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Finite Element Models for the Three-Web Sheave Design for the Shippingsport Vertical Lift Bridge	5. Report Date October, 1997
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This work was conducted jointly with the Bureau of Bridges & Structures and District 3.

16. Abstract
Finite element models for the Shippingport Vertical Lift Bridge over the Illinois River at LaSalle were created using a three-web design for the sheaves. The models used a linear load distribution along the periphery of the sheave. Models were created that include details of the outer web, inner web, and hub. Using an analysis developed at the University of Illinois, 4/5P downward loading and 1/5P per side was used for loading each semi-circular channel. The models were additionally rotated 18° for maximum loading. Peak tensile stresses generated in the cable tray were at 7.2 ksi, and the peak tensile web stress was 2.6 ksi. A hub analysis was also conducted using an internal pressure of 4,000 psi generated by shrink fit of approximately 0.010 inches interference between the hub and trunnion shaft. Peak tensile stresses generated by 4,000 psi interference pressure in the forged ASTM A668 Class C hub were 10.7 ksi internal and 7.2 ksi external.

17. Key Words	18. Distribution Statement
sheave; shafting; trunnion; shrink fit; hub; plate; finite element models; stresses; load distribution function; vertical lift bridge; movable bridge; Shippingsport Bridge; Illinois River	Unlimited.

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Analysis of the Shippingsport Vertcal Lift Bridge
Sheave Components - May 1997 - Report 3 -

CONTENTS

Introduction

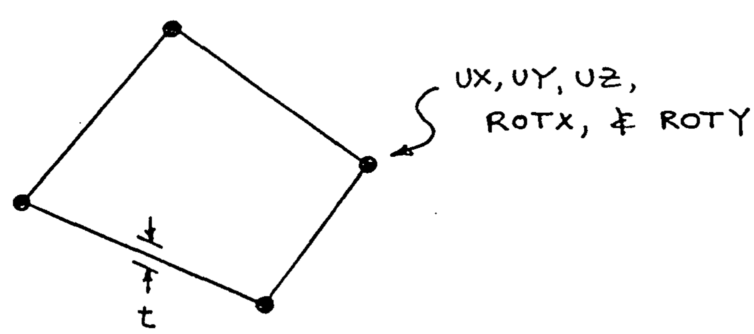
This report is the third part of the Shippingsport bridge sheave analysis. The first report should be referred to for a complete description of the applied loading. The objective of this analysis is to evaluate a revised design of the three-web design that was analyzed in the first report. This revised design has a new cutout shape in the outer webs and also has ribs located every 36 degrees instead of every 40 degrees. The various plate thickness remained the same as that used in the first design.

The load distribution for this analysis is only the linear. Again, two orientations of this loading were applied: zero offset and an 18 degree rotational offset.

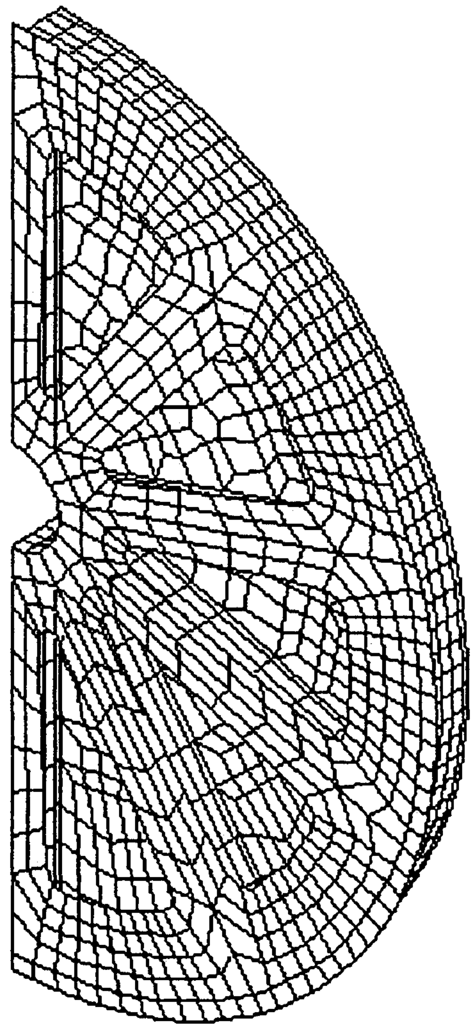
The FEA (Finite Element Analysis) models that were developed in this analysis for the sheave, were made using 3-D plate elements. These elements have 5 degrees of freedom at each node; translations in X, Y, and Z and two rotations. These elements are initialized using an input parameter for the thickness. For the sheave geometry, the thickness was set for the various plate sizes used in the design.

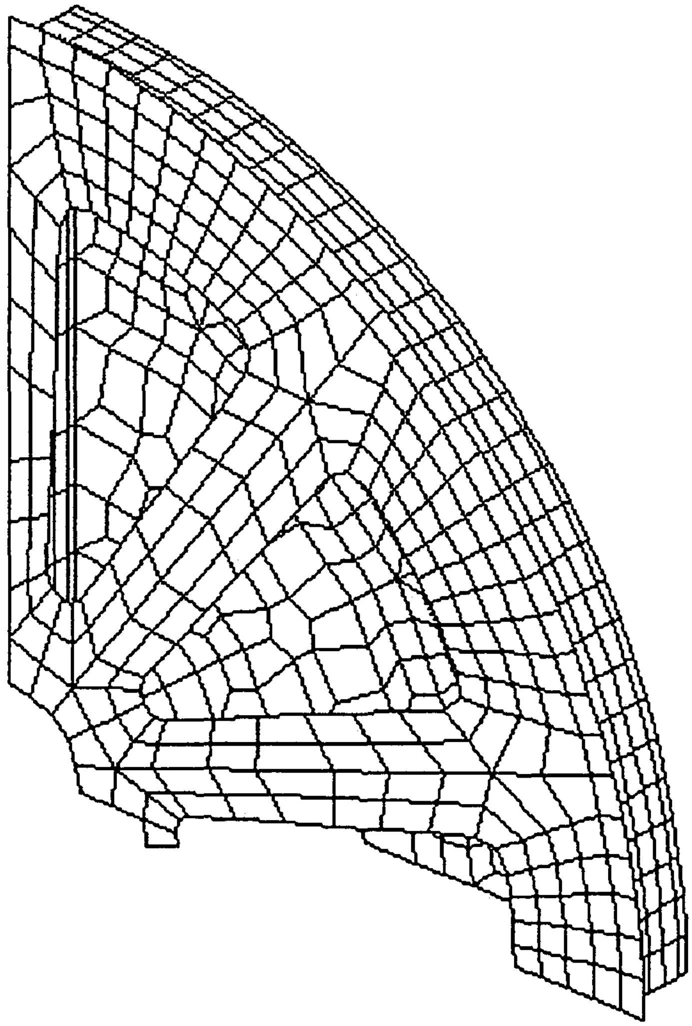
The following properties for the steel materials were used in this analysis:

