"A Review on Transient Thermal Analysis for Top Head Nozzle of Crack Gas Drier by Finite Element Method"

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Abstract-This paper presents the review related guideline in transient thermal analysis for top head nozzle of crack gas drier. Crack gas drier in which gases of high pressure and temperature are admitted through nozzle. When these gases are admitted then due to fluctuation of temperature and pressure there is some cracks/failures are developed in nozzle which cause damage of nozzle and reduce the life of pressure vessel. So for designing crack gas dryer this cracks/failure should be minimized. The different analysis FE methods are used for reducing the cracks/failure in crack gas dryer. By using different methods different result are obtained. In this review which method gives optimum parameters are discussed.

Keywords: Transient; Thermal; Crack gas drier; Nozzle; Stress; FEM

I. Introduction

Crack gas drier is one type of pressure vessel which is used in the industry for drying process. Pressure vessel is thin shell construction device which are fabricated from steel plate material and it is routinely used in power generation, chemical petroleum, food industry etc.So by using at different application some of these vessels are subjected to relatively severe condition that include chemical attack, rapid pressure and temperature fluctuations and steam water hammer. In plant piping systems impose loads upon pressure vessel through nozzle connections. So by these loading there is several cracks/failure are developed in nozzle. The various types of cracks/failure in nozzle are cracking due to external load, lack of penetration, chemical attack etc.

In pressure vessel whenever expansion or contraction would occur normally as result of heating or cooling there is thermal stresses are developed. The stress is always caused by some form of mechanical restraint. There are many types of stresses are developed in the element but they are categorized into primary stresses and secondary stresses. Primary stresses are generally due to internal or external pressure or produced by sustained external force and moments these are not self limiting. Thermal stresses are secondary stresses because they are self limiting. That is yielding or deformation of the part relaxes the stress (except thermal stress ratcheting).Thermal stresses will not cause failure by rupture in ductile materials except by fatigue over repeated applications. [8]

In pressure vessel mostly cracks are developed surrounding nozzle areas, when the distance the distance are increase from nozzle to vessel junction these stress should be decreased. [1].

II. Crack Developed In Nozzle

The cracks are developed in nozzle of pressure vessel around fusion line of bi-metallic weld as shown in fig.1 the nozzle is simultaneously subjected to operational pressure and coolant flow transient by analyzing it should be concluded that for transient flow conditions the safety margin against brittle fracture is large.

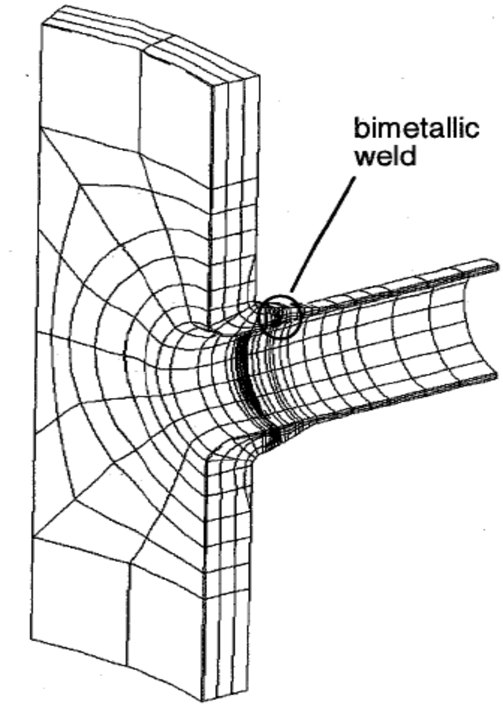


Fig.1 Finite element modal

For this model both loading cases strip cooling caused by stratified flow and perfect mixing were analyzed by simplified fracture assessment methods. The temperature and stress distribution due to the thermal shock are mainly defined by wall thickness, not by radius. Crack tip temperature for both perfect mixing and stratified flow condition remains higher shown in fig.2

