Clean Room Spacewalk (Stairs and Walkway)

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Clean Room Spacewalk (Stairs and Walkway)

Al Jaques

The CC Cryostat was moved to the cleanroom for the installation of modules. Work will continue on the top of the Cryostat with the help of platforms attached to both sides of the Cryostat. It was desired to access this platform from a nearby balcony via a walkway or "spacewalk". The spacewalk was to attach to the substructure of the east fold-down platform and across the balcony to some kind of staircase structure. The final design was a free standing stair frame and a rectangular box platform with handrails which hooks onto the stair frame and the substructure of the platform. A sketch of the cleanroom and spacewalk are included following this report.

Since the spacewalk structure had to be hand assembled once on the balcony, the material chosen was stock 6061-T6 aluminum. This aluminum combines high-strength (35 ksi yield) and light weight. A 1-1/2" aluminum bar across the staircase provides the structure for the walkway platform to hook onto. No-skid pads are placed on the channel stairs and the surface of the walkway platform to assure sure footing. The level of the walkway platform lies approximately 10" below the surface of the fold-down platform, thus requiring users to step up onto the platform.

The stress calculations and sketches are included at the end of this report. AISC rules were adhered to in designing and constraining the accompanying stresses.

6061-T6 Aluminum $\sigma_y = 35$ Ksi
 welded 6061-T6 Aluminum
 has $\sigma_{allow} = 6.0$ as per ASME
 Code

(FS = 2) $\sigma_{allow} = \frac{1}{2} 35(.66) = 11.55$ Ksi Non-welded
 $\sigma_{allow} = 6.0$ Ksi welded

*assume max. human load
 of 500 lbs
 (2 people (200# @) + 100# of Tools)

Stair channels - (welded)

$300 \text{ lbs} = 200 \text{ lb person} + 100 \text{ lb Tools}$

$I_{yy} = 2.28 \text{ in}^4$

$c = 2.6 - .634 = 1.966 \text{ in}$

$M_{middle} = \frac{Wl}{8} = \frac{300(36)}{8} = 1350 \text{ lb-in}$

(welds) $M_{ends} = \frac{-Wa}{8} (l-a)^2 = 1350 \text{ lb-in}$

$\sigma_{bending} = \frac{Mc}{I} = \frac{1350(1.966)}{2.28} = 1164.15$

$1.16 \text{ ksi} \leq 6.0 \text{ ksi}$

OK

stair welds - (welded)

$W = \frac{300 \text{ lbs}}{10 \text{ in}} = 30.0 = .030 \text{ kips/in}$
 AISC (shear)

$W_{allow} = (70.7) 6 = 4.242 \text{ kips/in}$

OK

Side Frame Channels - (welded)

$$A = 4.49 \text{ in}^2$$

$$I_{xx} = 67.4 \text{ in}^4$$

$$C = 5 \text{ in}$$

$$M = 173.4 (18.5) = 3208 \text{ in-lbs}$$

$$(\text{bending}) \sigma_b = \frac{M_c}{I} = 238.0 \text{ psi} = \pm .238 \text{ ksi}$$

$$(\text{compressive/tensile}) \sigma_{c,t} = \frac{173.4 \cos 45^\circ}{A} = 27.3 \text{ psi} = \pm .027 \text{ ksi}$$

$$\sigma_{tot} = |\sigma_b| + |\sigma_{c,t}| = 0.265 \text{ ksi}$$

1 1/2" Round - (Non-welded)

$$\leq 6.0 \text{ ksi}$$

OK

$$\frac{1}{2}(107.4) = 53.7 = \text{from weight of walkway platform}$$

$$\frac{1}{2}(500) = 250 = \text{from human weight}$$

Tool

* worst case would have platform sliding to one end, i.e. -

$$2049.3$$

$$2050.2$$

$$M_{max} = 329.6 (27)$$

$$= 2050 \text{ psi}$$

$$\frac{I}{c} = \frac{\pi r^3}{4} = \frac{\pi (.75)^3}{4} = 0.331 \text{ in}^3$$

$$(\text{bending}) \sigma_b = \frac{mc}{I} = \cancel{m} \left(\frac{I}{c} \right) = 6194.0 \text{ psi}$$

