Fermilab

Particle Physics Division 12-01-01

Mechanical Department Engineering Note

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Project: NuMi

Project Internal Reference:

Title: Power Supply Moving Base Hilman Roller Assembly

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Key Words: NuMi , Power Supply Box Frame, Moving Base Hilman Roller Assembly

Abstract/Summary:

The NuMi Power Supply Moving Base Hilman Roller Assembly was originally designed by David Tinsley. This engineering note is prepared in order to verify that this design is in compliance with the code.

The Hilman Roller Assembly is used to move the Power Supply Box Frame to its final location. Four Hilman rollers will be mounted, one at each

corner, to facilitate this move (see dwg. 8875.111-MD-4317XX for details) The frame weights 21,500 pounds.

The design analysis was performed according to AISC "Allowable Stress Design" code. The results show that the modified moving Base Support Plate will safely support the Power Supply Box Frame within the allowable stress and deflection limits.

Applicable Codes:

1. AISC Manual of Steel Construction, Allowable Stress Design, Ninth Edition

1. check the Hilman Roller capacity.

knowing. $W_{power\ supply} = 21500$ lbs

Thus, $W_{each\ Hilman} = \frac{1}{3} W_{power\ supply}$

$= \frac{1}{3} \times 21500$

$= 7166.6$ lbs

Hilman capacity $= 3.75$ ton

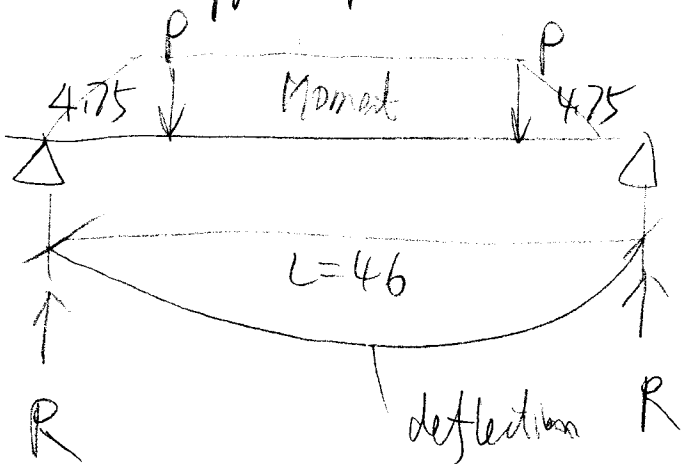
$= 3.75 \times 2000$

$= 7500$ lbs

$SF = \frac{7500}{7166.6} = 1.04$

OK

2. check the support plate.



knowing $W_{power\ supply} = 21500$ lbs

$P = \frac{1}{3} W_{power\ supply} = \frac{1}{3} \times 21500$

$= 7166.6$ lbs

bending: $M_{max} = Pa$

$= 7166.6 \times 4.75 = 34041.6$ lb·in

$S = \frac{ab^2}{6} = \frac{7 \times 0.75^2}{6} = 0.656 \text{ in}^3$

$f_b = \frac{M}{S} = \frac{34041.6}{0.656} = 51.89 \text{ ksi} < F_b$ N.G

check $\frac{b}{t}$: $\frac{b}{t} = \frac{7}{0.75} = 9.3$ $\frac{190}{\sqrt{F_y}} = \frac{190}{\sqrt{36}} = 31.6$

$\because \frac{b}{t} < \frac{190}{\sqrt{F_y}}$ $\therefore$ compact

$F_b = 0.75 F_y$ $F_y = 36$ ksi for A36

$= 0.75 \times 36 = 27$ ksi

propose to change A36 to ~~T1 TYPE A~~ ALLOY STEEL ASTM A514 Grade B.