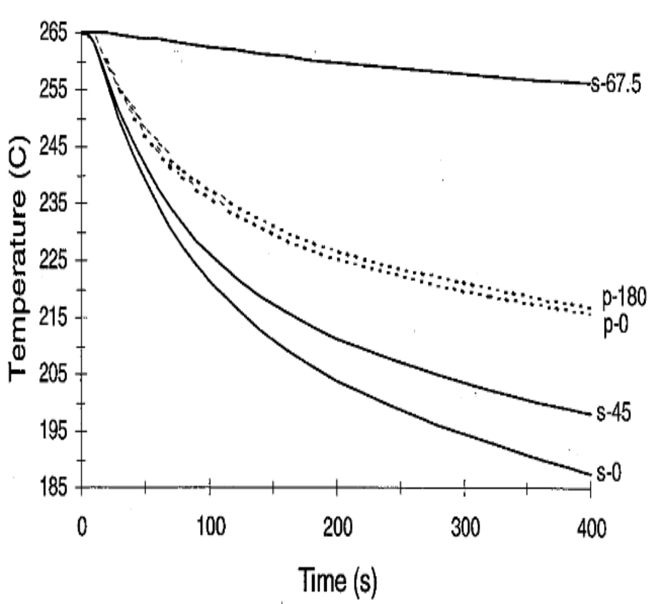


Fig.2 Crack tip temperature for both perfect mixing and stratified flow condition

In the perfect mixing loading case the 'Fixed' boundary condition gives higher stress intensity factor values than 'free' boundary conditions. In the stratified flow loading case the difference were small. So finally it conforms that safety margin against brittle fracture is relatively large under the assumed conditions [2]

The main purpose of the analysis was to estimate the safety against two different failure modes as a function of the postulated crack depth: 1) brittle fracture; 2) fatigue crack growth. Besides internal pressure load, the structure was subjected to transient thermal effect due to operation of the high pressure emergency cooling system. When the flow of fluid are entered in nozzle then the temperature are changes within time this transient flow of fluid give different analytical result for two conditions like stagnant loop and perfect mixing. [3]

III. GEOMETRY OF MODEL

In structural modeling and stress analysis of nozzle connection in ellipsoidal heads subjected to external loadings in which using Timoshenko shell theory and the finite element method the different result are obtained. The features of the structural modeling of ellipsoid-cylinder shell intersections, numerical procedure and SAIS special purpose computer program are used. For the ellipsoidal-cylinder intersection, two typical planes are selected. These planes pass through the normal ***n0*** to the ellipsoid surface at the point of the intersection of this surface by the nozzle axis Fig.3.

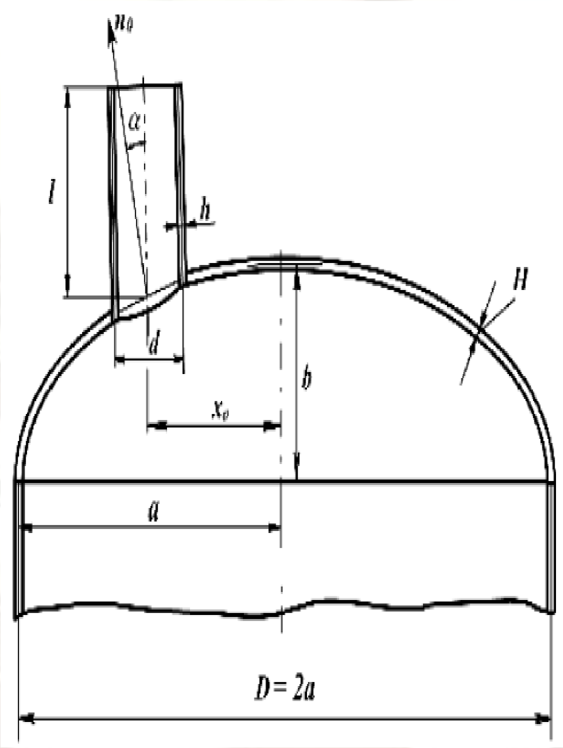


Fig.3 External loading and Stress directions

The main plane passes through the axis of the basic shell and the normal ***n0***. The transverse plane is perpendicular to the main one. The parameter ***x0*** defines the relative offset nozzle displacement from the central position, the parameter α defines the angular deflection from the radial position (from the normal ***n0*** to the head shell surface). In this analysis all forces and moments can be resolved into three components P_X, P_Y, P_Z, M_X, M_Y and M_Z. .These loadings cause the most significant stress concentration in shell intersection among the different external loading cases. The important non-dimensional geometric parameters of the ellipsoidal-cylinder intersection are:

b **= 2b/ D**, *d /D, D /H* (or *d/h), h /H,* $\bar{x}_0 = \frac{2x_0}{D}$, α

To examine the maximum effective stresses (by Tresca criterion) in shells of the nozzle connections under different loadings, the stress ratio was introduced in the following form:

$$\bar{\sigma}_e = \frac{\sigma_{e,\max}}{\sigma_0}, \sigma_e = \sigma_1 - \sigma_3 \quad (1)$$

Where σ_1 and $\sigma_3$are the maximum and minimum principal stresses; σ_0 is the nominal stress of the connection.