$$\underline{6.2 \text{ ksi}} \leq 11.55 \text{ ksi}$$

OK

~~6.2 ksi < 11.55 ksi~~

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Platform Frame - (Non-welded) *welds are not directly bearing the load

$$I = 2 I_{\text{angle}} = 2(17.4) = 34.8 \text{ in}^4$$

$$c = 6 - 1.99 = 4.01 \text{ in}$$

$$M_{\text{max}} = 214.7(42.5) = 9125 \text{ lb-in}$$

$$\sigma_b = \frac{Mc}{I} = \frac{9125(4.01)}{34.8} = 1051.5$$

$$\underline{1.05 \text{ ksi}} \leq 11.55 \text{ ksi}$$

OK

Platform Surface

- Stresses

* Roark + Young p 386, Table 26, case 1c.

- Conservatively assume simply supported edges
- Central rectangular area of load (300 lbs) is 4" x 12" (footprint size)

$$\frac{a_1}{b} = 0.49$$

$$\frac{b_1}{b} = 0.16$$

$$\frac{a}{b} = 1.39$$

$$\underline{\underline{\beta \approx 1.2}}$$

$$\text{Max } \sigma = \sigma_b = \frac{\beta W}{t^2}$$

$t = (0.25")$ (thickness)

$W = 300$ lbs, weight (300 lbs)

$$\sigma_b = \frac{1.2 (300)}{(0.25)^2} = 5760 \text{ psc}$$

$$\underline{\underline{5.76 \text{ ksc} < 11.55 \text{ ksc}}}$$

OK

Platform Surface

- Deflection

* Theory of Plates & shells 2nd Ed

Timoshenko + Woinowsky-Krieger, p. 138, eq. 143

"partially loaded (centered) Simply Supported Plate"

$$D (\text{aluminum}) = 14400 \text{ psi} \quad \left(\text{Flexural Rigidity} = \frac{E t^3}{12(1-\nu^2)} \right)$$

(deflection at center)

$$w_{\max} = \frac{4 q a^4}{D \pi^5} \sum_{m=1,3,5,\dots}^{\infty} \frac{1}{m^5} \sin \frac{m \pi u}{2a} \left\{ 1 - \frac{1}{\cosh \alpha_m} \right.$$

$$\left[\cosh(\alpha_m - 2\gamma_m) + \gamma_m \sinh(\alpha_m - 2\gamma_m) + \alpha_m \frac{\sinh 2\gamma_m}{2 \cosh \alpha_m} \right]$$

$$\alpha_m = \frac{m \pi b}{2a}, \quad \gamma_m = \frac{m \pi v}{4a}$$

Summing for $m = 1, 3$ and 5 :

$$w_{\max} = 7.57858 (0.02060 + 0.00107 + 0.00004)$$

$$= \boxed{0.165 \text{ in.}}$$

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Above each load are the magnitudes in lb, lb/ft, and lb-in.

Next to each support are reactions in lb and lb-in.

Positive reactions and deformations are to the right, upwards, and counter-clockwise.

Bar Support

Node 1	FReact	MReact	Elem 1,2	Node 2	FReact	MReact
6.00e+0	0.00e+0	---	L= 6.20e+1	6.80e+1	0.00e+0	---
6.00e+0	4.66e+2	---	E= 2.90e+7	6.00e+0	1.69e+2	---
---	---	3.556e+3		---	---	-2.566e+3

FL1
0.00e+0
3.04e+2

FL1
0.00e+0
3.04e+2

Bar Support (on Sauer Platform)

$$M_{max} = 3556 \text{ lb-in}$$

$$c = 1.0 \text{ in}$$

$$I = \frac{b \cdot h^3}{12} = \frac{(\frac{3}{4})(2)^3}{12} = 0.5 \text{ in}^4$$

$$\sigma_B = \frac{M c}{I} = \frac{3556(1)}{0.5}$$

$$(\text{see below}) = \underline{\underline{7.11 \text{ ksi}}} \quad \underline{\underline{OK}}$$