$\frac{b}{t} = 9.3$ $\frac{190}{\sqrt{F_y}} = \frac{190}{\sqrt{100}} = 19$

$\because \frac{b}{t} < \frac{190}{\sqrt{F_y}}$

$\therefore$ compact

$F_b = 0.75 F_y$

$= 0.75 \times 100$

$= 75$ ksi

$$\delta_{max} = \frac{Pa}{24EI}(3L^2 - 4a^2)$$

where $P = 7166.6$ lbs

$a = 4.75$ in

$E = 29 \times 10^6$

$I = \frac{ab^3}{12} = \frac{7 \times 0.75^3}{12} = 1.139 \text{ in}^4$

$L = 46$ in

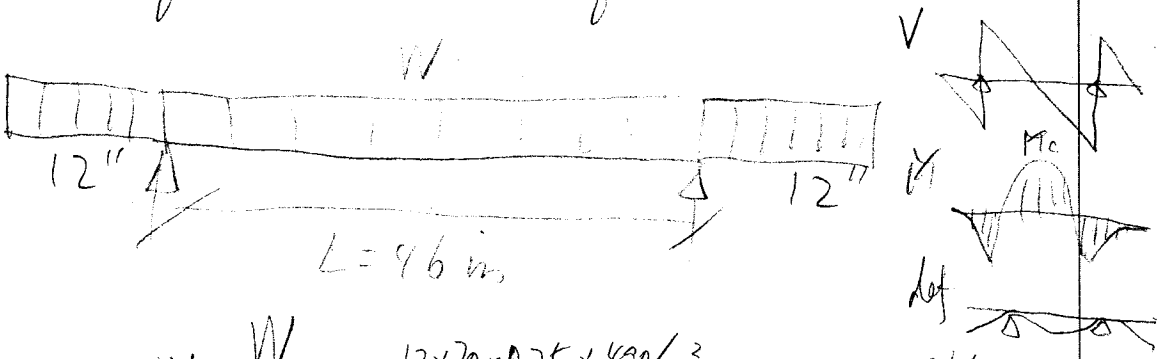
$$\delta_{max} = \frac{7166.6 \times 4.75}{24 \times E \times 1.139}\left(3 \times 46^2 - 4 \times 4.75^2\right)$$

$$= 0.268 \text{ in} < \frac{L}{180} \quad \underline{\underline{OK}}$$

Allowable deflection

$$\frac{L}{180} = \frac{46}{180} = 0.388 \text{ in}$$

Bending under its own weight:



$$w = \frac{W}{L} = \frac{12 \times 70 \times 0.75 \times 490/12^3}{70} = 2.55 \text{ lb/in}$$

Bending moments:

at supports: $M_R = -\frac{wa^2}{2} = \frac{-2.55 \times 12^2}{2} = -184 \text{ lb-in}$

at center: $M_C = \frac{W}{8}(L - 4a)$

$$= \frac{wL}{8}(L - 4a)$$

$$= \frac{2.55 \times 70}{8}(70 - 4 \times 12)$$

$$= 490.875 \text{ lb-in} \quad \text{(governs)}$$

$$S = \frac{ab^2}{6} = \frac{7 \times 0.75^2}{6} = 0.656 \text{ in}^3$$

$$f_b' = \frac{M}{S} = \frac{490.875}{0.656} = 748 \text{ psi}$$

Combined bending stress f_b'

$$f_b' = f_b + f_b'$$

$$= 51.89 + 0.748 = 52.638 \text{ ksi} < F_b = 75 \text{ ksi}$$

OK

at center:

$$def = \frac{W(L-2a)^3}{384EI}\left[\frac{5}{L}(L-2a) - \frac{24}{L}\left(\frac{a^2}{L-2a}\right)\right]$$

$$= \frac{70 \times 2.55(70-2\times12)^3}{384 \times 29 \times 10^6 \times 1.139}\left[\frac{5}{70}(70-2\times12) - \frac{24}{70}\left(\frac{12^2}{70-2\times12}\right)\right]$$

$$= 0.003''$$

at ends:

$$def = \frac{W(L-2a)^3 a}{24EI}\left[-1 + 6\left(\frac{a}{L-2a}\right)^2 + 3\left(\frac{a}{L-2a}\right)^3\right]$$

$$= \frac{70 \times 2.55(70-2\times12)^3 \times 12}{24 \times 29 \times 10^6 \times 1.139}\left[-1 + 6\left(\frac{12}{70-2\times12}\right)^2 + 3\left(\frac{12}{70-2\times12}\right)^3\right]$$

$$= -0.231''$$

Combined deflection:

at center: $\Delta = 0.268 + 0.003 = 0.271'' < 0.388$ in ok

at ends: $\Delta = -0.231$ in < 0.388 in ok

Compression:

