AD-A192 313 FEB (MULTIFILTER ELECTRONICS BOX) LIFTING DEVICE ANALYSIS REVISION A..(U) PENNSYLVANIA STATE UNIV UNIVERSITY PARK COMMUNICATIONS AND SP.. C L CROSKEY 1/1

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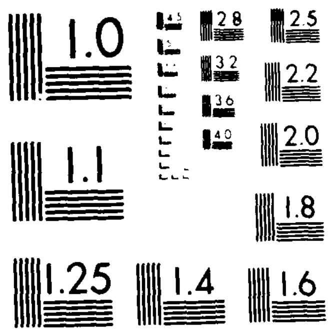

MICROCOPY RESOLUTION TEST CHART

TN 2036-9180 NR/01

FEB Lifting Device Analysis

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by

Dr. Charles L. Croskey

Communications and Space Sciences Laboratory

The Pennsylvania State University

FEB Lifting Device Analysis

1. Scope

This document is to determine the mechanical loads produced when the FEB is either lifted manually with handles or by a sling and overhead hoist.

2. Relevant Documents

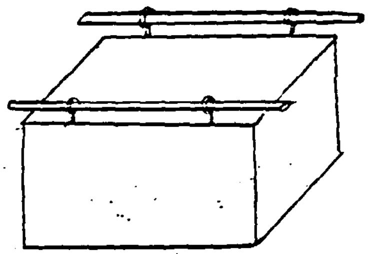
2.1 JA418

2.2 ES-MAS-DS-003 MAS Ground Support Equipment Specification

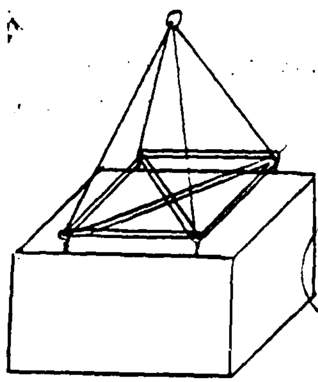
2.3 An Introduction to the Design and Behavior of Bolted Joints
John H. Bickford, MARCEL DEKKER, New York

3. Lifting Apparatus

3.1 For the lifting of FEB by either handles or a sling from an overhead hoist, four eyebolts are attached to the top mounting edge, through the top cover and into the top flange of the sidewalls. When the FEB is to be lifted manually without mechancial assistance, two long stainless steel rods are inserted lengthwise through the upright eyebolts. A small collar is then slipped over the rod so that the rod cannot shift lengthwise. The rod ends which extend beyond the eyebolt positions serve as handles for two people to lift the FEB.



When an overhead hoist is to be used, the rods are not used. Instead a wire-rope sling is attached to each eyebolt. The four sling arms meet at a center jump ring which is lifted by the hook of the overhead crane. A spreader frame is used just above the eye-bolt attachments so that the load transfered to the bolts is strictly vertical.



4. Physical and Mechanical Property Summary

For 316 stainless steel

ρ	0.290 lb/in^3	Specific Weight
E	27E+06	Young's Modulus of Elasticity
σ_y	30 ksi	Yield Tensile Strength
σ_{ut}	75 ksi	Ultimate Tensile Strength

For 6061-T6 aluminum

E	69 GPa = 10E06 psi	Young's Modulus of Elasticity
G	30 GPa = 4.35E06 psi	Shear Modulus
u	0.25	Possion's Ratio
σ_y	35 ksi	Yield Tensile Strength
σ_u	42 ksi	Ultimate Tensile Strength
σ_s	27 ksi	Shear Strength

5. Stress Analysis of lifting eyebolts

When the lifting rods are inserted through the eyebolts and the FEB is manually lifted, a simple tensile load is produced in each eyebolt. When the FEB is lifted with a hoist and sling, the spreader frame absorbs the lateral stress from the sling, insuring that the eyebolts are only loaded vertically. The total mass of the FEB is 60 kg. When the FEB hangs on its lifting rod as a dead weight, one-fourth of its weight is supported by each eyebolt. Drawing number 2036-1310-xxxx shows that the shank of each eyebolt is tapered from a nominal diameter of 0.375 inch to a 0.25 diameter when it attaches to the FEB. The stress cross section area for a 1/4-28 thread is 0.0362 in^2.

$$F_{eye} = \frac{60 \text{ kg}}{0.454 * 4 \text{ bolts}} = 33 \text{ lb}$$

While for the bolt,

$$\sigma_t = F_{eye} / A_{bolt}$$

$$= 33 / 0.0362 = 912 \text{ psi.}$$

The margin of safety is thus very large,

$$MS_u = 75E+03 / (2 * 912) - 1 = 40.$$

$$MS_y = 30E+03 / (2 * 912) - 1 = 15.$$

Considering the shear stresses which will tend to strip the threads of either the bolt or the nut, the shear strength is taken as 1/2 of the yield strength.

