CADD33D1 P1 Donnelly Joe

CRANE PROJECT CANTILIVER BEAM

The objective of this project is to design a cantilever beam that can withstand a fluctuating dynamic load. There for Case G Formula: Fluxuating Normal Stress was chosen to calculate the saftey factor
Given information: Structural Steel ASTM A36,

The hoist I chose was the LMES 3125 for its strength and light weight. Hoist weight+Trolley = 50lb,

Trolley was supplied by Chester Hoist.
Please see included brochure for detailed specifications

All math calculations were done manually at first using several different types of beams, but were then re-done in Mathcad for easy editing.

Shear and bending moment diagrams were done using MD Solids software

IMPORTANT NOTE

Definitions for MDSOLIDS DRAWINGS

P1 = Tension bar force

P2 = Total weight of crane and trolley and load/ also without load as in the drawings without the 800lb force.

W1 = Uniform weight of beam

M1 = Moment about A

P3 = Calculated force at point A

Material: Structural Steel ASTM A36 CADD33D1 P1 Donnelly Joe

I-Beam W 4 X 13

Let $\mathbf{TB_y}$ = vertical component of tension bar (TB), and $\mathbf{TB_x}$ = horizontal component of TB.
Let **Ay** = vertical reaction at pin, and **Ax** = horizontal reaction at pin.
Let **x** = distance to TB from the left, and **a** = distance to maximum load (**P**) from the left.
Let **E** = modulus of Elasticity, **I** = moment of Inertia to X-axis, and **S** = section modulus to X-axis.
Let **A** = cross-sectional area, ϕ = equivalent diameter, **w** = weight per inch, and **W** = wL (lb).
From table 14-2(b), between B and C at TB (cantilever with load only,pulling down).

Calculations with maximum load of 800lb plus 50lb for trolley and hoist totalling 850lbs

$E := 30\cdot 10^6 \frac{lb}{in^2}$ $I := 11.3in^4$ $S := 5.46in^3$ $A := 3.83in^2$ $\phi := \sqrt{\frac{4\cdot A}{\pi}}$ $\phi = 2.208\,in$

$L := 248in$ $w := \frac{13lb}{12in}$ $w = 1.083 \frac{lb}{in}$

From table 14-2(b), between B and C at TB (cantilever with load only)

Deflection due to force (Δ_F)=

$a := 8.5\cdot 12\cdot in$ $x := 244.875in$ $P := 850lb$

$$\Delta_F := \left(\frac{P\cdot a^2}{6\cdot E\cdot I}\right)\cdot(3\cdot x - a) \qquad \Delta_F = 2.751\,in$$

From table 14-2(c), between B and C at TB (cantilever with uniformly distributed load)

Deflection due to weight (Δ_Q):

$W := w\cdot L$ $W = 268.667\,lb$

$$\Delta_Q := \left(\frac{W\cdot x^2}{24\cdot E\cdot I\cdot L}\right)\cdot\left[2\cdot L^2 + (2\cdot L - x)^2\right] \qquad \Delta_Q = 1.486\,in$$

Deflection due to tension bar (Δ_{TB}):

$$\Delta_{TB} := \Delta_F + \Delta_Q \qquad \Delta_{TB} = 4.236\,in$$

From table 14-2(b), at load (cantilever with force of TBy pulling up)

$$TB_y := \frac{\Delta_{TB}\cdot 3\cdot E\cdot I}{x^3}$$

$TB_y = 293.401\,lb$

Calculations with maximum load of 800lb plus 50lb for trolley and hoist totalling 850lbs

Material: Structural Steel ASTM A36

Solving for Vertical Forces:

$\Sigma Fy = 0: \quad Ay - P + TBy - W = 0$

$Ay := P - TB_y + W \qquad Ay = 825.265\,lb$

Solving for Horizontal Forces:

$\Sigma Fx = 0: \; Ax - TB_x = 0$

$\theta := 27deg \qquad TB_x := \dfrac{TB_y}{\tan(\theta)} \qquad TB_x = 575.833\,lb$

$Ax := TB_x \qquad Ax = 575.833\,lb$

Plotting Shear Points for Shear Diagram

$A_{s1} := 0lb \qquad A_{s2} := A_{s1} + Ay \qquad P_{s1} := A_{s2} - (w \cdot a) \qquad P_{s2} := P_{s1} - P$

