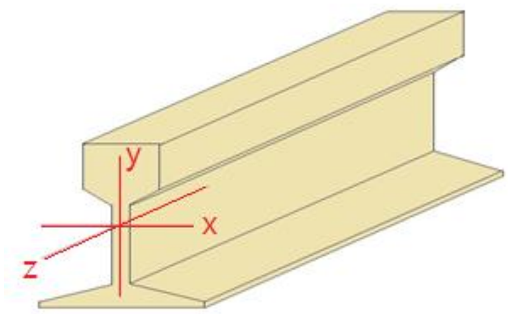


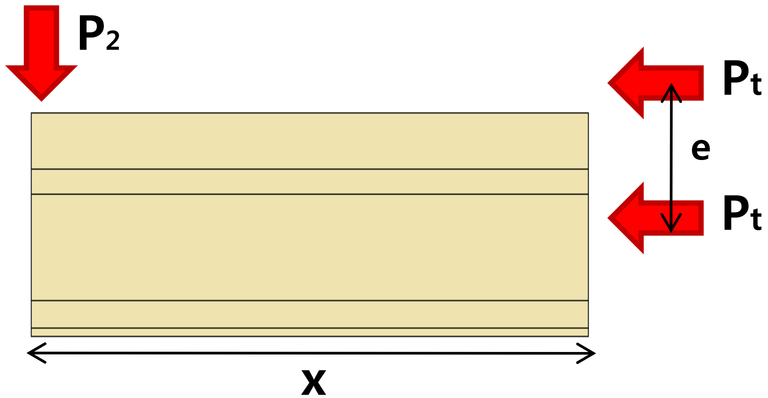
$$P_r = \frac{mV^2}{r}$$

Formulation

- **Step 5. Identification of Constraints**

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



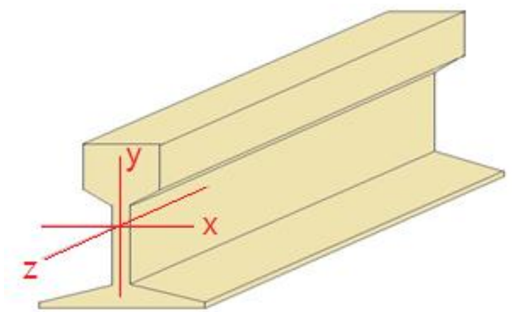


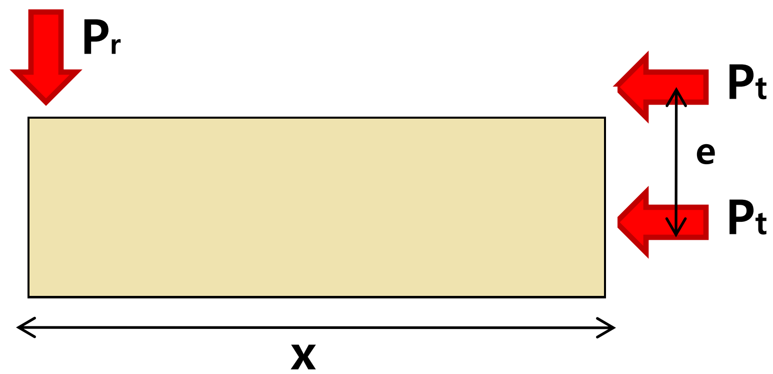
$$P_{cr} = P_t\left[1+\frac{ce}{r^2}\sec\left(\sqrt{\frac{P_t}{EI_x}}\frac{L_e}{2}\right)\right] \quad \left(where \quad e=\frac{P_2 x}{P_t}\ , \quad r^2=\frac{I_x}{A} \right)$$

