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Appendix A

Lifting Hooks for Numi Horn Module

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Introduction and Summary

The Numi horn module has four hooks that are used for lifting and positioning of the 30 ton module. The center of gravity of the module is such that a single hook may see a load nearly as great as half the module weight, or 30,000 lbs.

This note describes the finite element analysis of these hooks, under a load of 30000lbs/hook. It is shown that the primary membrane plus bending stresses across the hook cross section are well below the allowable of $S_y/3 = 21.6$ ksi.

Material Properties and Allowable Stress

The hooks are made of ASTM A710, Gr. A, Class 3 structural steel. The minimum specified yield for this material, in thickness of over 2 inches to 4 inches, is 65 ksi.

The maximum allowable stress for primary membrane plus bending stress across the hook cross section was taken as $S_y/3$, or 21.6 ksi.

Bearing stress between the pin and hook was also limited to 21.6 ksi.

Finite Element Model

The finite element model is shown in Fig. 1. Second-order brick elements were used for all solid components. Gap elements were used at the interface of the hook and pin to allow a natural redistribution of load as the system deformed.

Loading was applied by constraining the lifting fixture and applying a downward displacement on the hook. This displacement was adjusted to give a reaction force of 30000 lbs.

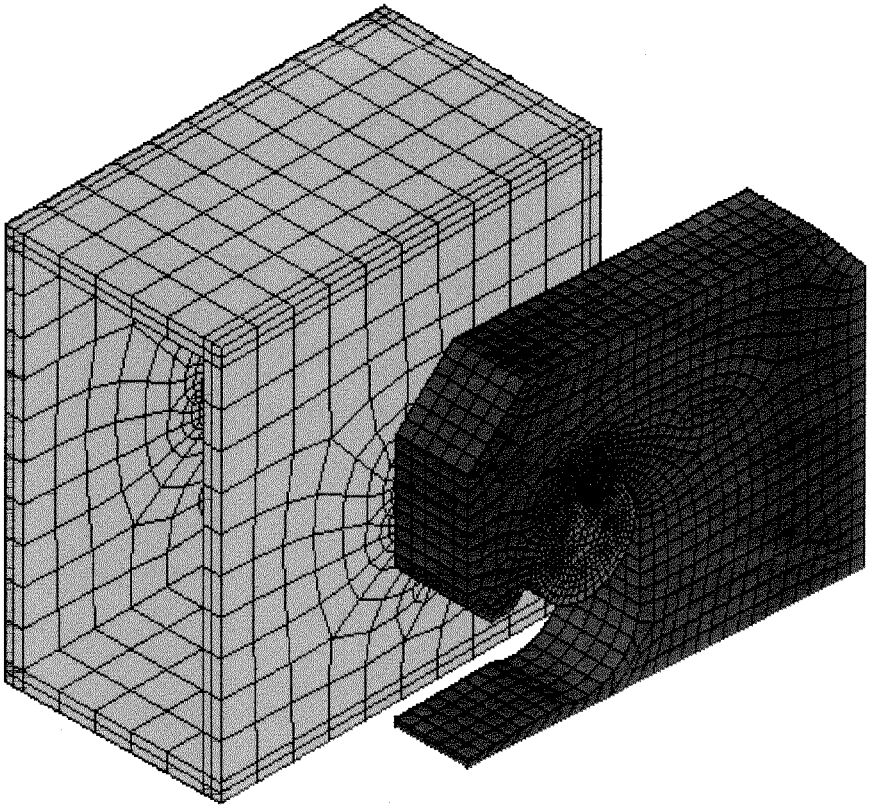

Figure 1. Finite Element Model of Hook and Portion of Lifting Fixture

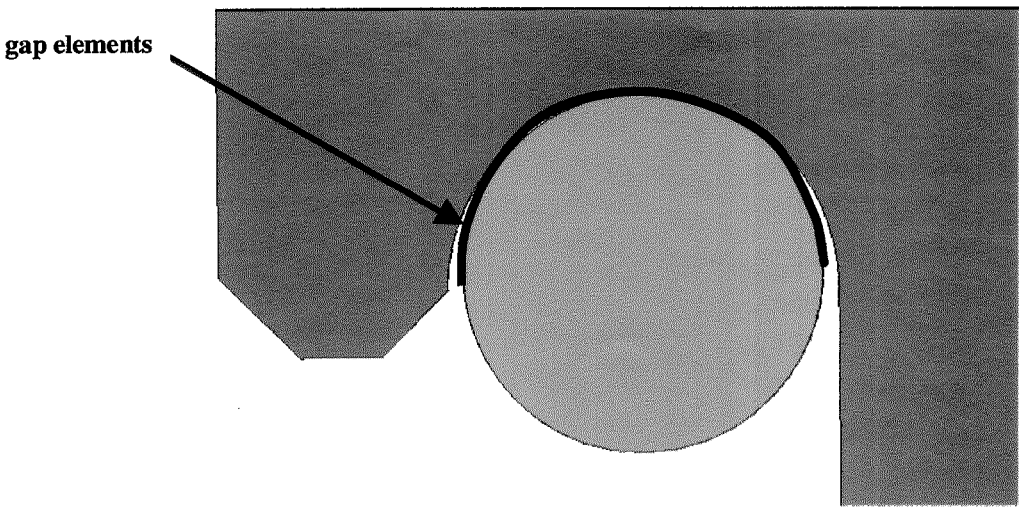

Figure 2. Gap Elements at Pin/Hook Interface

Results

Fig. 3 shows the deformation of the pin and hook. The pin bends downward approximately 0.011 inches, which places most of the load on the inner surface of the hook.

This concentration of load is shown in Fig. 4, which plots the hoop stress on the inner surface of the hook.

Stresses were evaluated by linearizing the membrane and bending stresses along a series of rays emanating from the center of the circle describing the hook's inner diameter (Fig. 5). Six different z-planes were used, ranging from 0 (nearest to the lifting fixture tube), to 2 inches (furthest from the lifting fixture tube, at end of pin).

As expected, the linearized membrane plus bending stresses for both upstream and downstream hooks are greatest at Z = 0, being a maximum of about 17 ksi for both cases. This is well below the allowable of 21.6 ksi.

