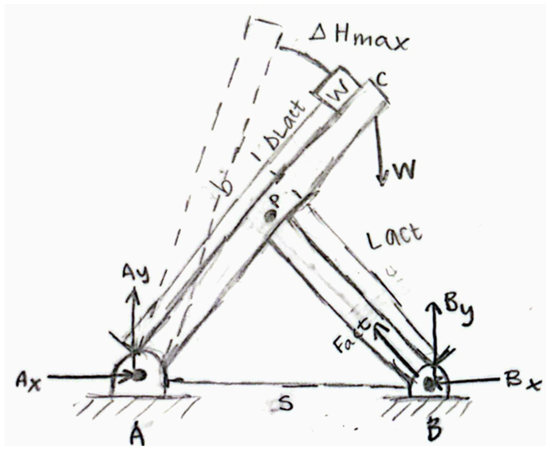
ENGRD 2020 Portfolio: Mechanism Including an Actuator

Problem Definition: The goal of my mechanism is to lift the maximum possible weight (W) to the highest vertical displacement using a linear actuator, within a fixed 2D working space of 150 cm width, and 50cm height. The system contains two ground-mounted pinned supports at points A and B, a rigid lifting bar, and a single rod-type linear actuator. All supports and the actuator are assumed rigid.

Sketch of design:



Design objectives:

- Maximize vertical lift height (ΔH)
- Maximize allowable lifting weight
- Satisfy actuator force limits (Rod-Style Actuator 58kN)
- Operate within spatial constraints.

Constraints:

- Design window: 150cm x 50cm
- Actuator maximum force: 58kN
- Horizontal distance between supports: s= 0.3m
- Bar length: b= 1m
- Actuator stroke: 1.5m

Degrees of Freedom:

The system behaves as a single degree of freedom linkage controlled by actuator stroke. The supports are pinned and the actuator imposes one displacement input, therefore only one geometric parameter controls lifting height.

Static Analysis:

Treating the member as a rigid bar, a vertical lifting reaction is produced by the actuator force projected vertically:

$$W_{max} = F_{act}\sin(\Phi).$$

With F_{max} = 58kN and geometry b= 1m, s= 0.3m:

$$\Phi = \tan^{-1}(b/s) = \tan^{-1}(3.33) = 73°$$

$$W_{max} = (58kN)(\sin(73°)) = 55kN$$

Therefore, the rigid-body upper bound load is approximately 55kN.

Step 2:

The bar is now treated as a beam, not perfectly rigid. It deflects under the payload weight and the actuator induced transverse load.

Assumptions:

- Linear elastic Euler-Bernoulli beam
- Small deflections
- Transverse loading only
- Simply supported between A-B
- Point load at distance b=1m
- Material: steel, E = 200 GPa

Analysis:

For a simply supported beam of length b under mid-span point load:

$$\delta_{max} = Wb^3/48EI$$

Assuming W=55kN and the rectangular section has a width of 20mm and a height of 40mm:

$$I=bh^3/12 = (0.02)(0.04)^3/12 = 1.07\text{x}10^{-7}\ m^4$$

$$\delta_{max} = 6.7mm$$

This maximum deflection meets the requirement $\delta_{max}< 0.02b= 20mm$.

Final Beam Design:

Rectangular steel beam made of structural steel:

- E=200 GPa
- b= 1m
- Cross-section: 40mm height x 20mm width

The heavier dimension is oriented vertically to maximize the area moment of inertia and reduce deflection.

Sketch: