

2001

Prediction of Burst Pressure of Steam Generator Tube with an Axial Through Wall Crack Using Finite Element Method

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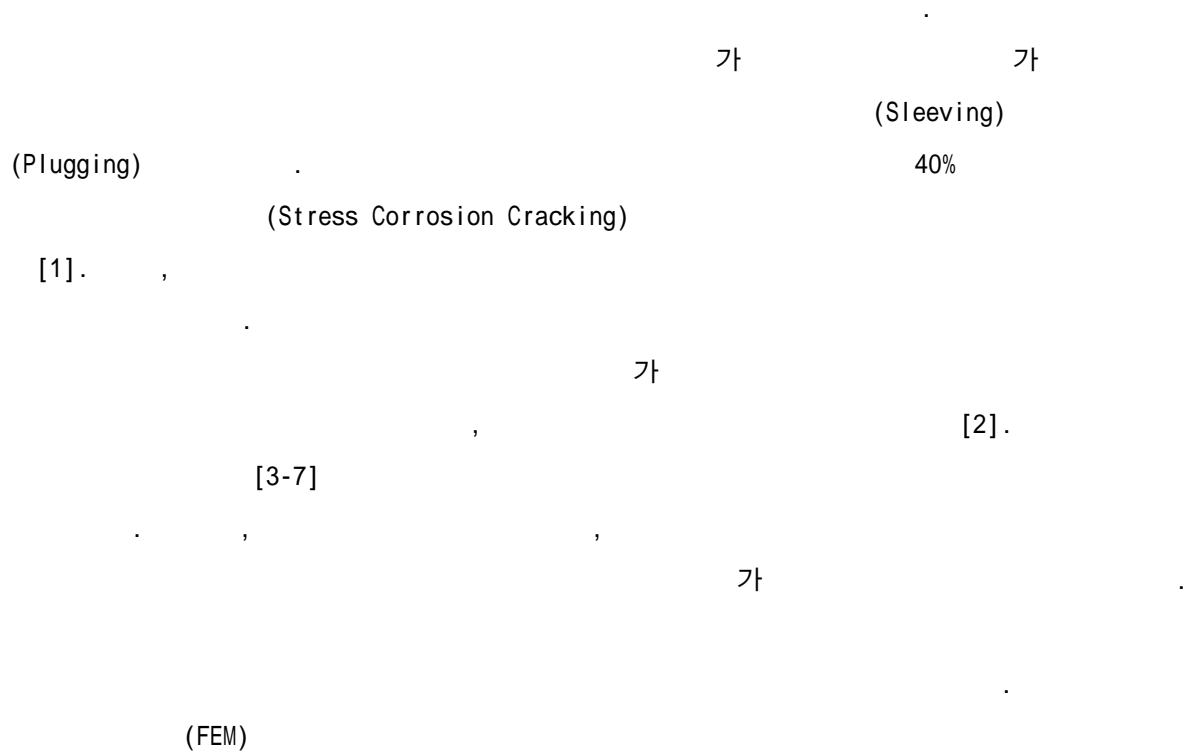
가
 y , E22(ϵ_y) . FEM
 : 1) (Bulging factor)
 , 2) y , E22(ϵ_y)
 76° , 3)
 yz , E23(γ_{yz}) E22
 가
 E22
 Framatome

ABSTRACT

A new method to predict a burst pressure of steam generator tubes containing an axial through wall crack by

the finite element method (FEM) technique is suggested. The burst pressure obtained by applying the new method is the pressure corresponding to the first peak of the strain component in the y-direction, $E22(\epsilon_y)$, of the crack tip element which is located at the center of the crack tip surface when strain components are calculated using the global coordinate. The major results from the FEM analysis are as follows; 1) In case of straight tube, each strain component at a crack tip shows similar behaviors for the different crack sizes if the applied pressures are modified by a bulging factor. 2) The crack tip slope angle of 76° is obtained irrespective of crack sizes and shapes when the tube is under the pressure corresponding to the first peak of $E22$. 3) The shear strain in the yz plane, $E23(\gamma_{yz})$ from the co-rotational coordinate system is abruptly increased at the first peak of $E22$ from the global coordinate system. This means that the deformation behavior in the vicinity of the crack tip changes abruptly at the first peak of $E22$. The burst pressure predicted by using the suggested definition is quite consistent with the results of the existing burst pressure expression and the Framatome data, therefore, the burst pressure prediction methodology suggested in this paper which is based on the strain behaviors of the crack tip element results in being valid.

