Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project Internal Reference:

Project: CDF Block Lifting Fixture

Title: CDF Block Lifting Fixture

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Reviewer(s):

Key Words: Lifting Fixture

Abstract Summary: Calculations to apply a load rating to an existing simple lifting fixture used at CDF to move steel shielding blocks.

Applicable Codes: B30.20, Below the Hook Lifting Devices

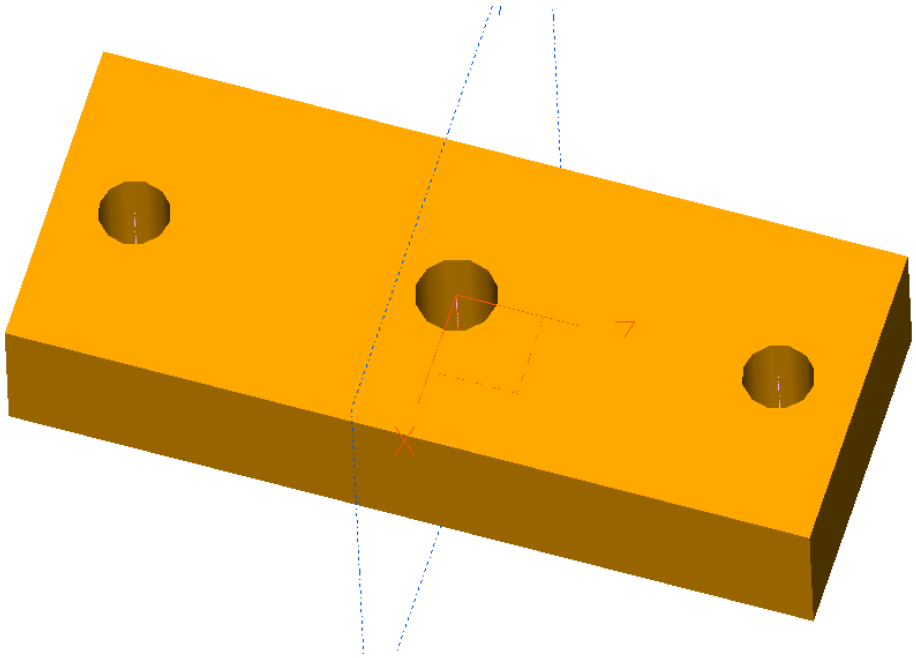

Image 1. Solid Model of the Existing CDF Block Lifting Fixture

Block is 10 inches long, 4 inches wide, and 2 inches thick. The center hole is tapped for a 1-8 thread. The outer two holes are 0.875 inches in diameter and centered 1 inch from the ends. All three holes are centered along the width.

Material is and unknown grade of mild carbon steel. For the purposes of this engineering note, the material is assumed to have a yield stress of 30 ksi.

Two ¾-10 A325 high strength structural steel bolts insert thru the two outer holes and into tapped holes in each block to be lifted. A hoist ring (lifting swivel eye) threads into the center hole.

The yield strength of A325 bolting is listed as 92 ksi in AISC 9th edition, page 4-4. Ber B30.20, the maximum allowable stress is 1/3 Fy. Therefore, the maximum load that this fixture could lift with the A325 bolts in pure tension on the nominal area (0.4418 inches square per bolt) is 13.54 kips per bolt or 27,097 pounds (13.5 tons).

As a check, consider the use of A307 bolting (hardware store grade 2 material). Fy for A307 material is about 45 ksi. Therefore, the limiting allowable tensile stress is 15 ksi. With two equally loaded ¾ inch bolts, the maximum allowable load is 13.25 kips (13,200 pounds or 6.63 tons).

The listed strength of a hoist ring with a 1-8 threaded shank is 10,000 pounds (refer to the McMaster-Carr catalog under hoist ring).

So, the limiting load is set by the hoist ring. Use 10,000 pounds and analyze the stresses in the block:

Because this block has two axis of symmetry, a ¼ model was created. Plane symmetric restraints were applied to the two surfaces and a 2500 pound load was applied to the center hole surface.