$F_H = 10\% \, H_V$

$= 10\% \times (71666 \times 2 + 2.55 \times 70)$

$= 1451.2$ lbs — governs

$F_{H-Hillman} = 5\% \times$ capacity

$= 5\% \times 7500$

$= 375$ lbs

$f_a = \frac{F}{A}$ where $F = F_H = 1451.2$ lbs

$A_1 = 7 \times 0.75 = 5.25$ in^2

$A_2 = (12-6) \times 0.75 = 4.5$ in^2 (governs)

$= \frac{1451}{4.5}$

$= 322$ psi

Find F_a

$\frac{Kl}{r}$ where $K = 1$, $L = 70''$ $\quad r = 0.288675d$

$= 0.288675 \times 70$

$= 20.20$ in

$\frac{Kl}{r} = \frac{1 \times 70}{20.20} = 3.46$

$C_c = 75.7$ $\quad \frac{Kl}{r} < C_c$

$$\frac{\frac{Kl}{r}}{C_c} = \frac{3.46}{75.7} = 0.046 \rightarrow C_a = 0.593$$

$$F_a = C_a F_y$$
$$= 0.593 \times 100$$
$$= 59.3 \text{ ksi}$$

$F_y = 100$ ksi for T1

Combined stresses:

$$\frac{f_a}{F_a} = \frac{0.322}{59.3} = 0.0054 < 0.15$$

Thus, $\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1$

$$\frac{0.322}{59.3} + \frac{52.638}{75} = 0.7 < 1$$

OK

3. check the counter bore of the plate

a. punch shear:

$$f_v = \frac{F}{A}$$
$$= \frac{7226}{6.88}$$
$$= 1.05 \text{ ksi} \ll 40 \text{ ksi}$$

OK

where $F = 7166.6 + \frac{1}{3}(\text{PL weight})$
$= 7166.6 + \frac{1}{3} \times 2.51 \times 70$
$= 7226$ lbs

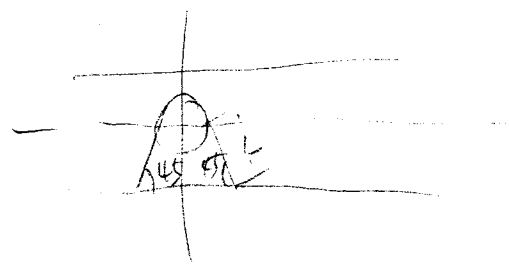
$A = \pi d t$
$= \pi \times 6 \times (0.75 - 0.385)$
$= 6.88 \text{ in}^2$

$F_v = 0.40 F_y$ $\qquad F_y = 100$ ksi for T-1

$= 0.40 \times 100$

$= 40$ ksi

b. Tear out shear



$f_{vt} = \frac{F}{A}$ $\qquad$ where $F = 7226$ lbs

$A = 2Lt$

$= \frac{7226}{10.5}$ $\qquad = 2 \times 7 \times 0.75 = 10.5 \text{ in}^2$

$= 0.688$ ksi $\ll F_v = 40$ ksi

OK

C. Bearing:

$f_p = \frac{F}{A}$ $\qquad$ where $F = 7226$ lbs

$A = \frac{1}{4}\pi d^2$

$= \frac{7226}{28.27}$ $\qquad = \frac{1}{4}\pi \cdot 6^2 = 28.27 \text{ in}^2$

$= 0.255$ ksi $\ll F_p = 90$ ksi

OK

$F_p = 0.90 F_y$ $\qquad F_y = 100$ ksi for T-1

$= 0.90 \times 100$

$= 90$ ksi

d. Bolt Bearing:

$$f_{p\text{-}bolt} = \frac{F}{A}$$

where $F = 7226$ lbs

$$A = \frac{\pi d}{2} \times t$$

$$= \frac{\pi \times 6}{2} \times (0.375)$$

$$= 3.53 \text{ in}^2$$

$$= \frac{7226}{3.53}$$

$$= 2.357 \text{ ksi}$$

$< F_p = 90$ ksi

OK