1.



2.

(1) 가

ABAQUS

가

가 1 :

가 2 :

(2)

1

1,4)

ABAQUS 20 (20-node isoparametric element)
 0.27, 0.39, 0.59 1.18
 - Framatome [8] (Heat No. WB-942)

가 (Strain hardening exponent) 0.36[8]

2

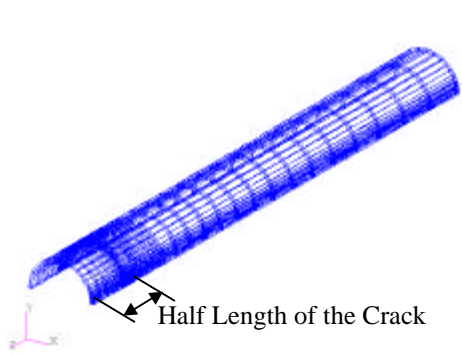
(3)

3 0.27 0.59 ()
 1)
 (Global coordinate) 가 가

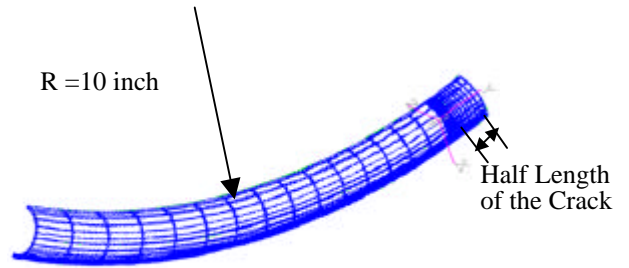
가 가 , 가 가

, 가 (Equivalent plastic strain) 가

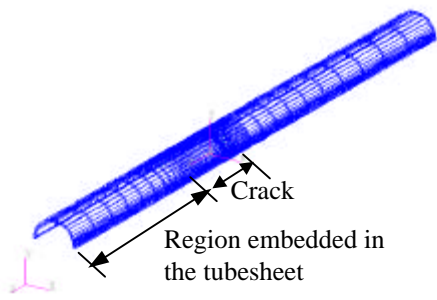
가



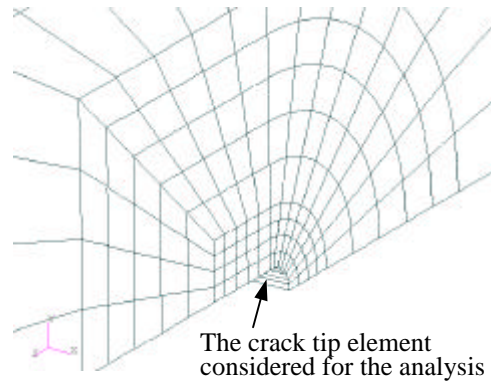
1)



2)

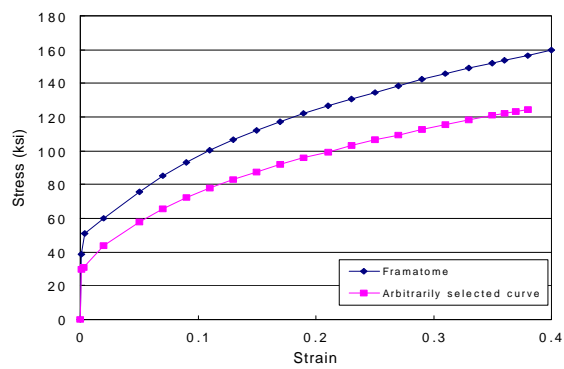


3)