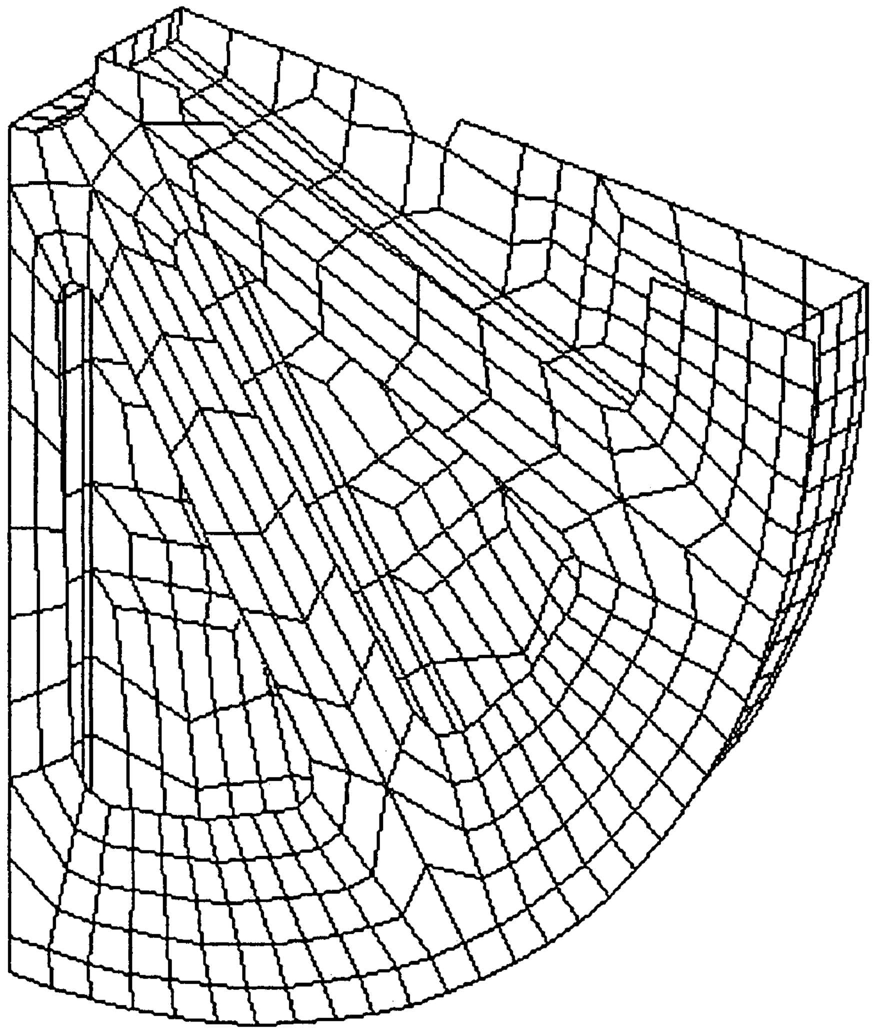
Modulus of Elasticity	(psi)	30,000,000
Poisson's Ratio		.3