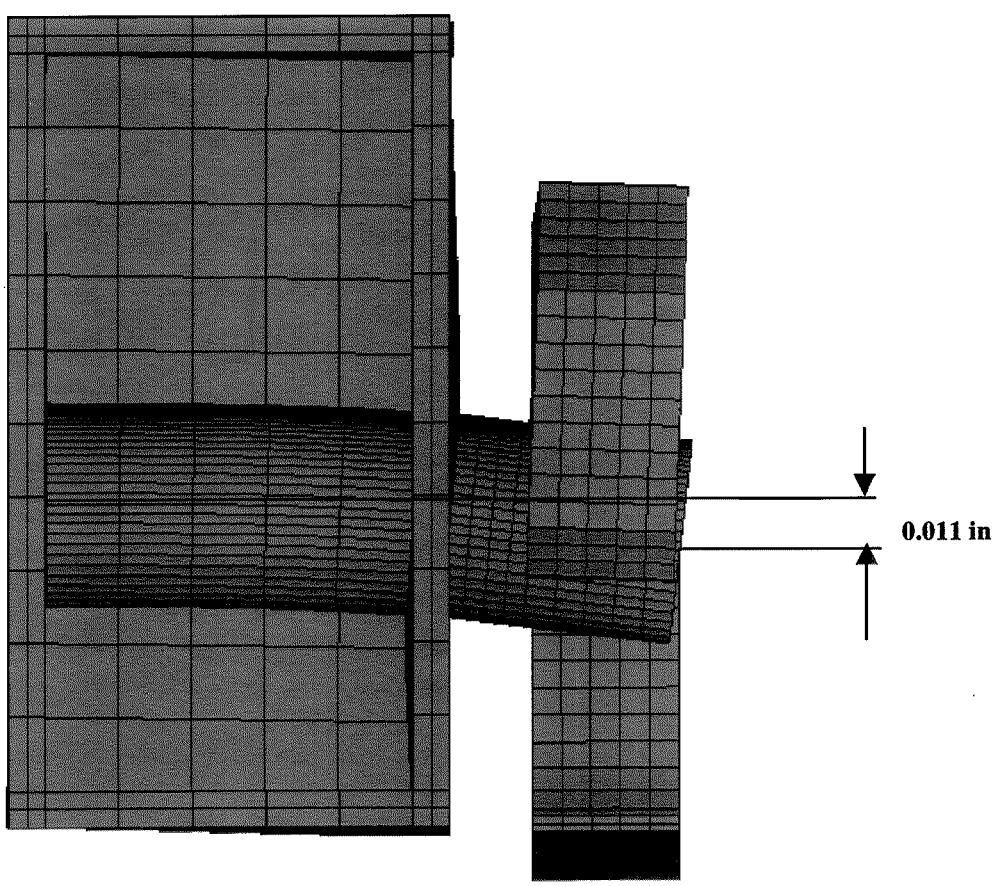

Figure 3. Deformation of Hook and Pin under 30000 lb. Load

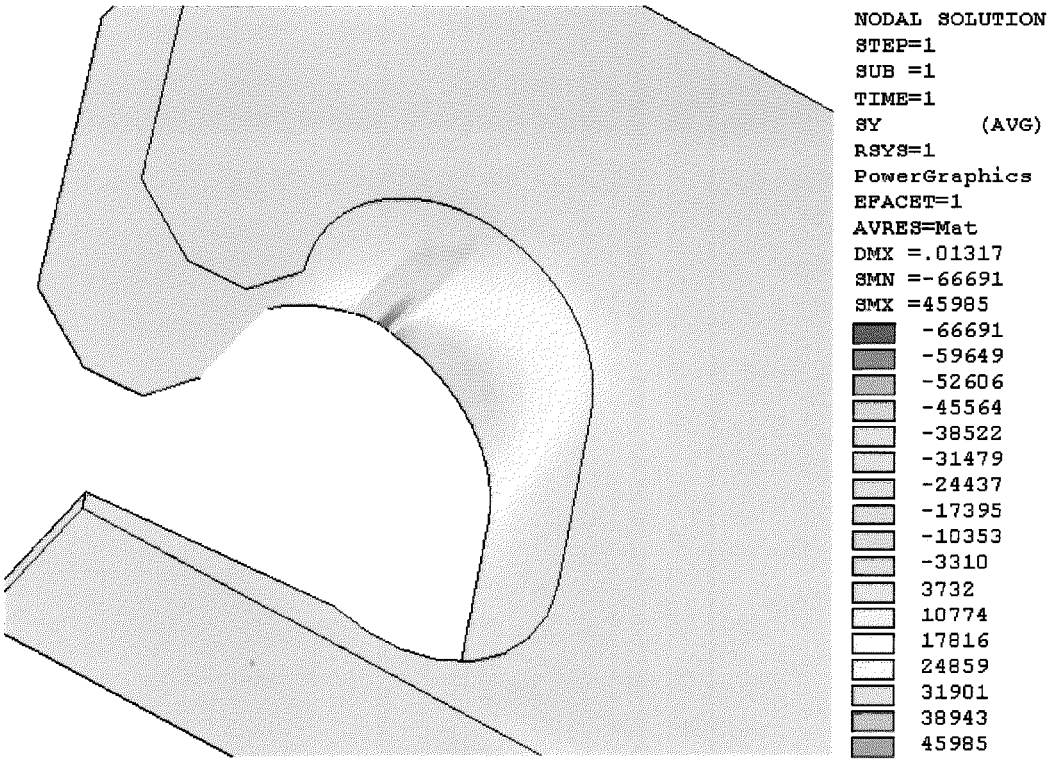

Figure 4. Azimuthal Stress in Hook (note concentration at pin contact region)