$$\sigma_S = 0.5 * 27 \text{ ksi} = 13.5 \text{ ksi}$$

Since the nut and bolt are equal strength materials, failure occurs simultaneously in both parts [Ref 2.3] The effective area can be calculated by

$$A_{TS} = 2 * A_S = 2 * 0.0362 = 0.0724 \text{ in}^2$$

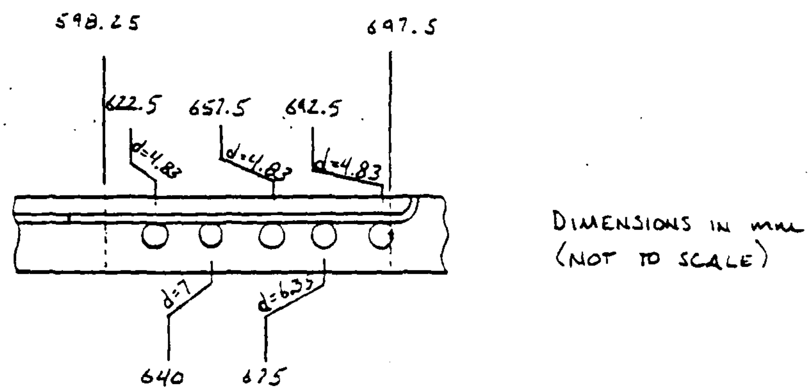
Then $\sigma_{nut} = F / A_{TS}$

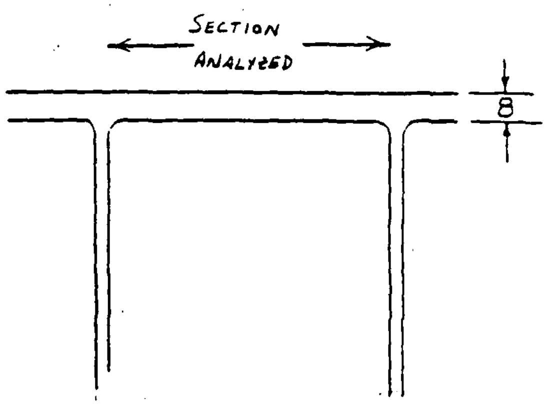
$$= 33 / 0.0724 = 456 \text{ psi}$$

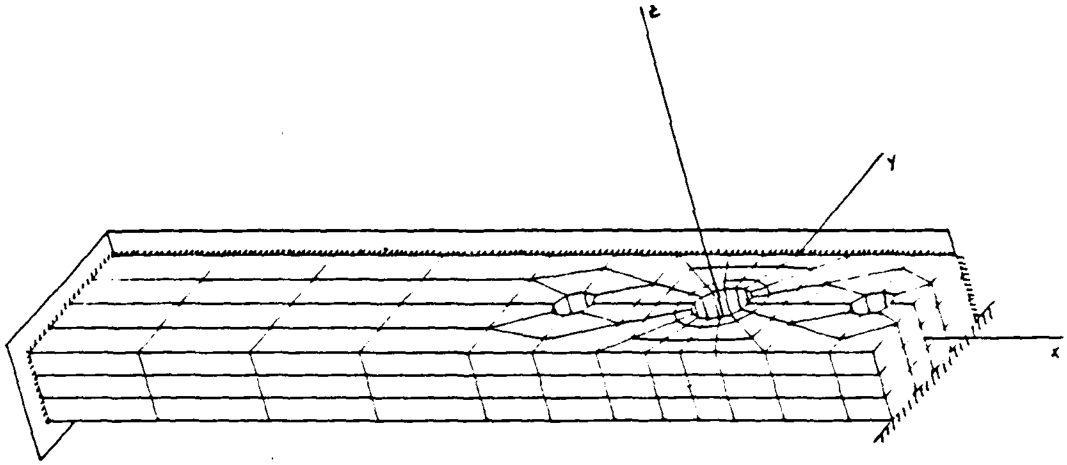
Thus $MS_s = 15E{+}03 / 456 = 33.$

6. Sidewall flange stress

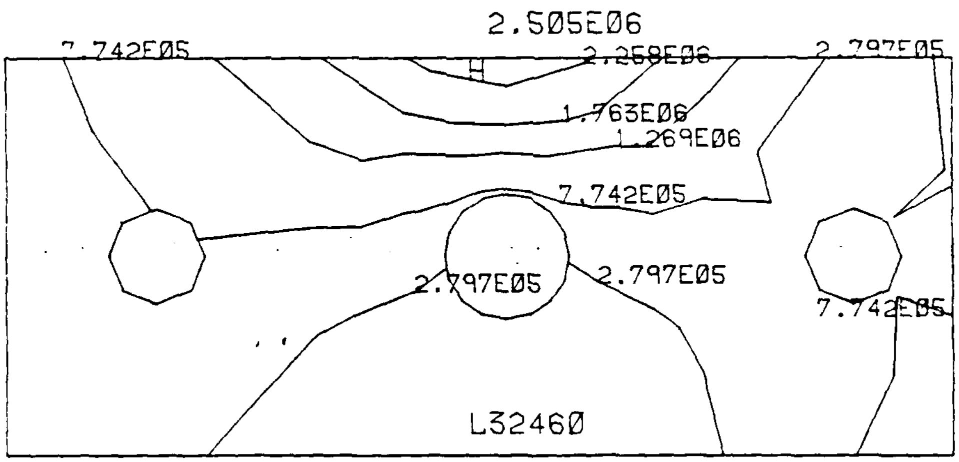
When the FEB is lifted, the axial stress through the eybolts will tend to bend the flange. The section of the flange that holds the eyebolt has been analyzed with a 472 node, finite element analysis program. The bolt hole lies between two reiforcing ribs and it is this section of the flange that is modeled by the finite element mesh. The elements used were 8-node, 3-dimensional brick elements. The wall of the box and the reinforcing ribs are considered solid supports for the flange.







FEB Flange Segment



Stress Contour

The resulting contour plots of the analysis show that the maximum stress is located near the wall, in the lower layer of elements. This maximum stress is on the order of 3.0 MPa (0.44 ksi).

The margin of safety is then

$$MS_y = 35 / (2 * 0.44) - 1 = 39.$$

6.0 Lifting rods

6.1 Lifting rod moment and shear forces

The lifting rods are placed through the eyebolts to serve as handles for manual lifting of the FEB. The lifting rods are tubular with an outside diameter of 0.75 inches and an inside diameter of 0.51 inch. The pipe cross-section area is

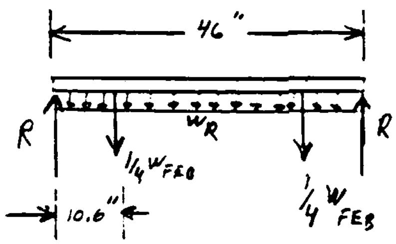
$$A_{cs} = (d_o^2 - d_i^2)/4 = 0.238 \text{ in}^2$$

The area moment of inertia for a hollow cylinder is