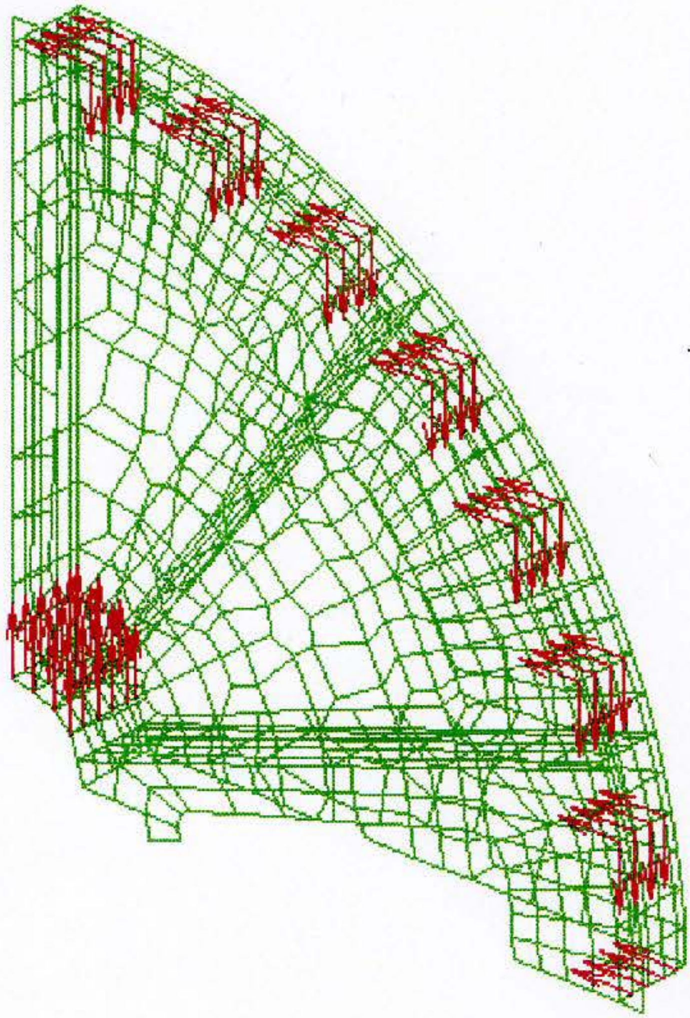
FEA MODEL OF THE SHEAVE - NO OFFSET





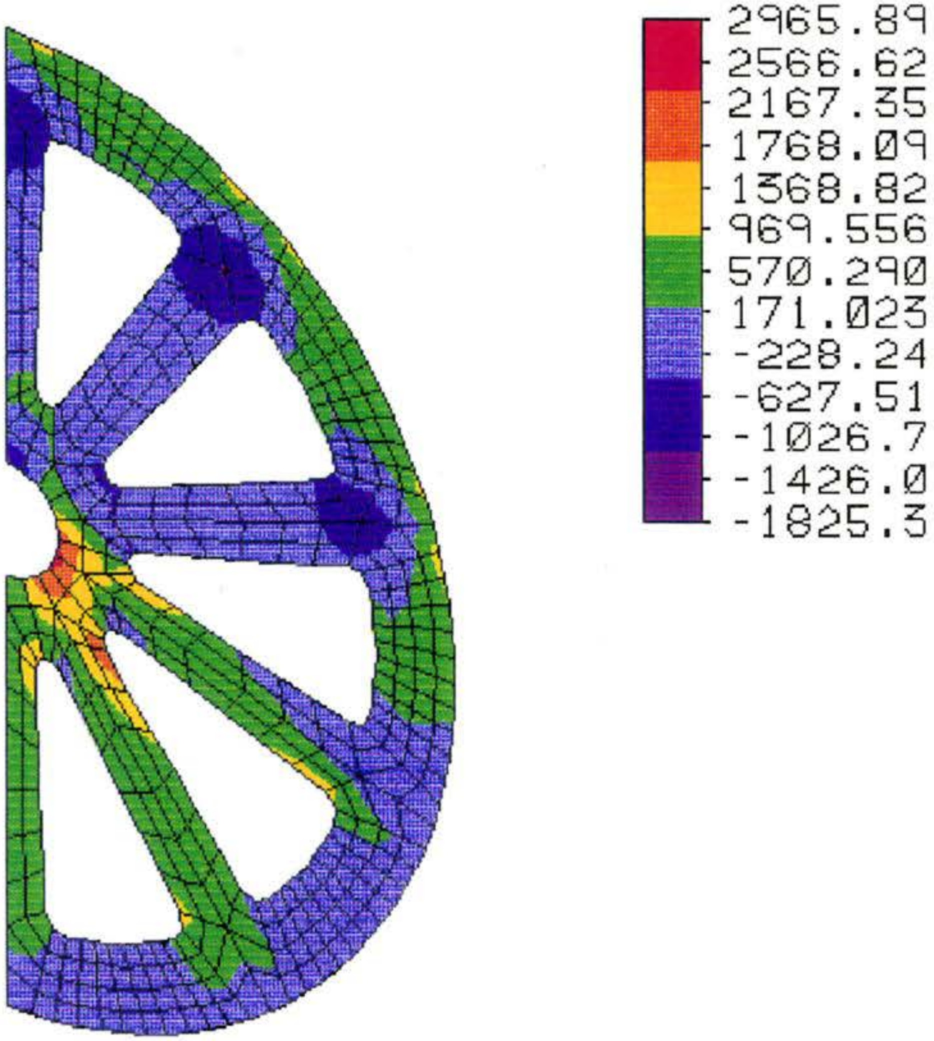


LOAD CASE 9



LOADING PLOT

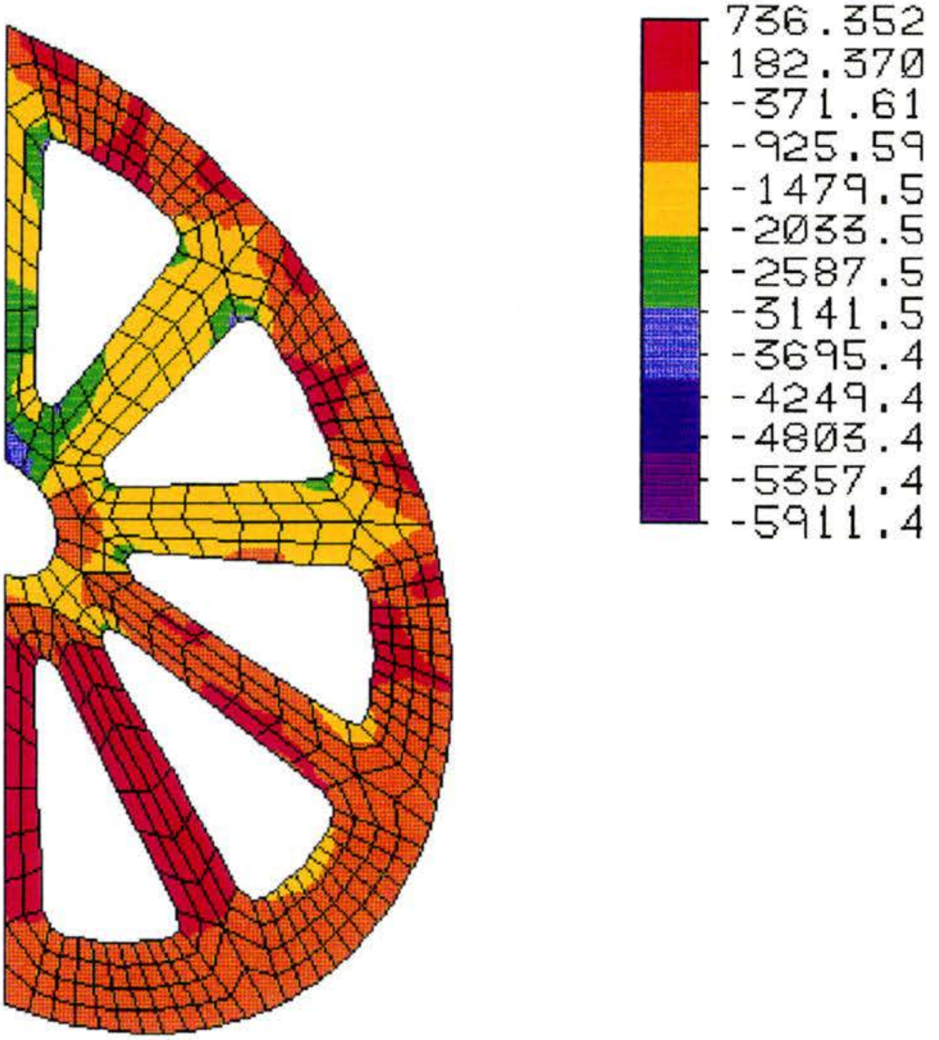
LOAD CASE 9



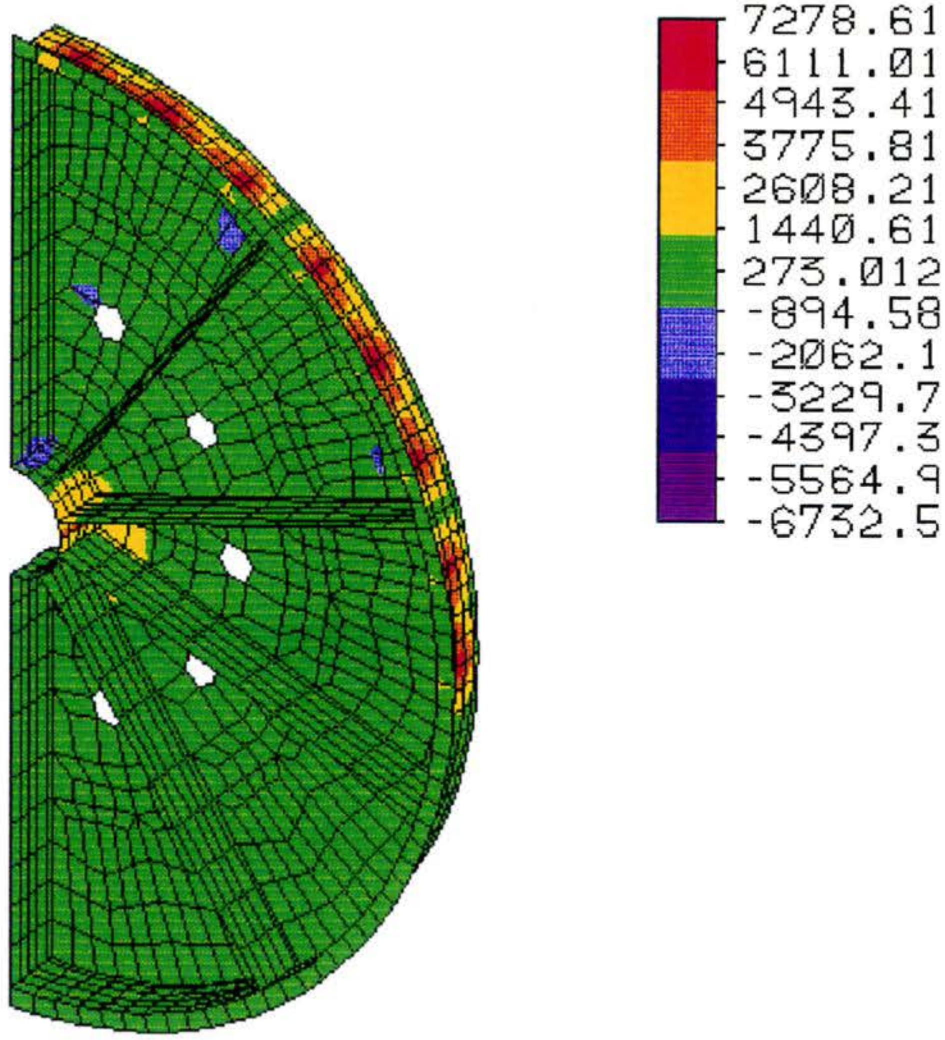
FRONT WEB

MAXIMUM PRINCIPLE TENSILE STRESS (psi)