Formulation

- **Step 5. Identification of Constraints**

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



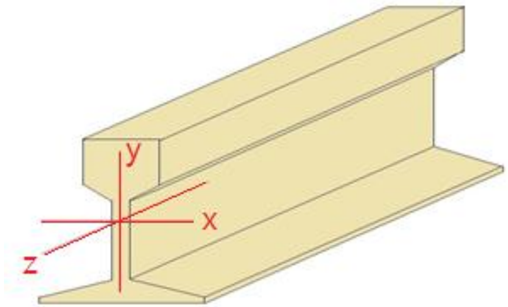


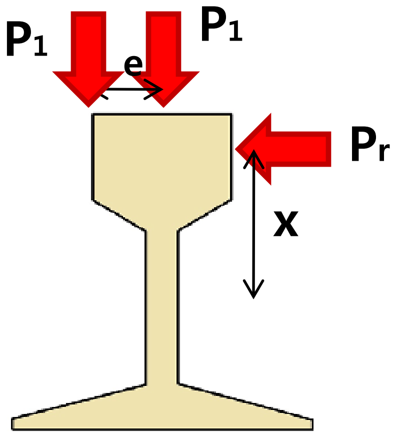
$$P_{cr} = P_t\left[1+\frac{ce}{r^2}\sec\left(\sqrt{\frac{P_t}{EI_y}}\,\frac{L_e}{2}\right)\right] \quad \left(where \quad e=\frac{P_r x}{P_t}\ , \quad r^2=\frac{I_y}{A}\right)$$

Formulation

- **Step 5. Identification of Constraints**

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



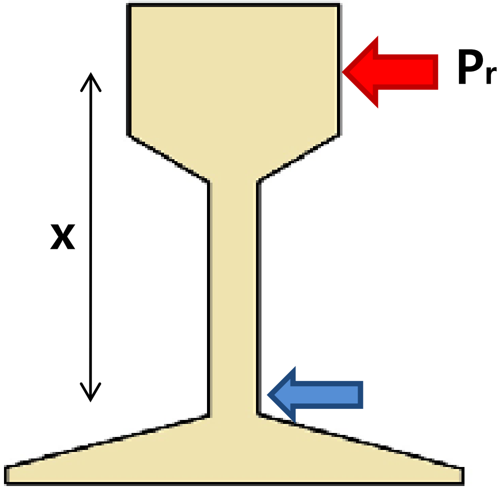


$$P_{cr} = P_t\left[1+\frac{ce}{r^2}\sec\left(\sqrt{\frac{P_t}{EI_z}}\frac{L_e}{2}\right)\right] \quad \left(where \quad e=\frac{P_r x}{P_t}, \quad r^2=\frac{I_z}{A}\right)$$

Formulation

- **Step 5. Identification of Constraints**

4) Maximum bending stress (by P_r)



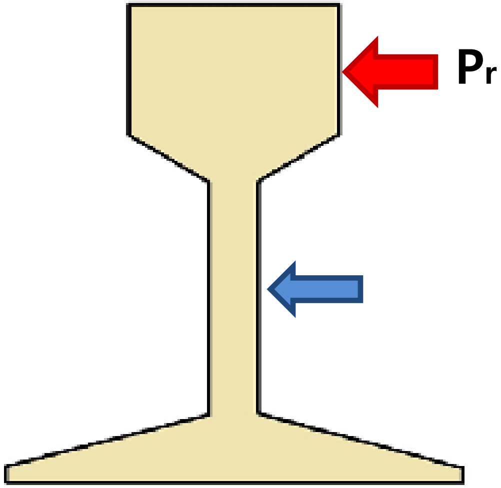
$$\sigma_{\max} = k\frac{Mc}{I_z}$$

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

Formulation

- **Step 5. Identification of Constraints**

5) Maximum Shear stress (by P_r)

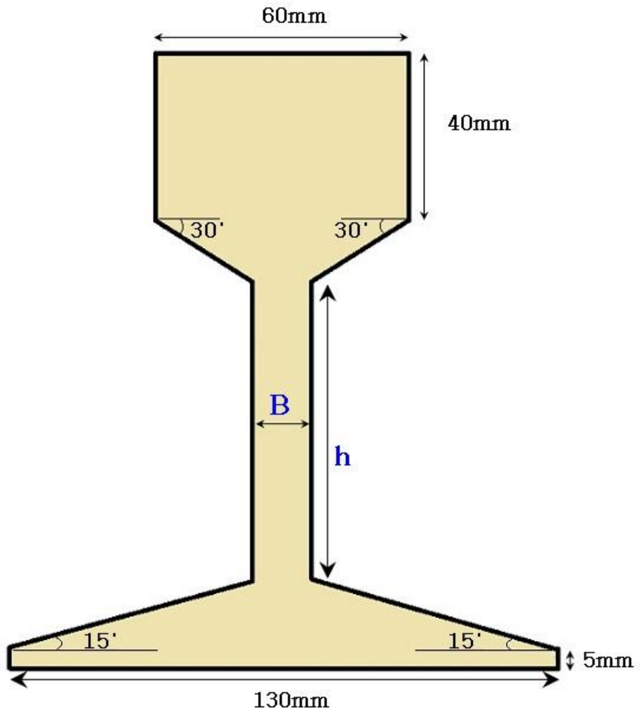


$$\tau_{max} = \frac{V}{A}$$

Formulation

- **Step 5. Identification of Constraints**

6) Geometric Shape



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

Graphical 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

Active constraints (4, 6)