$TB_{s1} := P_{s2} - (w \cdot x - w \cdot a) \qquad TB_{s2} := TB_{s1} + TB_y \qquad O_s := 0lb$

$A_{s2} = 825.265\,lb \qquad P_{s1} = 714.765\,lb \qquad P_{s2} = -135.235\,lb \qquad TB_{s1} = -290.016\,lb \qquad TB_{s2} = 3.385\,lb \qquad O_s = 0\,lb$

Plotting Points for Bending Moment Diagram

$w = 1.083\,\dfrac{lb}{in} \qquad L = 248\,in \qquad P = 850\,lb \qquad TB_y = 293.401\,lb \qquad x = 244.875\,in$

$M_A := -\left(w \cdot L \cdot \dfrac{L}{2}\right) - [P \cdot (a)] + (TB_y \cdot x) \qquad M_A = -4.817 \times 10^4\,lb \cdot in$

$M_P := M_A + (Ay \cdot a) - \left[w \cdot a \cdot \left(\dfrac{a}{2}\right)\right] \qquad M_P = 3.037 \times 10^4\,lb \cdot in$

$M_{TB} := w \cdot (L - x) \cdot \left(\dfrac{L - x}{2}\right) \qquad M_{TB} = 5.29\,lb \cdot in$

Material: Structural Steel ASTM A36 CADD33D1 P1 Donnelly Joe

Beam W 4 X 13

Let **TB_y** = vertical component of tension bar (TB), and **TB_x** = horizontal component of TB.
Let **Ay** = vertical reaction at pin, and **Ax** = horizontal reaction at pin.
Let **x** = distance to TB from the left, and **a** = distance to maximum load (**P**) from the left.
Let **E** = modulus of Elasticity, **I** = moment of Inertia to X-axis, and **S** = section modulus to X-axis.
Let **A** = cross-sectional area, ϕ = equivalent diameter, **w** = weight per inch, and **W** = wL (lb).
From table 14-2(b), between B and C at TB (cantilever with load only,pulling down).

Calculations with minimum load of 50lbs contributed by the hoist and trolley.

$E := 30\cdot 10^6 \frac{lb}{in^2}$ $I := 11.3in^4$ $S := 5.46in^3$ $A := 3.83in^2$

$L := 248in$ $w := \frac{13lb}{12in}$ $w = 1.083\frac{lb}{in}$ $\phi := \sqrt{\frac{4\cdot A}{\pi}}$ $\phi = 2.208\,in$

From table 14-2(b), between B and C at TB (cantilever with load only)

Deflection due to force (Δ_F)=

$a := 8.5\cdot 12\cdot in$ $x := 244.875in$ $P := 50lb$

$$\Delta_F := \left(\frac{P\cdot a^2}{6\cdot E\cdot I}\right)\cdot(3\cdot x - a) \qquad \Delta_F = 0.162\,in$$

From table 14-2(c), between B and C at TB (cantilever with uniformly distributed load)

Deflection due to weight (Δ_Q):

$W := w\cdot L$ $W = 268.667\,lb$

$$\Delta_Q := \left(\frac{W\cdot x^2}{24\cdot E\cdot I\cdot L}\right)\cdot\left[2\cdot L^2 + (2\cdot L - x)^2\right] \qquad \Delta_Q = 1.486\,in$$

Deflection due to tension bar (Δ_{TB}):

$$\Delta_{TB} := \Delta_F + \Delta_Q \qquad \Delta_{TB} = 1.647\,in$$

From table 14-2(b), at load (cantilever with force of TBy pulling up)

$$TB_y := \frac{\Delta_{TB}\cdot 3\cdot E\cdot I}{x^3} \qquad TB_y = 114.104\,lb$$

Material: Structural Steel ASTM A36 CADD33D1 P1 Donnelly Joe

Calculations with minimum load of 50lbs contributed by the hoist and trolley.