The influence of parameter *2b/D* on the maximum effective stresses in the shells of the radial nozzle connection is shown in fig.4.for P_X and M_Y loadings in which a minimum value of the effective stresses in the shells is received for the sphere head. Now as shown in fig.4 it investigate that it is necessary to pay more attention to the effective stresses in the shells in these loading cases Although the stresses due to the external loadings are secondary stresses with respect to primary stresses from the internal pressure, these stresses should be taken into consideration in a complete stress analysis for nozzle connections of a pressure vessel. [4]

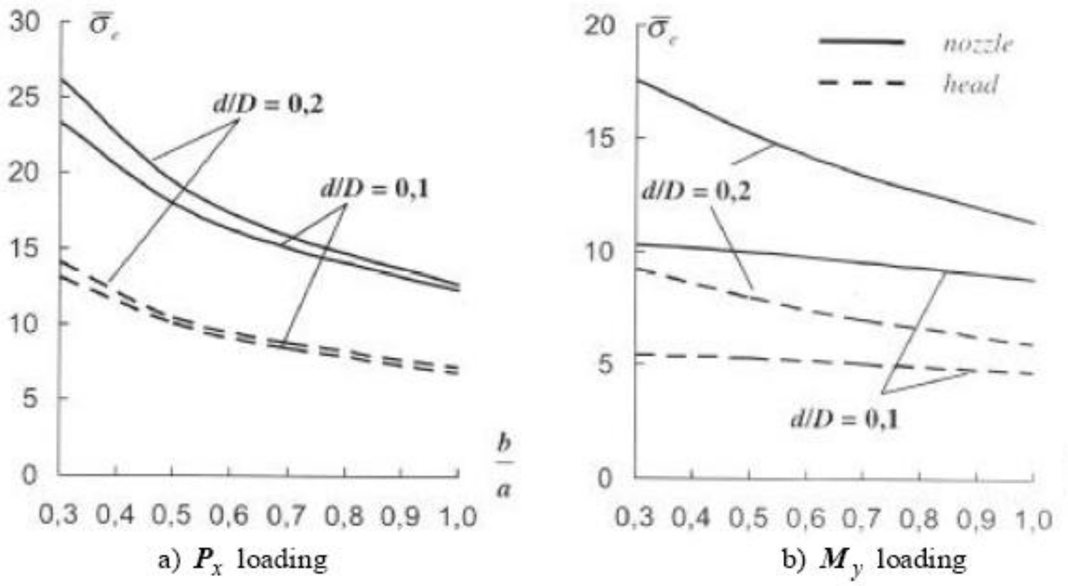


Fig. 4 Influence of the parameter *2b/D* (*h/H = 0.7*; *α = 0*; $x_0 = 0$)

The variation of local pressure stress (local pressure stress/internal pressure) at the juncture of a pipe-nozzle intersection varies from the standard 90° to 30° lateral. These stress factors at 90° intersection, a standard pipe-nozzle exhibit less several local stresses. These stresses are increasing as the angle of intersection is decreasing from 90° and become more several when the angle of intersection is further decreasing from 45°