Graphical optimization

- **Active constraints**

G1 : Max bending stress

$$b \geq 0.0000926\sqrt{2258h + 180} - 0.00041$$

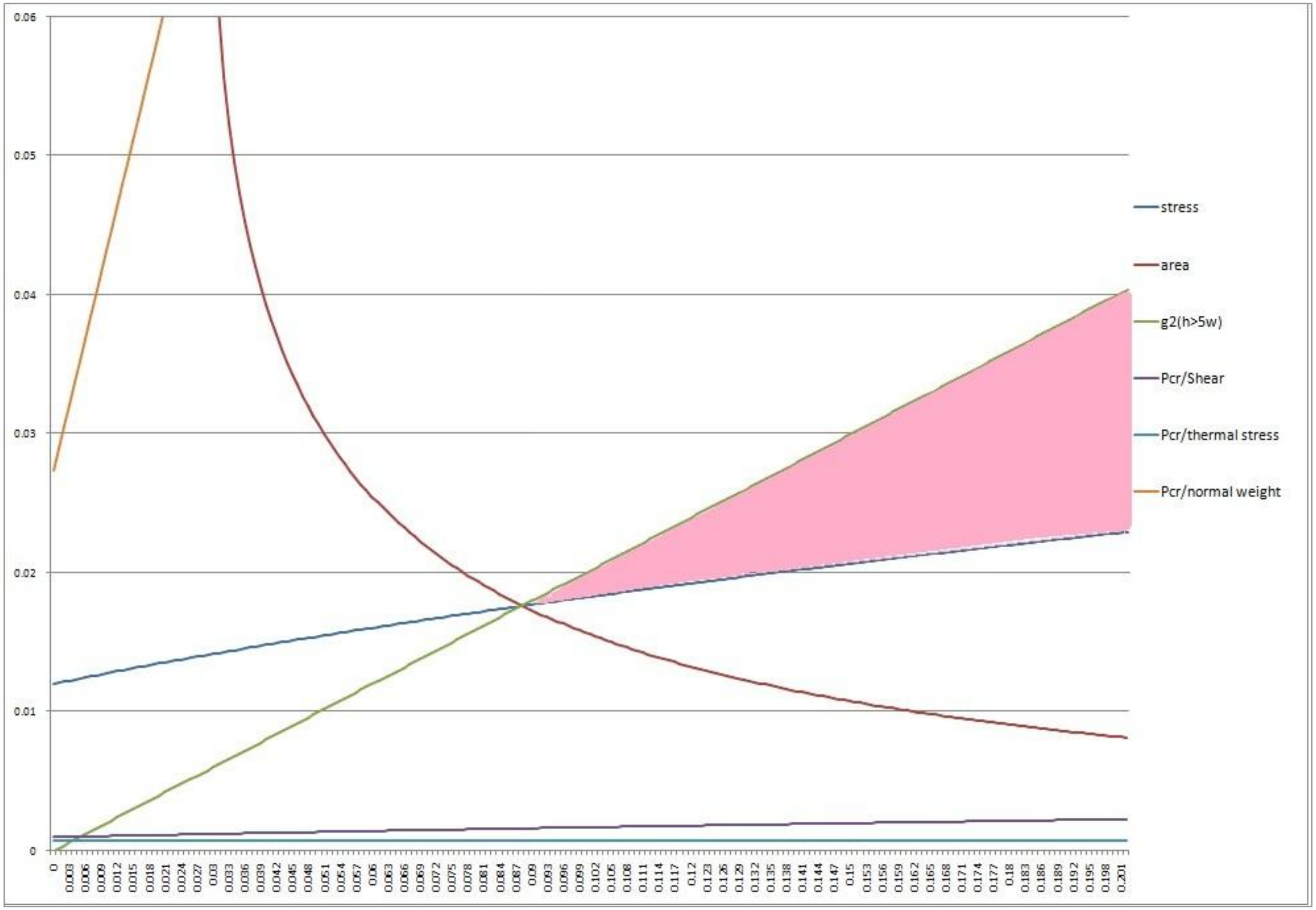
G2 : Geometric shape

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

F : Area minimize

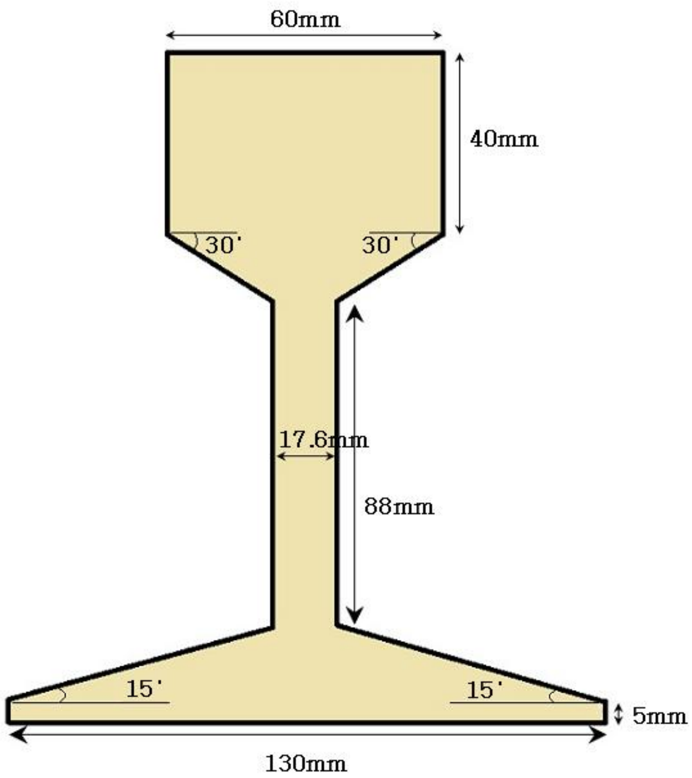
$$b = 158h - 158\sqrt{h^2 + 0.035h - 127A + 0.0052} + 0.027$$