Solving for Vertical Forces:

$\Sigma Fy = 0$: $Ay - P + TBy - W = 0$

$Ay := P - TB_y + W$ $Ay = 204.562\,lb$

Solving for Horizontal Forces:

$\Sigma Fx = 0$: $Ax - TB_x = 0$

$\theta := 27deg$ $TB_x := \frac{TB_y}{\tan(\theta)}$ $TB_x = 223.942\,lb$

$Ax := TB_x$ $Ax = 223.942\,lb$

Plotting Shear Points for Shear Diagram

$A_{s1} := 0lb$ $A_{s2} := A_{s1} + Ay$ $P_{s1} := A_{s2} - (w \cdot a)$ $P_{s2} := P_{s1} - P$

$TB_{s1} := P_{s2} - (w \cdot x - w \cdot a)$ $TB_{s2} := TB_{s1} + TB_y$ $O_s := 0lb$

$A_{s2} = 204.562\,lb$ $P_{s1} = 94.062\,lb$ $P_{s2} = 44.062\,lb$ $TB_{s2} = 3.385\,lb$ $TB_{s1} = -110.719\,lb$

$O_s = 0\,lb$

Plotting Points for Bending Moment Diagram

$w = 1.083\,\frac{lb}{in}$ $L = 248\,in$ $P = 50\,lb$ $TB_y = 114.104\,lb$

$M_A := -\left(w \cdot L \cdot \frac{L}{2}\right) - [P \cdot (a)] + (TB_y \cdot x)$ $M_A = -1.047 \times 10^4\,lb \cdot in$

$x = 244.875\,in$

$M_P := M_A + (Ay \cdot a) - \left[w \cdot a \cdot \left(\frac{a}{2}\right)\right]$ $M_P = 4.756 \times 10^3\,lb \cdot in$

$M_{TB} := w \cdot (L - x) \cdot \left(\frac{L - x}{2}\right)$ $M_{TB} = 5.29\,lb \cdot in$

Beam W 4 X 13 CADD33D1 P1 Donnelly Joe

Material: Structural Steel ASTM A36

Sx = section modulus to X-axis.
A = cross-sectional area.

$Q := \frac{13}{12} \frac{lb}{in}$ $A := 3.83in^2$ $Sx := 5.46in^3$ $Q = 1.083 \frac{lb}{in}$

$$Mmin := \left(50lb \cdot 28.625in + Q \cdot 28.625in \cdot \frac{28.625in}{2}\right)$$

Eqivalent dia $\phi_e := \sqrt{\left(4 \cdot \frac{A}{\pi}\right)}$ $\phi_e = 2.208\,in$

$Mmin := 10470lb \cdot in$

$Mmax := 48170 \cdot lb \cdot in$

Reliability factor $Cr := 1$

Consitration Stess Factor $Kt := 1$

Material $Cm := 1$

Stress factor for bending $Cst := 1$

Size factor for eqivelent diaamiter $Cs := .84$

Endurance Strength $Sn := 21000 \frac{lb}{in^2}$

Estamated Endurance Strength $S_n := Sn \cdot Cs \cdot Cm \cdot Cst \cdot Cr$

Estamated Endurance Strength $S_n = 1.764 \times 10^4 \frac{lb}{in^2}$

A36 Material Properties $Sy := 36000 \frac{lb}{in^2}$

A36 Material Properties $Su := 58000 \frac{lb}{in^2}$

$$\sigma max := \frac{Mmax}{Sx}$$

$$\sigma max = 8.822 \times 10^3 \frac{lb}{in^2}$$

$$\sigma min := \frac{Mmin}{Sx}$$

$$\sigma min = 1.918 \times 10^3 \frac{lb}{in^2}$$

$$\sigma m := \frac{(\sigma max + \sigma min)}{2}$$

$$\sigma a := \frac{(\sigma max - \sigma min)}{2}$$

$$\sigma m = 5.37 \times 10^3 \frac{lb}{in^2}$$

$$N := \frac{1}{\left[\frac{\sigma m}{Sy} + \left(\frac{Kt \cdot \sigma a}{S_n}\right)\right]}$$

Case G Formula: Fluxuating Normal Stress

$N = 2.9$ **Saftey factor**

Conclusion:

After trying several beams I found that the **W4 X 13** with a saftey factor of **2.9** was the most suitable beam for the weight(load required to hold) and application. The others had a safty value either to large or to small for the load the crain needed to carry. I felt that a saftey factor of 3 was adequate for this system since there would be no shock loading.

Normal case for structures or machine elements N=3