

Stress analysis of overhung flange and head sections in Yankee dryers

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SEVERAL INSTANCES OF CRACK initiation in Yankee dryer edge extensions have been reported in the tissue industry^{1,2}. Concern over catastrophic failure has prompted many in the industry (Yankee owners, insurers, designers, and builders) to safeguard the critical head/shell joint by performing periodic detailed inspections. Corrective actions, such as removal of the overhung flange, are generally recommended.

The decision to remove an overhung shell flange depends on the ability to restore the dryer shell to a level of adequate structural integrity and reliability without reducing performance. Finite element analysis (FEA) is an effective method to determine the thermal and structural response of complex structures such as Yankee dryers. Effects of changes in geometry (such as removing an overhang), design, and loading conditions can be modeled using this technique. Recent research has shown how useful FEA can be in illustrating the adverse effects of corrosion in Yankee dryer head/shell interfaces.

Finite element analysis was performed on a Yankee dryer with an overhung shell design. This dryer, manufactured in 1960, has a diameter and a length of 3.66 m (12 ft). The end of the shell overhangs the head, which is bolted to the shell section. The shell is manufactured from ASME SA-278 Class 30 cast iron, which is common for these types of applications. The purpose of the analysis was to determine the feasi-

bility of removing the overhung section of the shell without adversely affecting the integrity of the dryer.

FINITE ELEMENT MODEL

A two-dimensional axisymmetric nonlinear FEA approach was performed using the ANSYS finite element software. Two models were generated. The first model was for the original design, which includes the overhung shell region. The second model is identical to the first except that the portion of the shell above the head has been removed.

Figure 1 shows the model of the original dryer design with the overhung shell. A close-up of the head/shell interface is given in **Fig. 2**, with the shell overhang indicated. **Figure 3** shows a close-up view of the head/shell area for the second model, which has the overhung portion removed. All of the other dimensions were unchanged. Original drawings of the dryer, giving all dimensional details, were not available, so approximate dimensions obtained from scale drawings were used for this analysis. Exact dimensions and operations were not critical since this analysis was performed to show the difference between the original and modified designs.

Both of the models were created using two-dimensional axisymmetric elements. Axial symmetry was used so that only half of the dryer was modeled, and the appropriate symmetrical boundary conditions were applied. Over 670 elements were generated for the head and shell, resulting in over 875 degrees of free-

DRYER SAFETY

ABSTRACT

Finite element analysis was carried out to determine the effects of removing the overhung shell region on a 3.66 m (12-ft) diam Yankee dryer under typical operating conditions. Models were created for the original and modified designs and subjected to thermal, pressure, rotational, and head bolt clamping loads. The results showed that the structural integrity of the dryer was not compromised after the removal of the overhung shell. This represents an acceptable method to modify this type of dryer without affecting dryer safety, provided proper analysis is performed.

Application:

Modifications to overhung Yankee dryer head/shell designs to rectify the effects of crevice corrosion are possible after proper analysis and design considerations are performed.

dom. The interface between the head and shell was modeled using contact elements. These elements allow load to be transferred under compression but not under tension. Because of the nonlinear nature of the contact elements, an iterative solution is required.

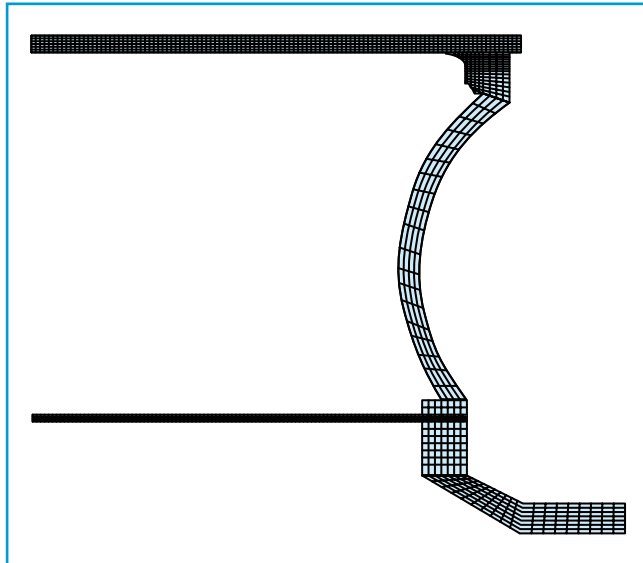
The head bolt clamping load was approximated by an axial load applied to the head and shell at the bolt location. The axial load was taken to be 31.1×10^7 N (7×10^6 lb), which corresponds to the total preload in the bolts.

Material constants that are typical for cast iron were used in the analysis and are shown in **Table I**. The operating conditions shown in **Table II** were applied as loads in all of the analyses.