LC 9



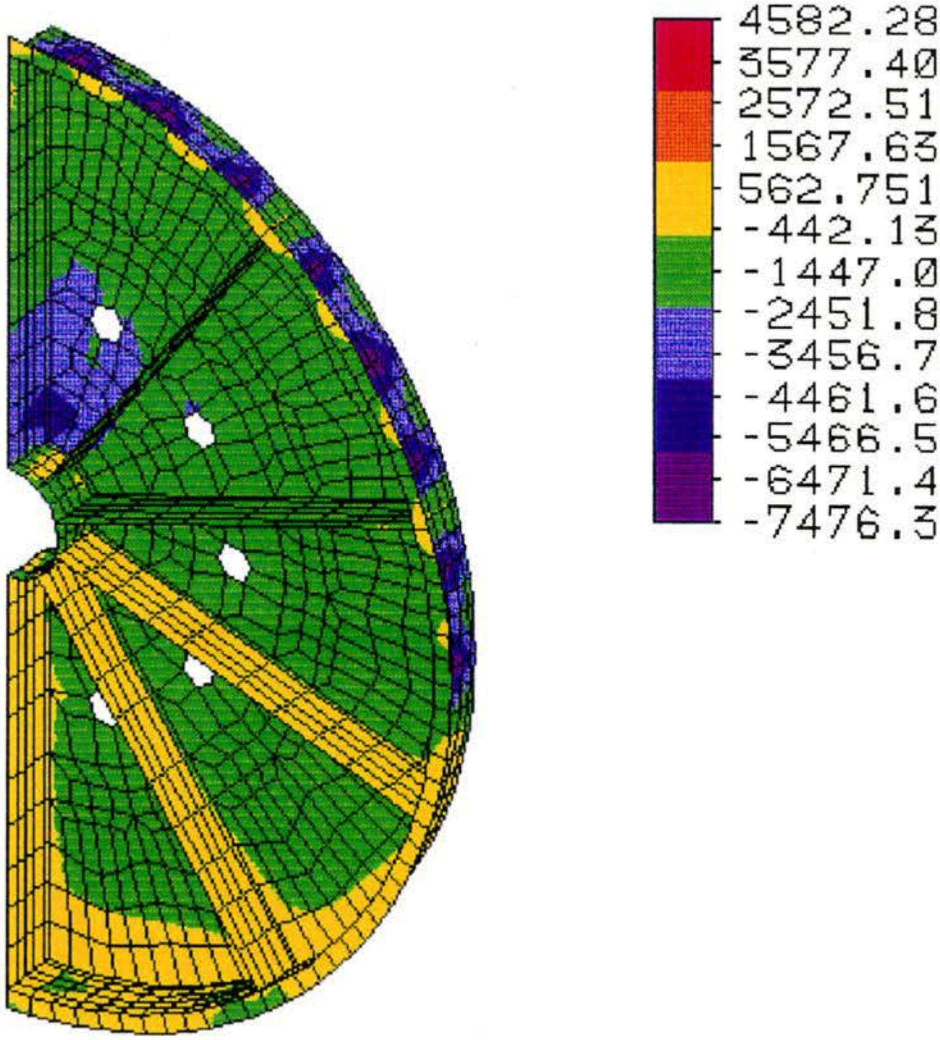
MAXIMUM PRINCIPLE COMPRESSIVE STRESS (psi)



FRONT WEB REMOVED

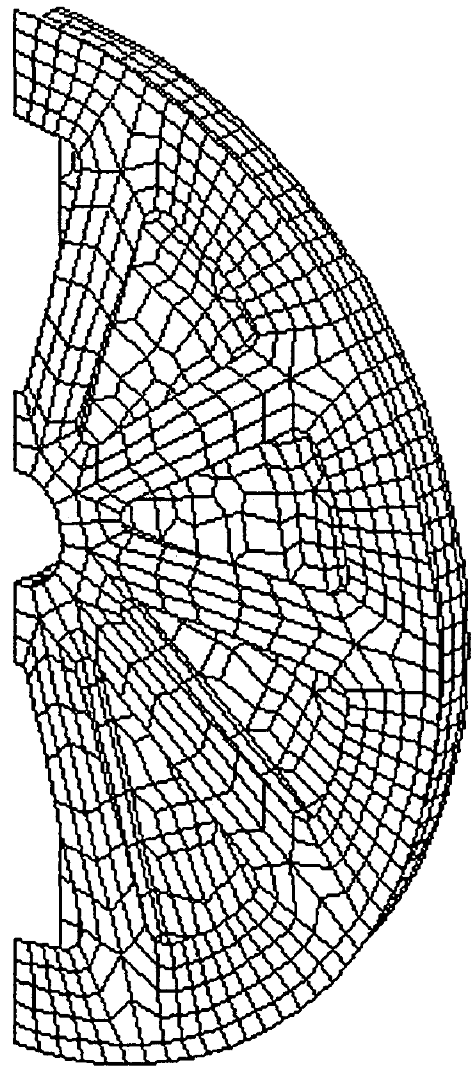
MAXIMUM PRINCIPLE TENSILE STRESS (psi)

LC 9

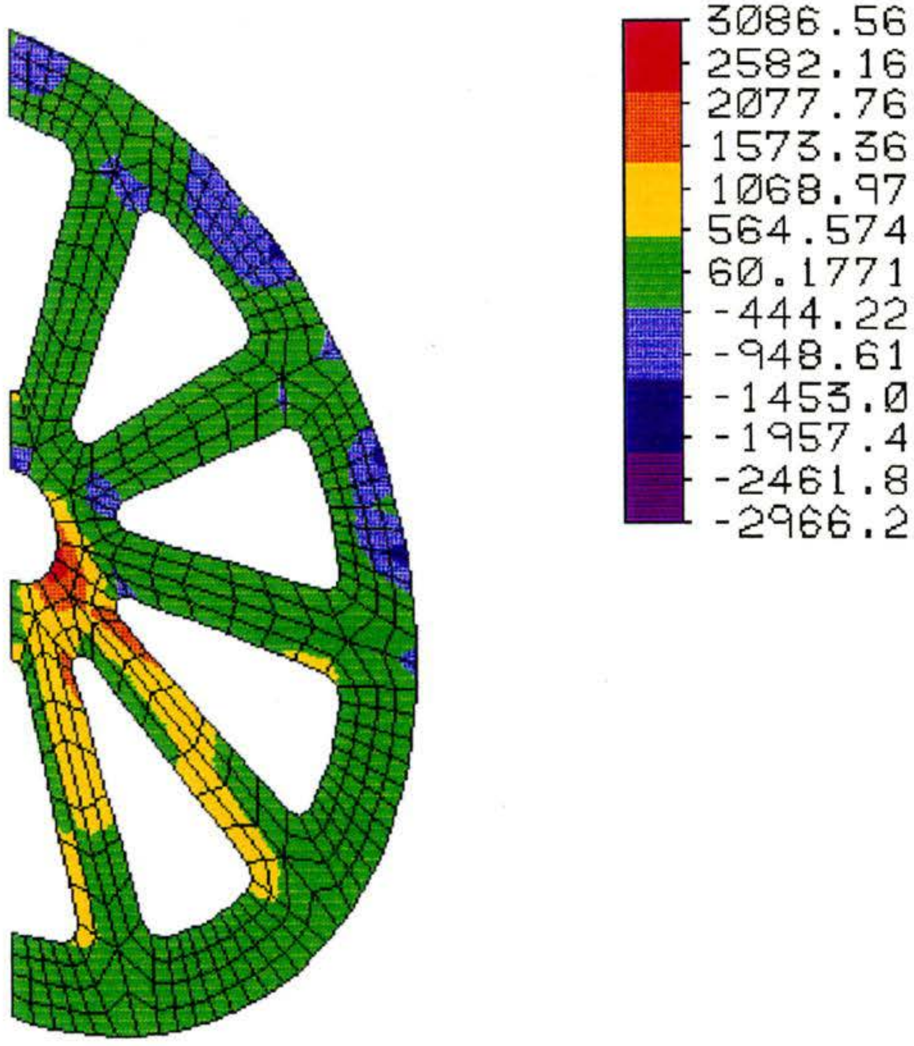


MAXIMUM PRINCIPLE COMPRESSIVE STRESS (psi)