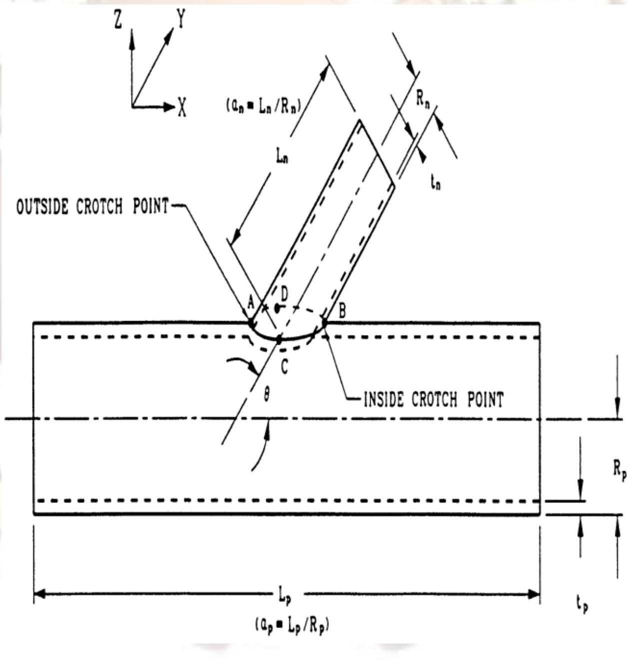
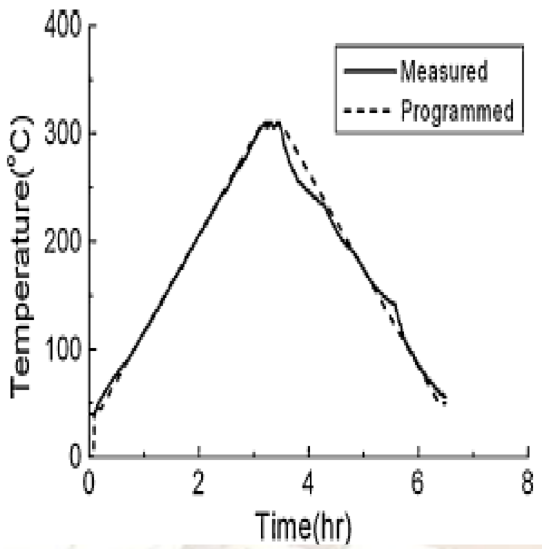


Fig.5 Pipe-nozzle configuration

The circumferential stress at the inside crotch point exhibits the worst stress value. (fig.5) the stress factor results in pipe circumferential direction at the inside crotch points are in good agreement with the stress factor equation from the ASME boiler and pressure vessel code. [5]

In thermo-mechanical simulation for nozzle header of steam generator by experimental and finite element method both give good agreement result. The nozzle feed water header suffers from several thermal transient during the operation.

In Start-up and Shut-down period the changes in temperature and pressure are shown in fig.6 and fig.7.in the fig.6 the dotted line is the programmed value and the solid line is the measured primary coolant temperature. The measured primary coolant temperature follows the programmed primary coolant temperature well within the tolerance range. The temperature gradient results in high



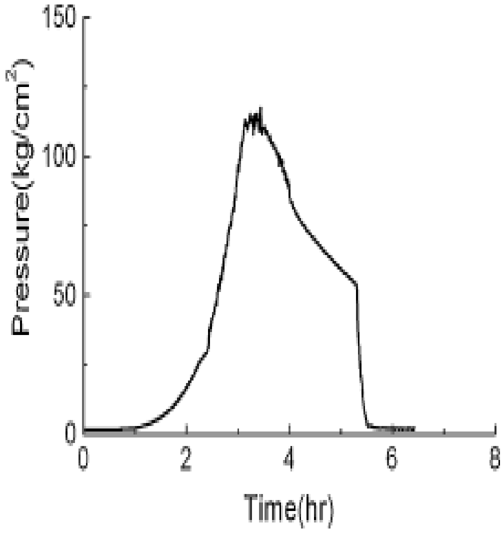


Fig.6 Primary coolant temperature Inside Vessel

Fig.7 Primary coolant pressure Inside Vessel

thermal stresses in nozzle header. In parallel with the experimental study, the transient behavior of the nozzle header was simulated by utilizing a commercial finite element code. The fluid temperature and pressure obtained from this experiment were used as inputs to the finite element analysis. After investigating the thermo-mechanical load carrying capacity of the developed steam generator nozzle header was proved numerically and experimentally. [6]

The elastic stress and deformation of pressurized cylinder with hillside nozzle was investigated by H.F.Wang and Z.F.Sang in which two full scale test models were designed and fabricated specially for the test. A 3D finite element numerical analysis was also performed. They obtained the elastic stress distribution, stress concentration range, deformation characteristics and stress concentration factors. The elastic results show that the distinct stress concentration occurs on the hillside-nozzle intersection, and the intersection shrinks in the longitudinal section of cylinder, while a bulge appears in the transverse section. The range of stress concentration of the hillside nozzle intersection in the transverse section is larger than that in the longitudinal section and the stress concentration factor declines with the incremental angle β.