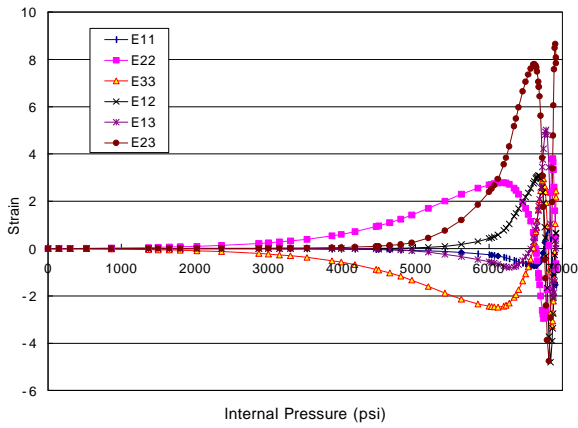


4)

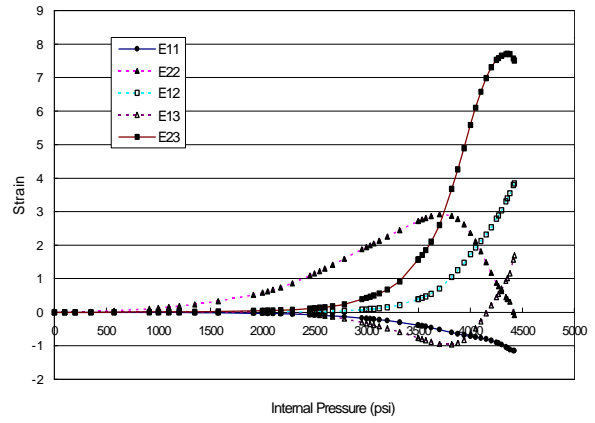
1.



2.



1) 0.27



2) 0.59

3.

(4)

(Bulging factor)

(Effective pressure)

(1)

$$P_{eff} = P_{int} M_T R / t \quad (1)$$

, P_{eff} , P_{int} , M_T , R , t .

, M_T (2) (3) .

Erdogan[7]

$$M_T = 0.614 + 0.481\lambda + 0.386\exp(-1.25\lambda) \text{ for } 5 \leq R/t \leq 50 \quad (2)$$

$$\lambda = [12(1-\nu^2)]^{0.25} (c/\sqrt{Rt}) \quad (3)$$

, λ , ν , c .

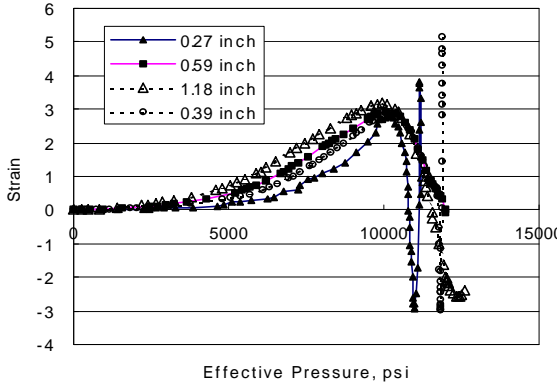
4 (1)

0.27, 0.39, 0.59 1.18

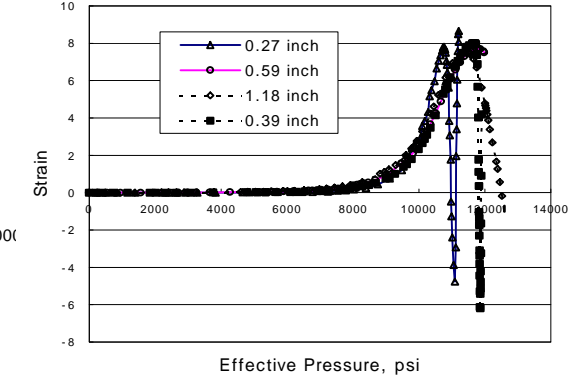
E22 E23 . E22 E23

E22

E23



(1) E22(ϵ_y)



(2) E23(γ_{yz})

4.