LOAD CASE 10 - 18° ROTATIONAL OFFSET



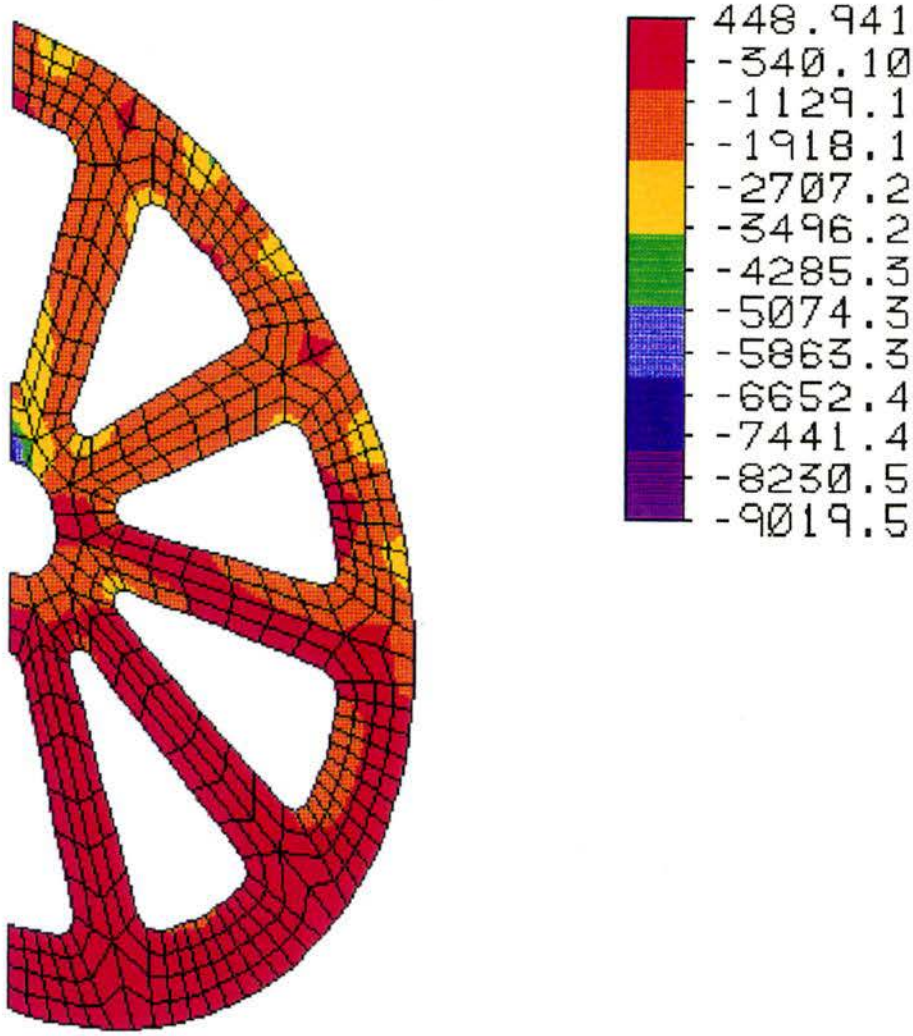
LC 10



FRONT WEB

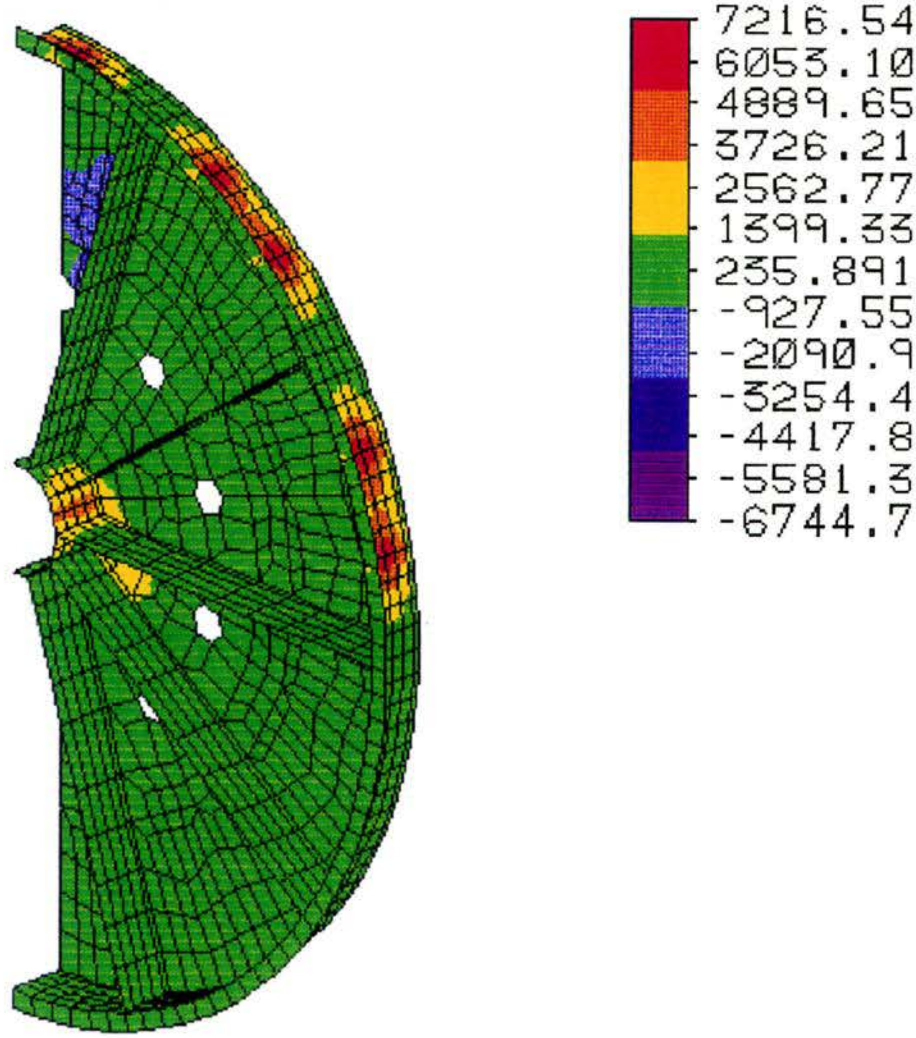
MAXIMUM PRINCIPLE TENSILE STRESS (psi)

LC 10



MAXIMUM PRINCIPLE COMPRESSIVE STRESS (psi)