$$I = (d_o^4 - d_i^4)/64 = 0.0122 \text{ in}^4$$

The total length of the rod, 46 inches, is used to calculate the weight of the rod. (In actual use the rods will not be lifted at the very end. The "grip" position is expected to be in at least 2 inches, which will increase the margin of safety.)

$$W_R = \; * A_{cs} * L = 0.29 * 0.238 * 46 = 3.17 \text{ lb.}$$



The reaction at each rod end is then

$$R = 0.5 * (3.2 + 66.1) = 34.6 \text{ lb}$$

At any section between points A and B, the shear force and moment reaction are:

$$\Sigma F_Y = 0$$

$$R - \rho * A_{cs} * X - V = 0$$

$$V = (34.6 - 0.069 * X) \text{ lb.}$$

The moments must also sum to zero, so

$$M - R * X + \rho * A_{cs} * X = 0$$

$$M = 34.6 * X - 0.0345 * X^2$$

At any section between points B and C, the shear force is calculated in a similar way.

$$R - W_{FEB}/4 - \rho * A_{cs} * X - V = 0$$

$$V = (1.6 - 0.069 * X) \quad lb$$

For the moment calculation:

$$M + \rho * A_{cs} * X * (0.5 * X) + W_{FEB}/4 * (X - 10.6) - R * X = 0$$

$$M = 350 + 1.6 * X - 0.0345 * x^2 \quad in\text{-}lb$$

Due to symmetry the shear and moments along the rod between points C and D are the same as those between points A and B.

6.2 Maximum lifting rod deflection

The maximum deflection will occur at the center. The double-integration method is used to find this deflection.

$$E * I \, d^2Y/dX^2 = M = 350 + 1.6 * X - 0.0345 * X^2$$

Integrating both sides with respect to X,

$$E * I \, dY/dX = 350 * X + 0.8 * X^2 - 0.0115 * X^3 + C_1$$

At midspan, X = 23 in, the slope is zero.

$$dY/dX = 0 = 350 * 23 + 0.8 * (23)^2 - 0.0115 * (23)^3 + C_1$$

$$C_1 = -8338$$

Then integrating again,

$$E * I * Y = 175 * X^2 + 0.267 * X^3 - 0.002875 * X^4 - 8338 * X + C_2$$

The second boundary condition is Y= 0 at X = 0, thus $C_2 = 0$.