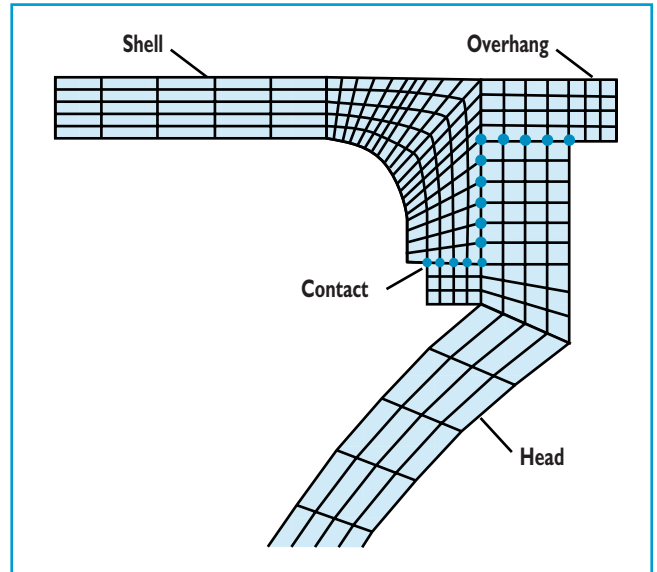
The analyses were carried out by first determining the steady-state temperature profiles with the thermal boundary conditions shown in **Table II**. These temperature profiles

¹Thielsch Engineering, Inc. internal data.

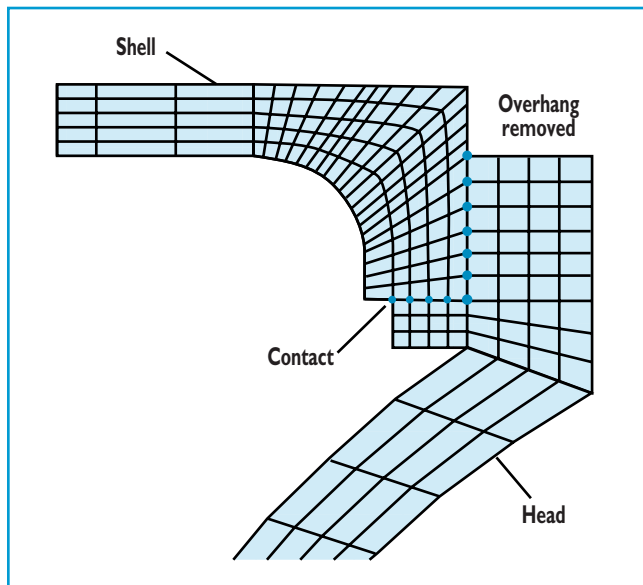
²Ferrari, F.J., *Tappi J.* 75(4): 133(1992).



1. Axisymmetric finite element model of Yankee dryer with shell overhang



2. Close-up view of the model showing the overhung head shell region including the contact interface



3. Close-up view of the head shell region with the shell overhang removed

were then used as the input temperatures for the structural analyses, where rotation and thermal expansion were taken into account.

Case 1

Case 1 consists of the original overhung shell design (shown in Figs. 1 and 2) with the thermal and structural boundary conditions as shown in Table II.

Case 2

Case 2 consists of the modified shell design with the

overhang removed, as shown in Fig. 3. In this case, the thermal conditions that were applied to the overhung shell were applied to the newly exposed portion of the head. All other boundary conditions and loads were the same as those in Case 1.

RESULTS

The results of the analysis of Case 1, which includes the original overhung design, are shown in Figs. 4–6. Figure 4 gives the results of the thermal analysis, showing the steady-state temperature profile throughout the dryer. These results show a relatively uniform temperature profile along the face length of the shell from the centerline to the edge of the felt. The temperature here is about 90°C (194°F). The temperature then rises to approximately 120°C (250°F) at the edge of the shell overhang. In addition, there is a steep temperature gradient through the shell thickness under the felt, rising from 90°C (194°F) on the outer surface to about 143°C (290°F) on the inner surface.