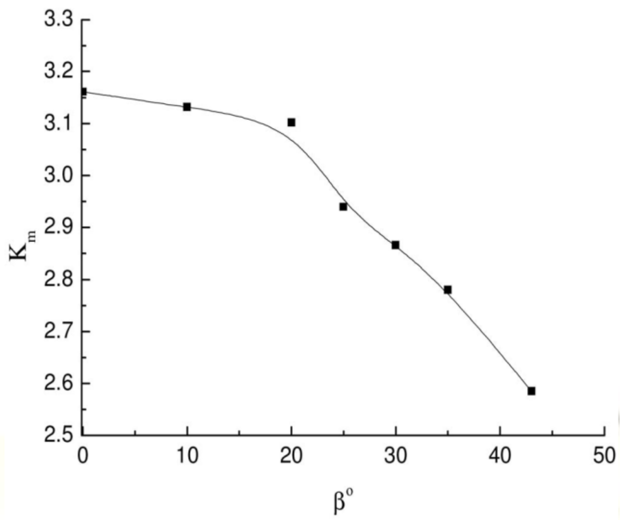


Fig.8 Maximum stress concentration factor of Hillside nozzle

As shown in fig.8 it indicates that compared with radial nozzle hillside indicate less stress concentration. Compared with radial nozzle the hillside nozzle investigates the maximum stress $S_{\beta.}$ These can be estimated by

$$s_{\beta} = s_0[1 + 2(\sin\beta)^2] \qquad (2)$$

Where, *So*=Maximum stresses in radial nozzle, *Sβ*=Maximum stresses in hill-side nozzle

The results will serve as the basis for developing a design guideline for pressurized cylinders with various angles of the hillside nozzle. The results in this study also indicate the maximum elastic Stress occurs at inside corner of hillside-nozzle intersection in the longitudinal section of cylinder, which can be determined by the equation presented by Mershon for relating stresses in hillside-Nozzles relative to stresses in radial nozzles. [7]

CONCLUSION AND SCOPE

The study shows that in pressure vessel different types of cracks/failure are developed. After investigating different methods it should be concluded that nozzle is essential part of pressure vessel in which maximum cracks are developed. The analyzing by different finite element methods gives different parameters. After analyzing the 'maximum' parameters are find out which gives maximum strength for nozzle.

The analysis for top head nozzle of crack gas dryer by finite element method which can reduce the stresses and crack/failure of nozzle. After analysis the optimum parameters should be considered which can minimize the stresses in pressure vessel. This can increase the life of pressure vessel and reduce the cost of pressure vessel which is benefit for applicant.

It should be concluded that stress and other parameters are also decreased by changing the weld design and angle of nozzle weld which can gives improving result.

The analysis by different methods gives the different result. All these result should be compared and the optimum results should be evaluated. The optimum parameters evaluated by analyzing procedure should be considered the "maximum" strength parameter for nozzle.

IV. REFERENCES

[1] Michael A. Porter, Dennis H.Martens, S.M.Caldwell A suggested shell/plate finite element nozzle evaluation procedure, Int.Journal of pressure vessel and technology Aug-2008 Vol.130
[2] Keinanen and Talija, Brittle fracture analysis of primary Nozzle of VVER 440 reactor pressure vessel, Transactions of the 14th International conference of structural mechanics in reactor technology, Lyon, France, Auguest 1997 (17-22)

[3] Z.Pammer and G.Szabolcs, Analysis of pressure vessel nozzle crack subjected to cyclic pressure and transient thermal stress loads using the P-extended finite element system PEXFE-3D, Elsevier science publishers 1993, B.V. 369-374

[4] V.N.Skopinsky and A.B.Smetankin, Modeling and stress analysis of nozzle connections in ellipsoidal heads of pressure vessel under external loading, Int.Journal of applied mechanics and engineering.2008 vol.11, No.4 PP.965-979

[5] James J. Xu, Benedict C. Sun, Bernard Koplik, Local pressure stresses on lateral pipe-nozzle with various angles of intersection, Nuclear engineering and design 199 (2008) 335-340

[6] Yong Wan Kim, Dong Ok Kim, Jae Seon Lee, Suhn Choi, Sung Quun Zee, Thermo-mechanical simulation for nozzle header of once-through steam generator by experiment and finite element pmethod,Int.Journal of pressure vessel and piping 82 (2005) 602-609

[7] H.F.Wang and Z.F.Sang "Elastic stresses of pressurized cylinders with hillside nozzle" Department of mechanical engineering, Nanjing university of Technology, Nanjing, 210009, P.R.China

[8] Moss D.R.Pressure Vessel design manual Third edition