(5)

5 가 ,
 가 3 ,
 yz
 가 (4)

2

$$(\text{degree}) = \text{Arctan} [(PY_{\text{node1}} + UY_{\text{node1}}) / (UZ_{\text{node1}} - UZ_{\text{node2}})] \quad (4)$$

PY_{node1} node1 y , UY_{node1} node1 y , UZ_{node1}
 node1 z , UZ_{node2} node2 z . Node1 node2 5

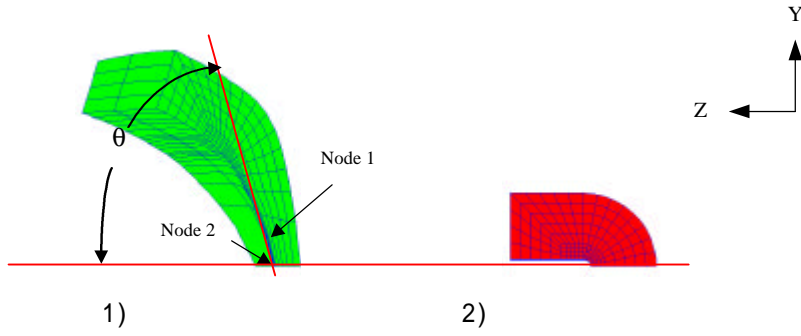
6 0.27, 0.59 1.18 가

가 90 55

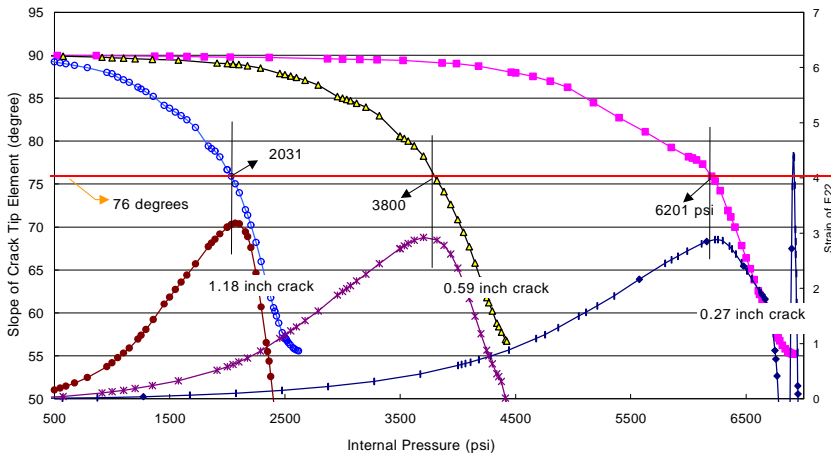
E22(ϵ_y)

E22

가



5.



6.

(6)

7 (Co-rotational coordinate)