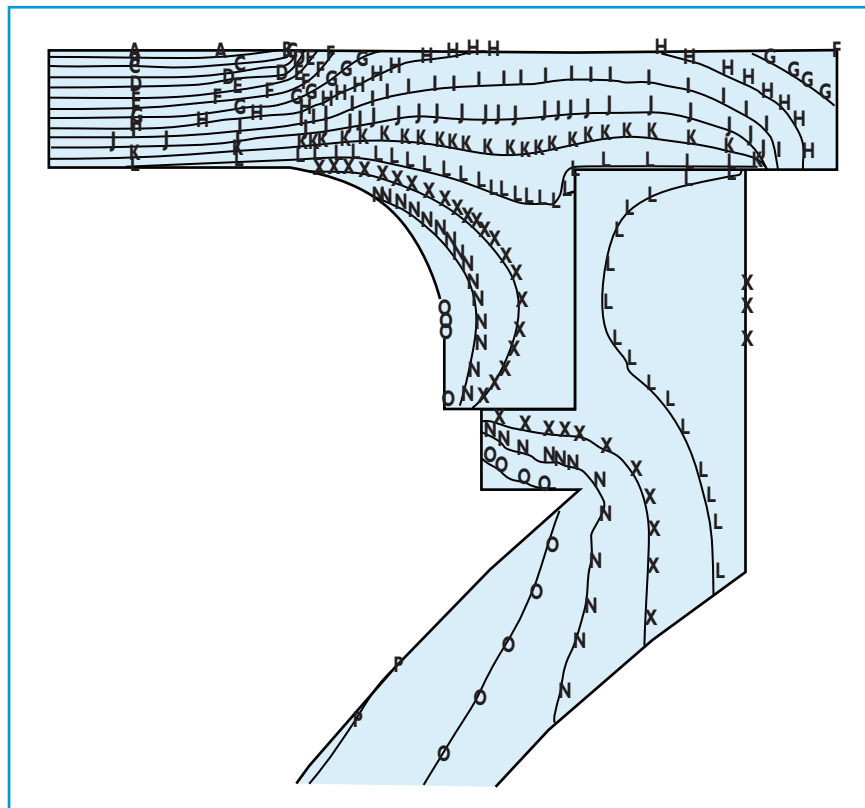
This temperature profile was entered into a structural analysis to determine the response of the dryer to these temperatures as well as the internal pressure, rotation, and clamping forces. The deformed shape of the dryer resulting from these conditions is shown in Fig. 5. A maximum deformation of 6.3 mm (0.248 in.) occurs at the edge of the shell overhang as a result of thermal expansion, internal pressure, and rotation. The entire dryer expands in both the axial and radial directions. The distortion in the head/shell joint region is evident.

Parameter	Material constant
Elastic modulus (E)	137 MPa (20×10^6 psi)
Poisson's ratio (γ)	0.3
Density (ρ)	70,600 N/m ³ (0.26 lb/in. ³)
Coefficient of thermal expansion (α)	10×10^6 in./in. $^{\circ}$ C (6×10^6 in./in. $^{\circ}$ F)

I. Material constants used in the analysis

Figure 6 shows the tangential stress contours in the head/shell region for the original overhung shell design. Because of the axisymmetric design, the tangential stresses are essentially the same as the maximum principal stresses. The highest tangential stress of 137 MPa (19,888 psi) occurs at the outer diameter of the shell at the edge of the overhang. This is where there is a significant temperature gradient resulting from the heat transfer cooling effects of the overhang. The stress decreases rapidly through the shell thickness at this location to a compressive stress of about -15.2 MPa (-2200 psi.) The stress along the outer diameter of the shell also decreases from the maximum to about 41.4 MPa (6000 psi) and then increases to a uniform level across the face length of the felt.

The results of the analysis of Case 2, the modified design where the shell overhang has been removed, are shown in Fig. 7. Here, the tangential stress contours in the head/shell joint area are similar to the view shown in Fig. 6. In this case, the maximum stress of 112.7 MPa (16,340 psi) occurs in the outer periphery of the shell at



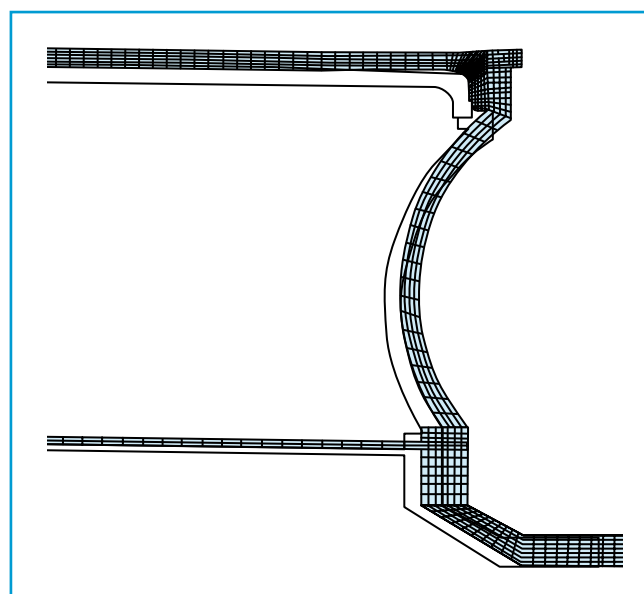
4. Temperature profile in original design

the edge of the felt. The maximum deflection is 5.93 mm (0.2334 in.). A similar stress gradient occurs through the shell thickness, and the stress decreases along the outer