Material is 2018 C.D.S.

given a 30 ksi yield

we will take 90% of that

to cover any uncertainty.

$$\sigma_{yield} = (0.9)(30) = 27 \text{ ksi}$$

$$(\text{AISC allowable}) \therefore \sigma_{allow} = (0.66) 27 = \underline{\underline{17.8 \text{ ksi}}}$$

Torsion = $T \approx M_{max} = 3556 \text{ lb-in}$

Weld Pattern

* Steel Plate Engineering
Data - Volume 2
Published by AISI

$$J_w = \frac{(b+d)^4 - 6b^2d^2}{12(b+d)} = \frac{(1.5+2)^4 - 6(1.5)^2(2)}{12(1.5+2)} = 2.287 \text{ in}^3$$

$$C_v = 2 - \bar{Y} = 1.43''$$

$$C_h = \bar{X} = 0.32''$$

(See Frame)
Max Results) $V = 466 \text{ lbs}$

(AISC) $f_t = 70.7(30)(.4) = 8.5 \frac{\text{kips}}{\text{lin-in}}$

Allowable
Shear

$$W_v = \frac{TC_h}{J_w} = 497.6 \frac{\text{lbs}}{\text{lin-in}}$$

$$W_s = \frac{V}{A_w} = \frac{466}{3.5} = 133.14 \frac{\text{lbs}}{\text{lin-in}}$$

$$W_h = \frac{TC_v}{J_w} = 2223.5 \frac{\text{lbs}}{\text{lin-in}}$$

$$Min \text{ weld size} = \frac{W}{f_t} = \frac{\sqrt{(W_v + W_s)^2 + (W_h)^2}}{8.5} = \frac{2.31 \frac{\text{kips}}{\text{lin-in}}}{8.5 \frac{\text{kips}}{\text{lin-in}}} = 0.27'' \leq \boxed{\frac{5}{16}}''$$

Fold-down
Platform
Framework

10

Structural Tube analysis

(Due to moment from bar)

lb-ft
= 3556 lb-in

CC
Cryostat

Fold-down
Platform
level

Stiffening
Ring

FRAME MAC file: framework; Last modified at 10:28:50 AM on Thu, Jan 26, 1989

Node 2	FReact	MReact	Elem 2,3	Node 3	FReact	FNd1	MNd1
2.4000e+1	2.89e+2	---	L= 1.1250e+1	2.4000e+1	-3.02e+2	1.35e+1	---
5.7625e+1	1.99e+0	---		6.8875e+1	7.86e+0	5.87e+0	---
---	---	5.03e+1	E= 2.90e+7	---	---	---	-2.49e+1

MD1

-2.96e+2

* Maximum Bending Stress (4280 psi) occurs at application of moment from Bar Support.

compressive or tensile loading →
 With a cross-sectional area of 1.25 in², the box-beam structural tubing would have to see a load of 17000# each along with this bending stress to approach the allowable 17.8K

CC
Cryostat

Scaffolding Stages (see sketch on previous page)

- treat as a cantilever beam

Stage has a 500 lb capacity
(assume stage weight = 100 lbs)

total load = 600 lbs

$$\Sigma M_0 = 25(2) + 495(14)$$

$$= \underline{6980 \text{ in-lbs}}$$

$$I = \frac{1.5^4}{12} - \frac{1^4}{12} = \underline{0.34 \text{ in}^4}$$

$$C = \underline{0.75}$$

$$\sigma_b = \frac{M_c}{I} = \frac{6980(0.75)}{0.34} = \boxed{15.4 \text{ ksi}} \quad \text{OK}$$

< 17.8 ksi

* This assumes a cantilever beam when in actuality it is a member of a box frame. (See page 8)

$$\Sigma M_{R1} = 250(204 - 24) + 250(204) - R_2(204) = 0$$

$$R_2 = 470.6 \text{ lbs}$$