7 가

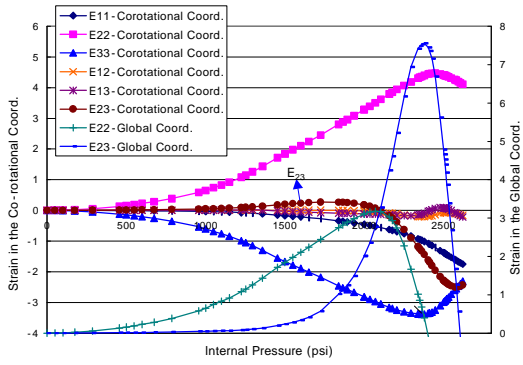
가

7 $E_{23}(\gamma_{yz})$
 , $E_{23}(\gamma_{yz})$

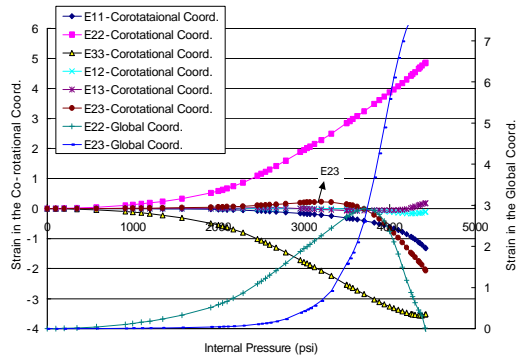
가 가
E23

E22

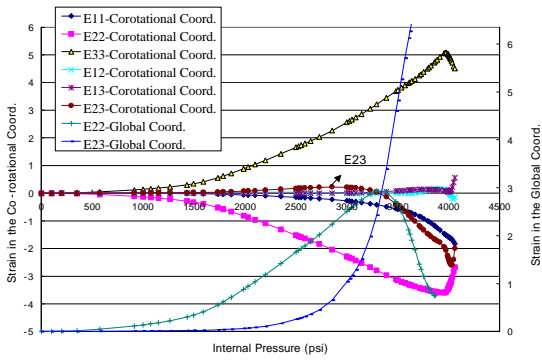
가



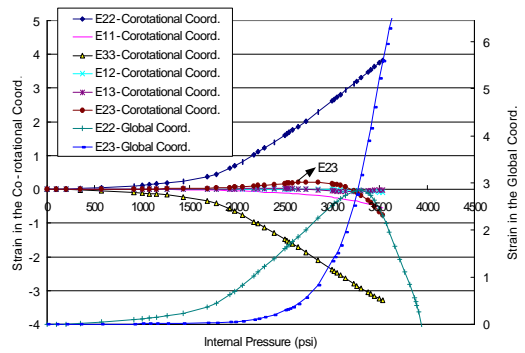
1) 1.18



2) 0.59



3) 0.59



4) 0.59

7.

: 1) 2) Framatome , 3) 4) 가 (2)

E23(γ_{yz})가

: 1)

, 2)

E22(ϵ_y)

3.

(1)

E22(ϵ_y)

, 2)

: 1)

가 76

가

, 3)

E23(γ_{yz})

가

y

, E22(ϵ_y)

(2)

8

Framatome

[8] Erdogan

[7] Follias

[3]

8

Follias

가 가

Erdogan

Framatome

(3)

Framatome

-

5 가

(1200%, 46%

26%

2

, bi-linear

-

)

3 가

(

가

,

)

8

8

1200%

Framatome

. 가

-

. bi-linear

2

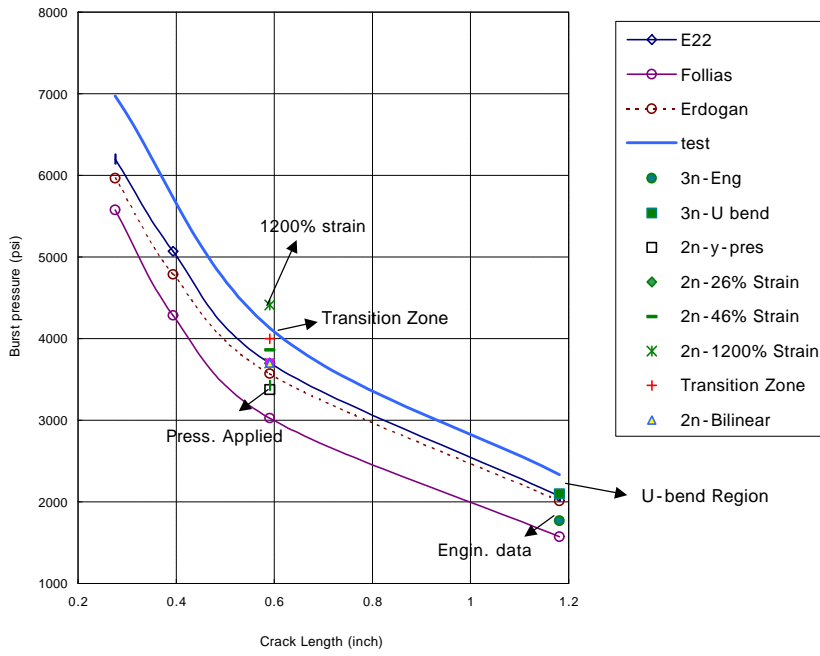
가 . bi-linear
(Uniform strain)

1.5%

8 %

가

가



8.

4.

(1)

가

y , E22(ϵ_y)

(2) FEM

1)

2)

y , E22(ϵ_y)

76°

3) E23(γ_{yz}) E22(ϵ_y) E22(ϵ_y) yz 가

(3) 가 , bi-linear (Uniform strain)

(4) Framatome

5.

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