Then the deflection, Y, at midspan (X = 23) can be found:

$$Y = \frac{(175 * 23^2 + 0.267 * 23^3 - 0.002875 * 23^4 - 8338 * 23)}{27E+06 * 0.01221}$$

$$Y = -0.26 \text{ inch}$$

6.3 Lifting rod Margin of Safety

The maximum bending produced stress occurs at midspan.

$$M = 350 + 1.6 * (23) - 0.0345 * (23)^2 = 368 \text{ in-lb}$$

$$\sigma_t = M * r_o / I$$

$$= 368 * 0.375 / 0.0122 = 11320 \text{ psi}$$

The the margin of safety is

MS_t = 75E+03 / (2 * 11320) - 1 = 2.3

Checking for yield,

MS_y = 30E+03/ (2 * 11320) - 1 = 0.33

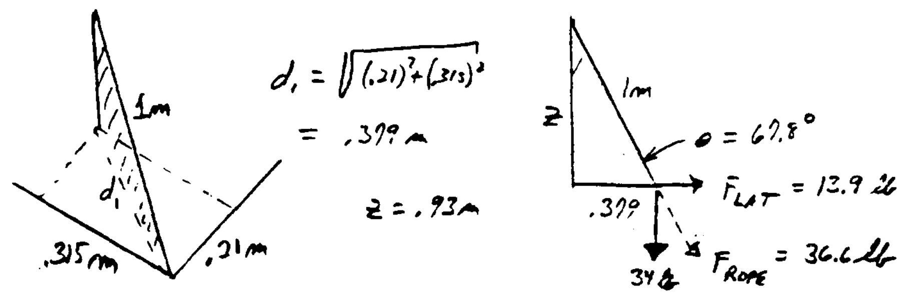
The maximum shear force occurs at end very ends of the handles,

σ_s = R / A_{cs} = 34.6 / 0.238 = 145

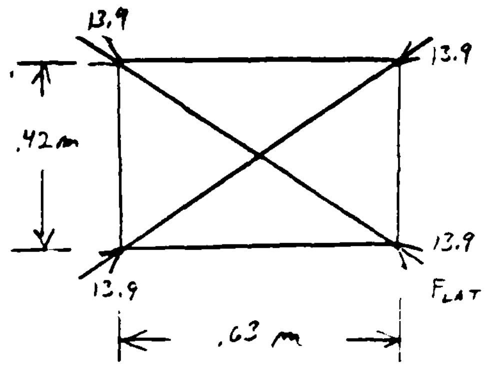
MS_s = 15E+03 / (2 * 145) - 1 = 51

7. Hoist and sling lifting

When the FEB is lifted by a hoist and sling attached to the eyebolts, the spreader frame absorbs the lateral stress produced by the sling. The weight of the spreader frame itself (4 lbs.) must be added to the weight of the FEB. The net tensile load at each corner of the spreader frame is 34 lb.



This vertical load of 34 lb produces a lateral load of 13.9 lb. The cross bracing of the spreader frame is not quite symmetrical: however, the asymmetry is small enough that this lateral force can be assumed to be directly along the longitudinal axis of the cross braces.



All bracing elements are in compression. For simplicity all of this lateral loading is assumed to taken by the cross diagonals (Finite element analysis predicts a load of 5.7 lbs in the cross diagonal.) Since this brace is long and slender, Euler's formula lfor the buckling load of a long slender column with pinned ends is used.

$$P_{buck} = A * (PI)^2 * E / (L / r)^2$$

For the 1" x 1" angle extrusion the cross section area is

$$A = 0.24 \text{ in}^2$$

and the smallest radius of gyration is

$$r = 0.20 \text{ in}$$

The length of the diagonal is 0.76 meter = 36 in.

$$P_{buck} = 0.24 * (3.14)^2 * 1 \text{ E+07} /(36/0.2)^2$$
$$= 731 \text{ lb.}$$

Thus, $MS = 731 / (2 * 13.9) - 1 = 25.3$

The maximum shear force on the *1/4-28 stainless bolts* used in the spreader frame is the lateral force lof 13.9 lb. The bolt stress cross section is 0.0364 in^2.

$$MS = \sigma_s * A_s / (2 * F_{lat}) - 1$$
$$= 13.5 \text{ E+03} * 0.0364 / (2 * 13.9) - 1 = 16.7$$

The maximum tensile load in the steel wire rope of the sling is 36.6 lb. The rated strength of the 1/8 diameter rope is 1800 lbs. Thus

$$MS = 1800 / (2 * 36.6) - 1 = 23.6.$$

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