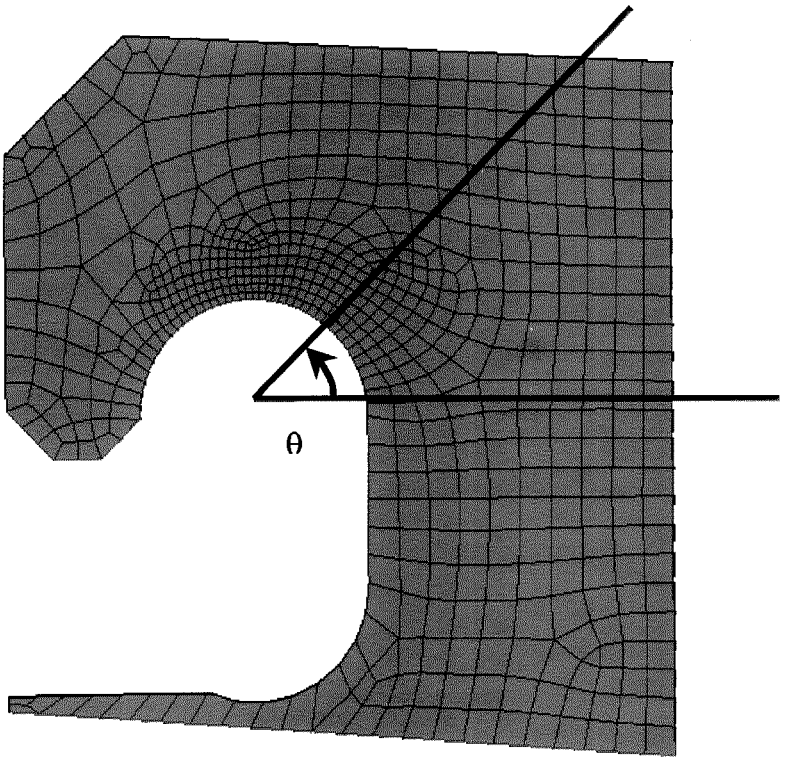

Figure 5. Sections for Primary Membrane plus Bending Stress Evaluation

Figure 6. Maximum Membrane Plus Bending in Upstream Hook