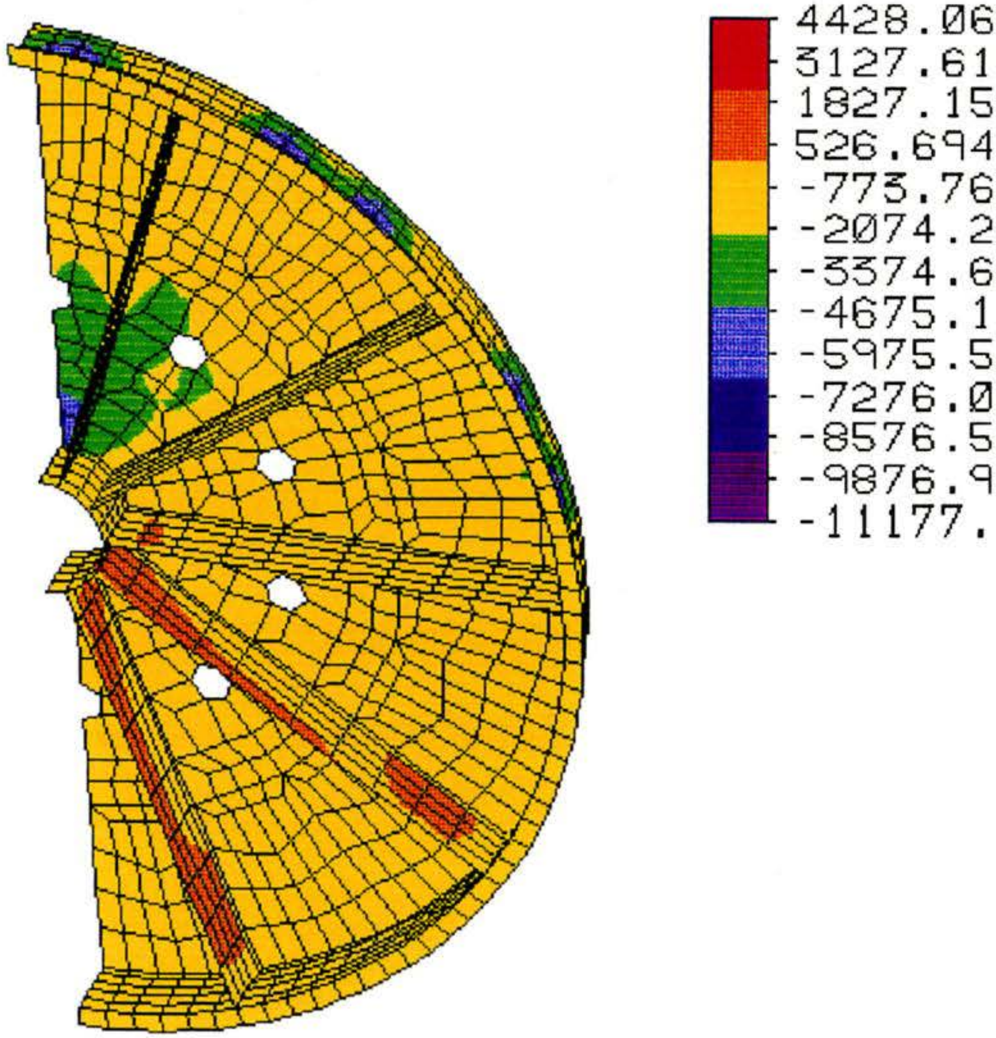
LC 10



FRONT WEB REMOVED

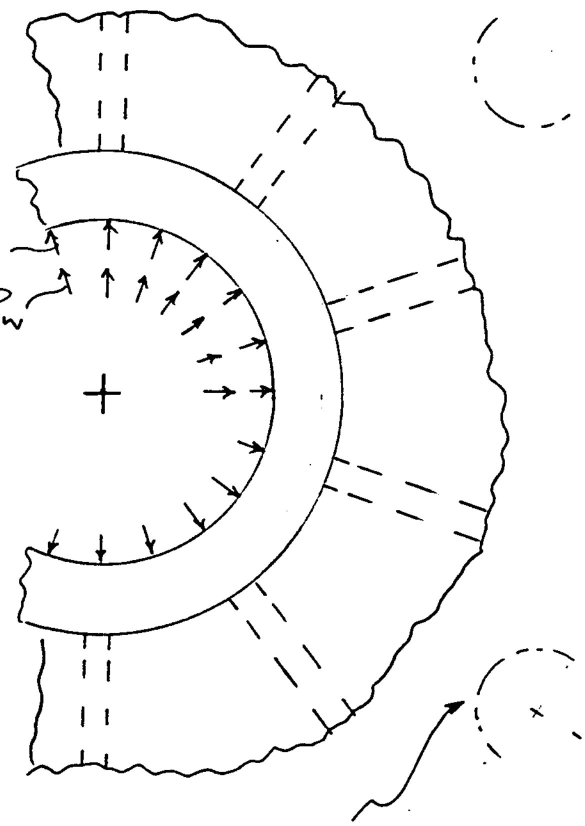
MAXIMUM PRINCIPLE TENSILE STRESS (psi)

LC 10



MAXIMUM PRINCIPLE COMPRESSIVE STRESS (psi)

HUB ANALYSIS WITH 4000 psi SHRINK FIT PRESSURE



$$P_{SHRINK} = 4000 \text{ psi}$$

$$P_{WEIGHT} = \frac{443,306 \text{ LB}}{14 \text{ IN } (20 \text{ IN})}$$

$$P_W = 1583 \text{ psi}$$

LET HALF OF P_W ADD TO THE SHRINK FIT PRESSURE AT THE TOP, AND HALF SUBTRACT FROM THE BOTTOM

$$P_{TOP} = 4000 + \frac{1583}{2} = 4792 \text{ psi}$$

$$P_{BOTTOM} = 4000 - \frac{1583}{2} = 3208 \text{ psi}$$

TORQUE CAPACITY IS;

$$T = F \times R$$

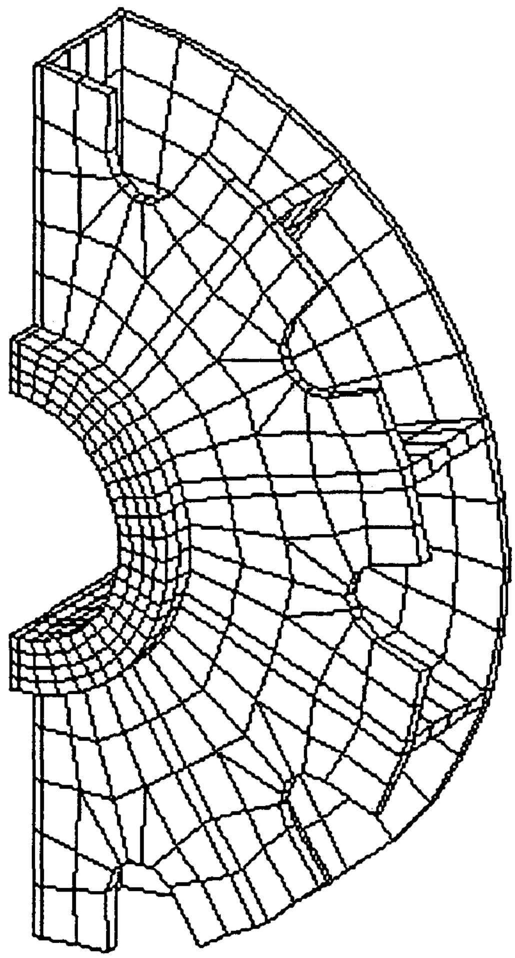
$$T = \left[4000 \text{ psi } \left(\pi (14 \text{ IN}) 20 \text{ IN}\right) .1\right] 7 \text{ IN}$$

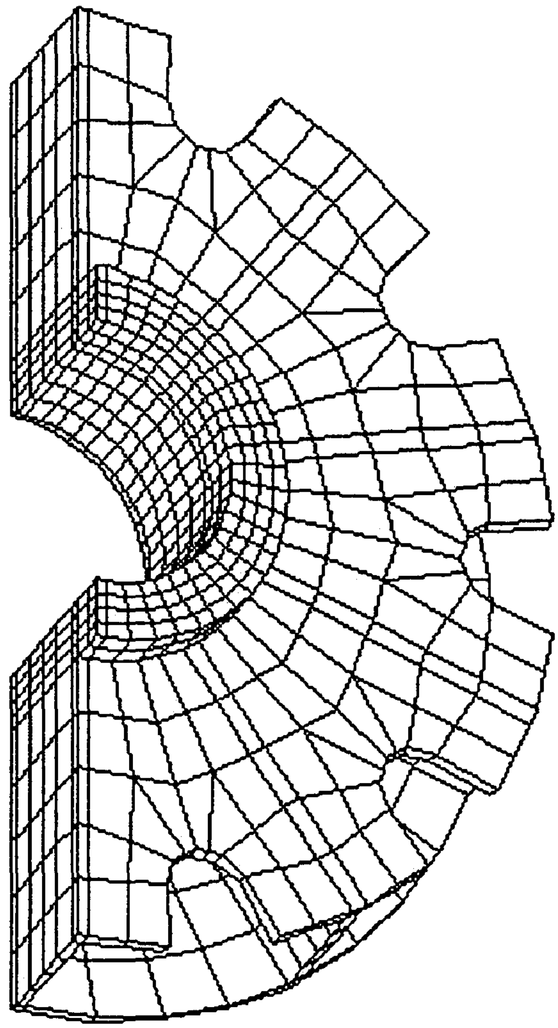
($.1 = \mu_{FRICTION}$)