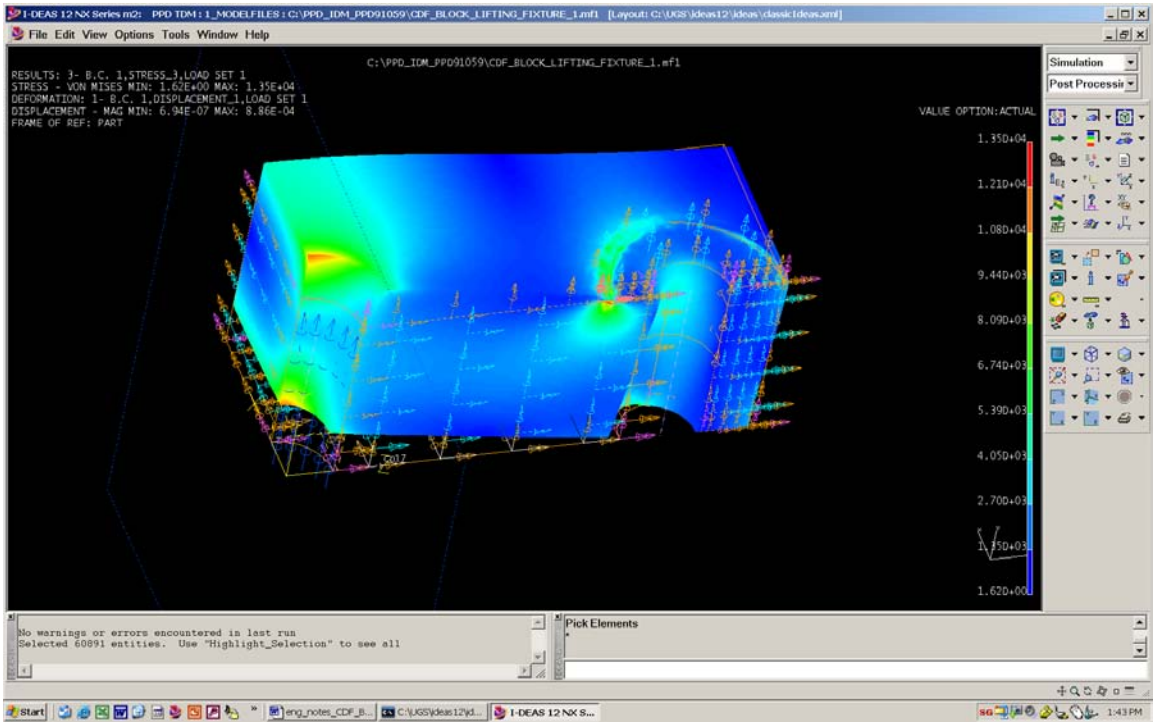

Image 2, Results of the FEA analysis on ¼ portion of the lifting block.

Maximum displacement calculated is 0.00088 inches and the maximum stress, which is highly localized, is 13,500 psi. Stress in the bulk of the volume is less than 10,000 psi.

For mild carbon steel, yield strength of 30,000 psi is conservative. From ASME B30.20, the actual bending stress must be less than 1/3 of the yield stress. Therefore, set the maximum allowable bending stress to 10,000 psi.

As a check, consider the calculations for a simple beam.
Load, P = 10,000 pounds
Beam length, L = 8 inches,
Beam Moment of Inertia, I = (1/12)* (a) * b^3
a = 4 inch width less the bolt diameter of 1 inch = 3 inches
b = beam thickness = 2 inches
I = 1/12 * 3 * 2^3 = 2.0 inches^4
Bending Moment, M = P*L/4 = 20,000 inch-pounds
Bending Stress, σ = M*y/I,
y = 1 inch;
σ = 20,000 in-pounds * 1 inch, 2.0 in ^4 = 10,000 psi.

The simple beam model allows beam rotation at the ends. Clearly, when bolted to a large, steel shielding block, the rotations are limited by the steel shielding block. If this is considered a beam fixed at both ends, then the Moment changes to:

M = P*L/8 = 10,000 inch-pounds.
Resulting bending stress becomes: σ = 10,000 in-pounds * 1 inch, 2.0 in ^4 = 5,000 psi.

FEA model predicts a bending stress between the values predicted by the two hand calculations.

Conclusion, the block steel strength is adequate for a 10,000 pound load.

Therefore, set the lifting fixture capacity at 10,000 pounds.