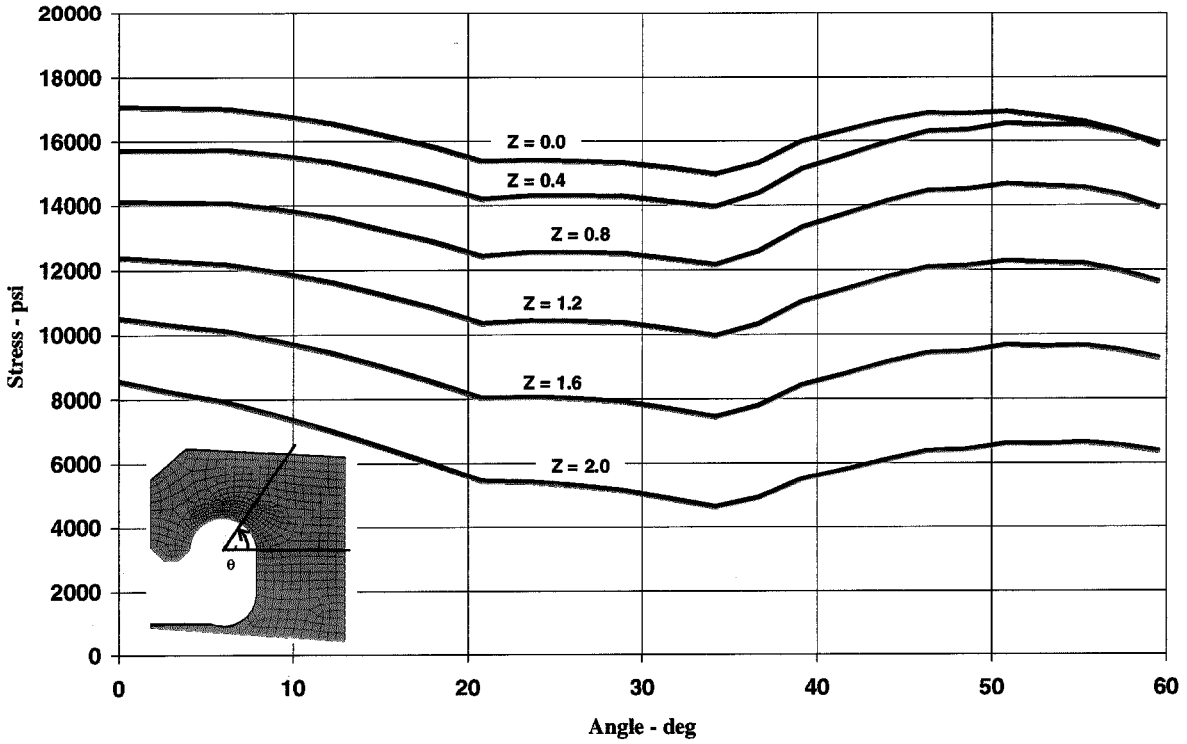
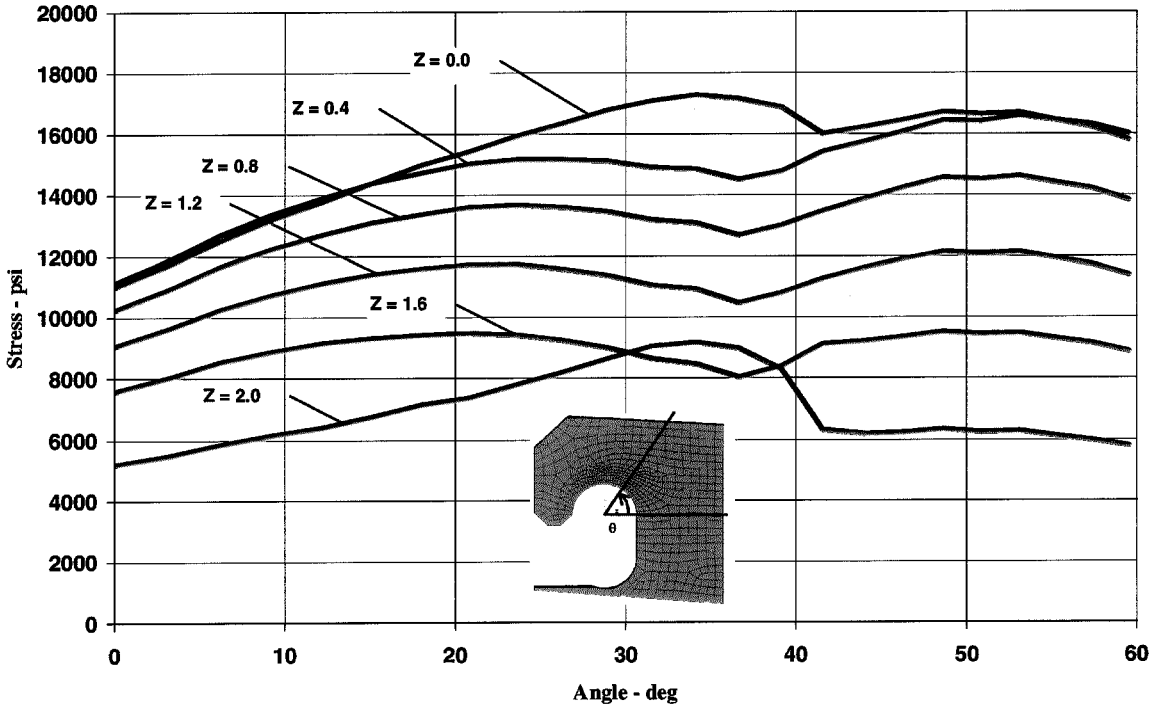
Figure 7. Maximum Membrane plus Bending in Downstream Hook