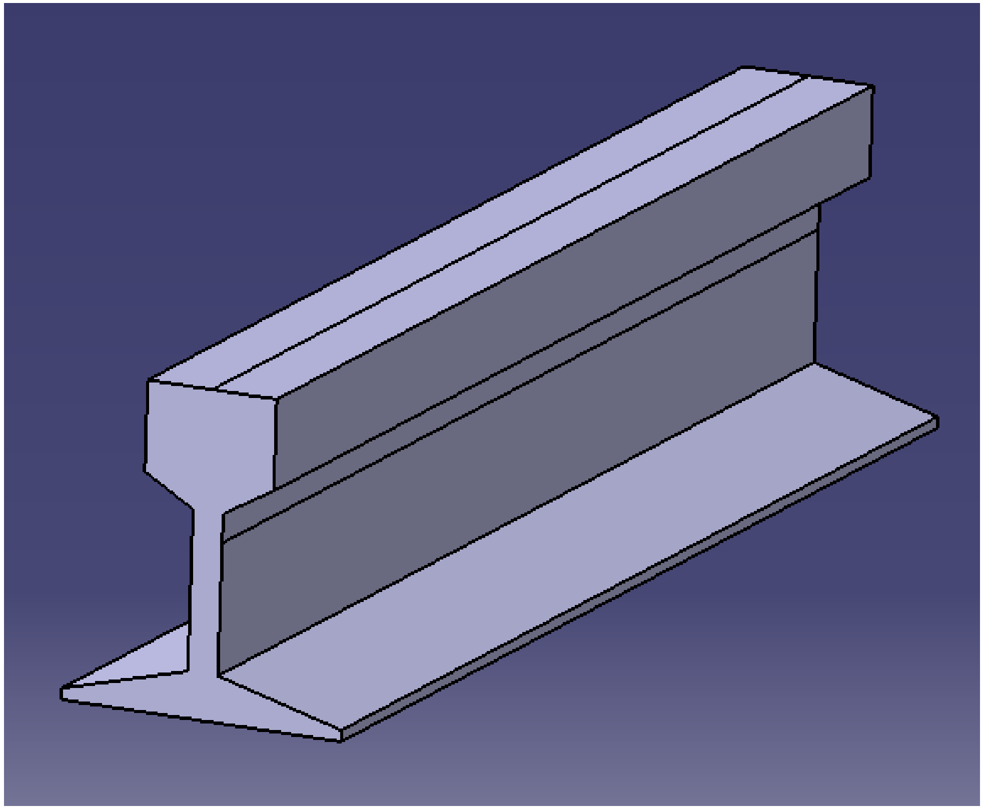
Graphical optimization



Optimized solution

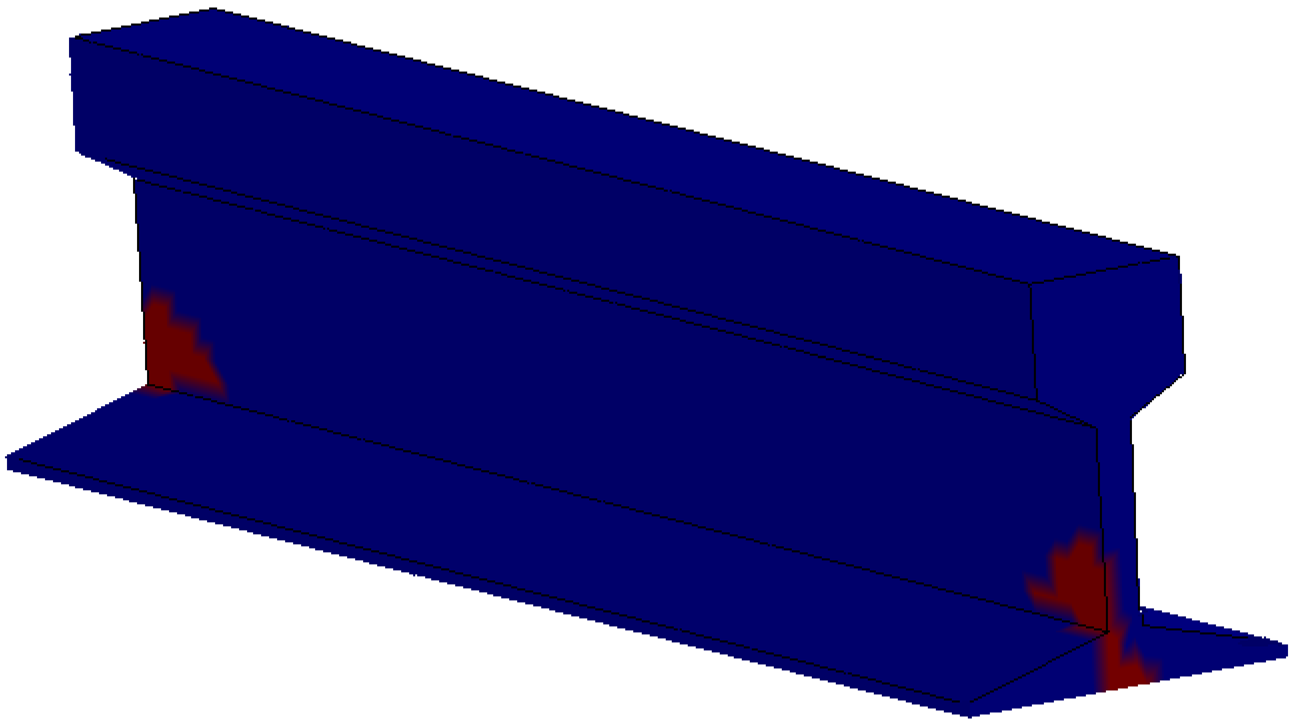
b=17.6 mm h=88 mm
A= 5635.7 mm^2 (<7750 mm^2)





Simulation

- Simulation by solidworks



Comments

1. KS60의 면적보다 좋은 결과 값 도출

2. 가정한 사실이 많아 실제로 적용 시키기는 무리

3. Simulation 결과 아랫부분에서 집중응력 발생

Reference

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2. 재료역학 / 임장근 외 3명 저 / 병진

3. 재료역학 / Beer 저 / McGrawhill

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

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