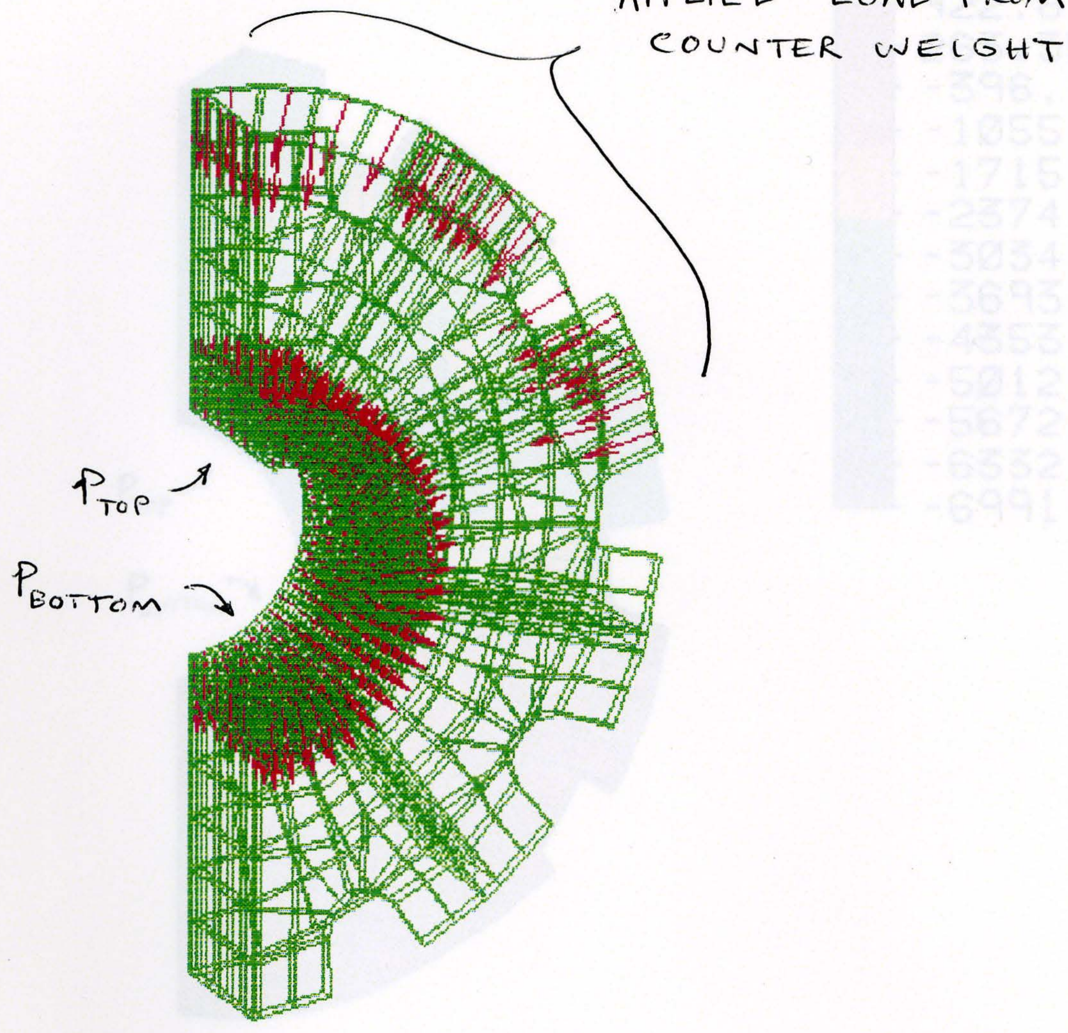
$$T = 2,463,000 \text{ IN-LB}$$

(205,250 FT-LB)