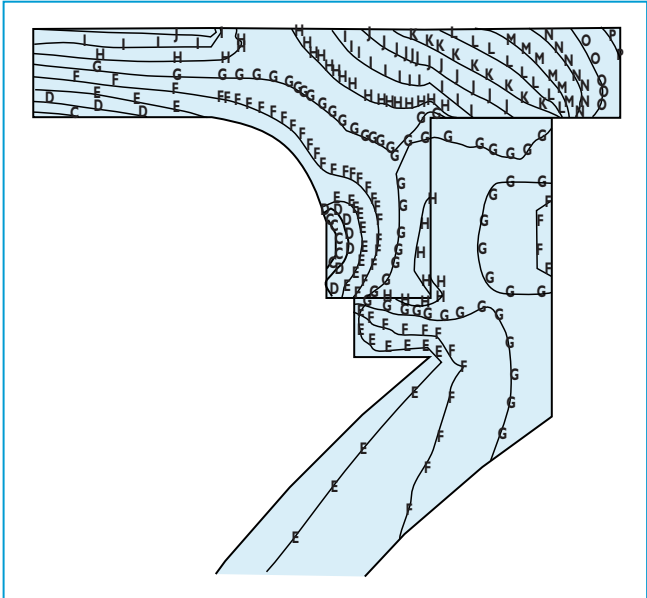
Parameter	Value
Internal pressure, MPa (psi)	0.62 (90)
Rotational speed, rpm	66.3
Temperature, $^{\circ}$ C ($^{\circ}$ F)	
Internal	165 (330)*
Shell face	87.8 (190)
Shell edge	121 (250)

*Thermal boundary conditions consisted of applying various bulk temperatures and film coefficients on all surfaces of the dryer. This resulted in the above approximate surface temperatures.

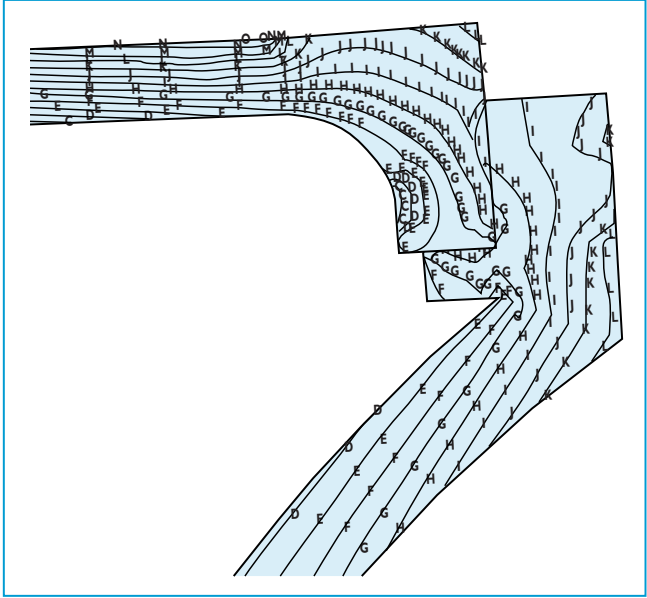
II. Operating conditions



5. Distorted shape of original dryer design under operating conditions



6. Tangential stress contours in the head/shell area in the original overhung design



7. Tangential stress contours in the head/shell area of the modified design

Case	Max. tangential stress and location	Max. tangential stress at shell edge, MPa (psi)	Max. deflection, mm (in.)
1 Original overhang	137 MPa; Shell OD at edge of overhang	137 (19,888)	6.3 (0.248)
2 Overhang removed	112.7 MPa; Shell OD at edge of felt	64.8 (9,400)	5.93 (0.2334)

III. Summary of maximum stresses and deflections

diameter of the shell toward the edge. However, in this case, where the overhang has been removed, the maximum stress at the shell edge is only about 64.8 MPa (9400 psi), which is 53% less than the 137 MPa (19,888 psi) stress when an overhang was present.

A summary of the maximum tangential stresses and deflections obtained from the analyses of Cases 1 and 2 is provided in **Table III**. Given are the maximum tangential stresses and locations, maximum tangential stresses

at the shell edge, and the maximum deflections. These results show that the maximum stress in the dryer shell decreases by removing the shell overhang. In addition, the stresses at the outer edge of the dryer shell are considerably reduced when the overhang is removed.

SUMMARY

Results of the finite element analysis have confirmed that removing the overhang region of the dryer shell is an acceptable method of providing continued safe and reliable service of the dryer. The maximum stress in the dryer decreases significantly when the overhang region is removed, and the stresses in the shell edge are reduced in the modified design. **TJ**

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