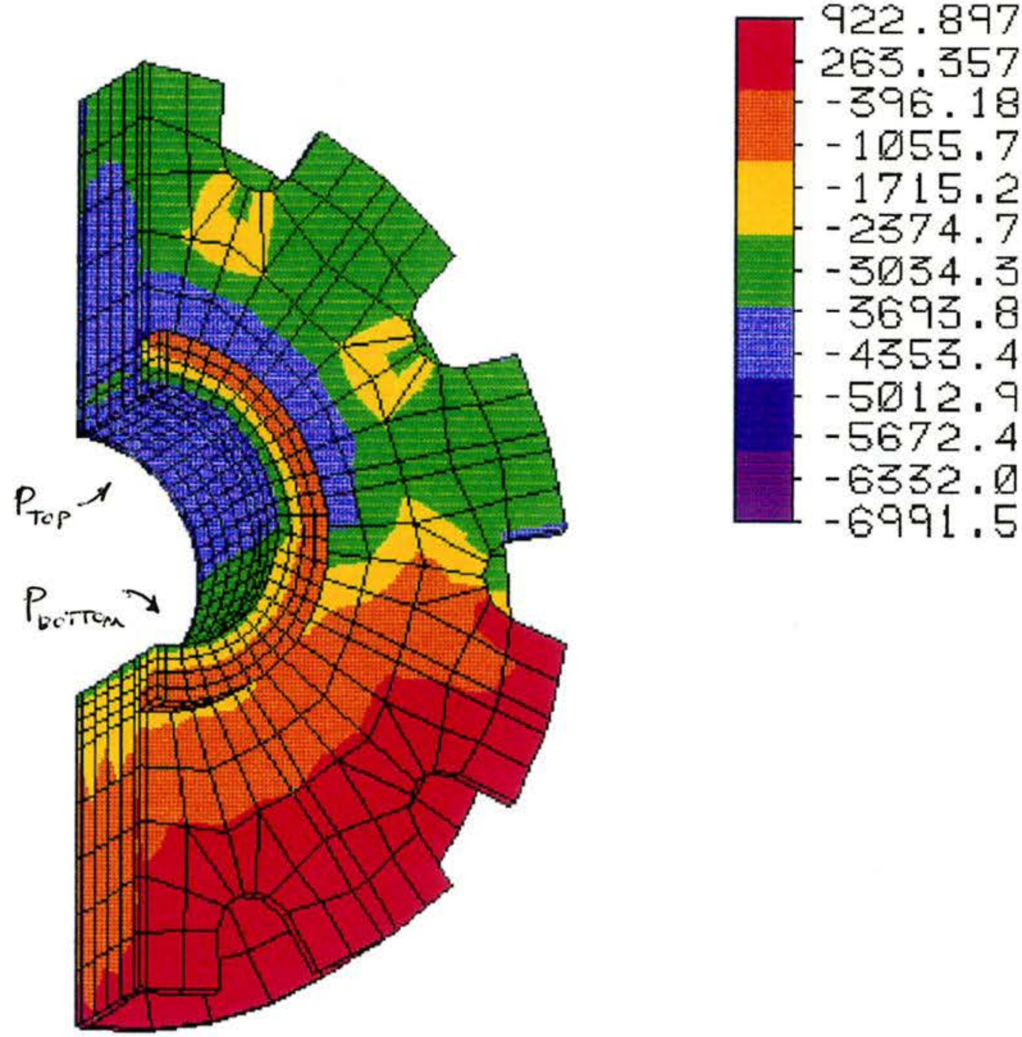
FEA 1/4 MODEL OF CENTRAL HUB



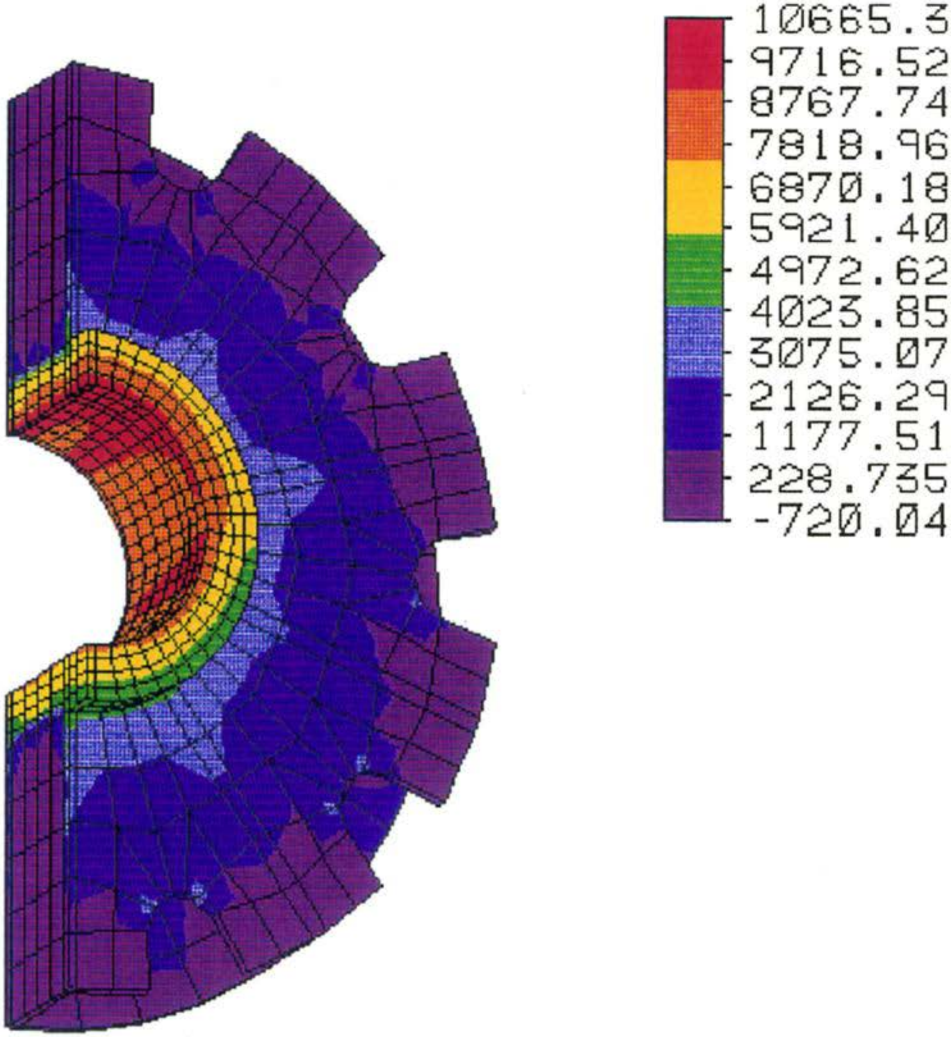




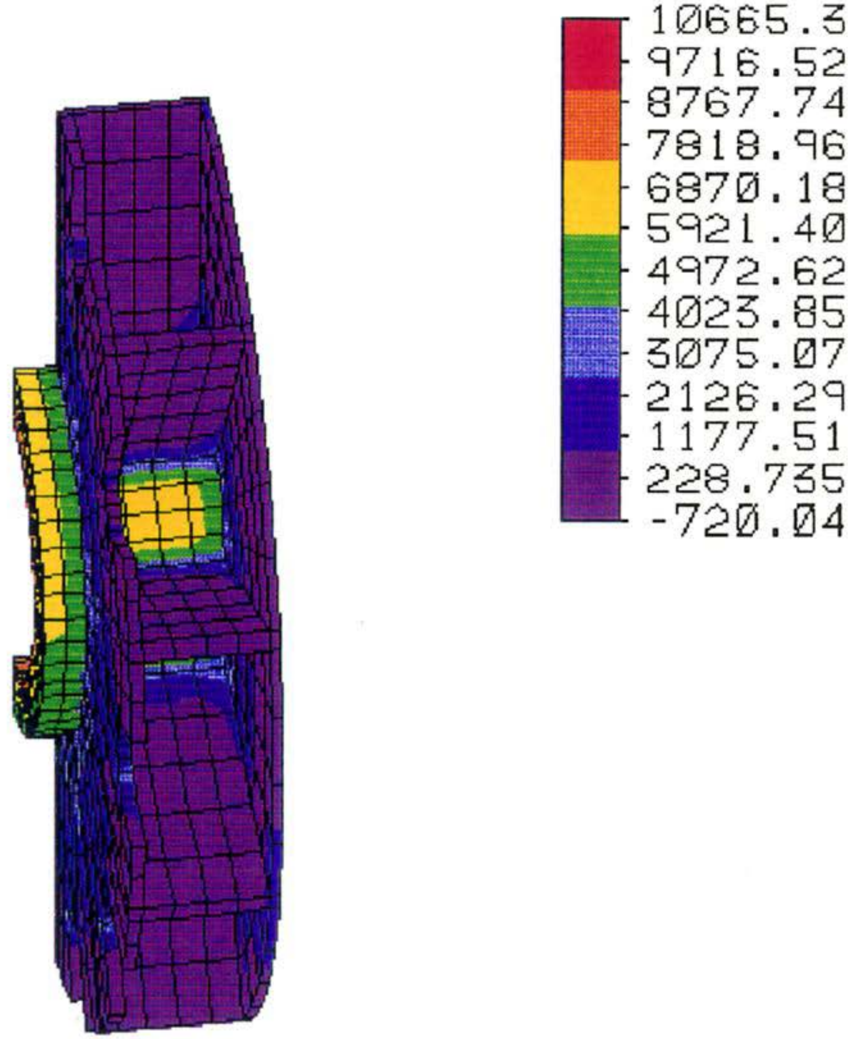
LOADING



MAXIMUM PRINCIPLE COMPRESSIVE STRESS (psi)



MAXIMUM PRINCIPLE TENSILE STRESS (psi)



MAXIMUM PRINCIPLE TENSILE STRESS (psi)

Summary

The following summary is separated into sections that correspond to the sheave's main components that were reviewed in this analysis.

- SHEAVE -

The revised 3-web sheave model was created using 3-D plate elements that require a thickness input. Part of the model verification was to check this input against the various plate thickness used in this design. Load cases 9 and 10 were run using a linear load distribution and two rotational locations of the sheave during operation. The loading was verified by using a single boundry element in the vertical direction. Since loads were placed at the central hub to react to the main cable tray loading, this boundry element is there only to balance the model. The magnitude of this boundry element was confirmed to be less than 100 pounds for both load cases. This small amount confirmed the vertical component of the loading was balanced between the cable tray and the central hub.

The output of the sheave FEA model gave an estimated weight of 4000 pounds for a quarter model, or 8 tons for the entire sheave. The output stress plots are presented on pages 6 through 14 and are sorted by the specific load case. The following tables are the summary of peak stresses for the previous 3-web design and the revised 3-web design that was analyzed in LC 9 and 10. SIG1 corresponds to the maximum principle tensile stress and SIG3 corresponds to the maximum principle compressive stress.

3-web Design

	-- Front Web --		Front Web Removed	
	SIG1	SIG3	SIG1	SIG3
Linear Load - No Off	3750	6340	5200	6000
- 20 Deg	3640	10,000	5420	8000

3-web Design Revised

	-- Front Web --		Front Web Removed	
	SIG1	SIG3	SIG1	SIG3
Linear Load - No Off	2970	5000	7150	7380
- 18 Deg	3090	9020	7045	8500

- CENTRAL HUB -

The load case used for the central hub was based on a 4000 psi shrink pressure between the sheave central hub and the trunnion shaft. The estimated torque capacity for this pressure is 205,000 foot pounds.

The stress plots for this load case are shown on pages 19 - 21. Page 19 gives a good view of how the pressure re-distributes as the counter weight loading is applied to the hub. On page 20, the tensile stress around the hub ID reaches a maximum of about 10,000 psi. Page 21 shows the stress gradient between the outer and center webs. The maximum in this area is about 6800 psi.

This analysis and the presented results are based on the primary loading as being due to the cables, counterbalance, and center bridge section. If any significant additional loads do exist, they can be analyzed and superimposed with the above results.