Stress component indices for elbow-elbow connection

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1 INTRODUCTION

Nuclear piping often has two adjacent elbows lying in different planes and having different elbow angles. Piping stress analysis is done using flexibility factors and stress indices. Detailed stress analysis of elbow connected to straight pipe and subjected to inplane and out of plane loading has been reported in literature (Karabin, Thomson, Natarajan). However, results of stress analysis for adjacent elbows in different planes are not generally available.

In this paper an elbow-elbow connection with one elbow in vertical plane and other in horizontal plane are analysed using three dimensional Finite Element method for different loadings, like axial pull, inplane bending and internal pressure. A parametric study is done for different piping ratios. Results are presented for the run of piping and circumferential distribution along mid sections of the elbows and also at their junction. An attempt is made to estimate the stress component indices for different sections.

2 DESCRIPTION

The elbow in vertical plane is a 90° elbow while the one in horizontal plane is a trimmed 60° elbow. Straight pipes of infinite length ($> 6/\beta$) are connected to each of the elbows to eliminate the end effects. Elbows of three piping ratios (h) of 0.2423, 0.375 and 0.6795 are analysed, where piping ratio is tR/r^2.

Axial pull and bending moments are applied at far end of vertical pipe. The far end of horizontal pipe is fixed. For internal pressure, a force equivalent to pD/4t is applied on far end face of the vertical straight pipe.

3 FINITE ELEMENT ANALYSIS

Three dimensional 8-noded isoparametric brick element available in program SOLID (Buragohain) is used for analysis. A total number of 216 elements bounded by 448 number of nodes are used. Each node has 3 displacements in mutually perpendicular directions as degrees of freedom. Fig.1 shows the typical finite element mesh used. All the three displacements of the nodes lying on far end of the pipe in horizontal plane are restrained. The load is applied on the nodes on far end of the vertical pipe.

It may be noted that load at an end may give rise to a combination of axial force, bending moment and twisting moments.

4 RESULTS AND DISCUSSIONS

Detailed stress distribution for the piping rato of 0.375 are presented here. Fig.2(a) shows the variation of normalised meriodinal and tangential stresses along the runs of the elbows for inplane bending moment applied at straight pipe end for different θ planes. A θ plane is defined as section of elbows cut by a plane making angle θ from the diametral plane containing centre of vertical elbow. Fig. 2(b) shows the variation of stresses along the circumference at ends and at middle length of both the vertical and horizontal elbows.

Figs.3(a) and 3(b) show the variation of normalised stresses along the pipe run and along circumference for the internal pressure. The stresses are quite uniform in elbows whereas end effects are seen near junctions.

Figs.4(a) and 4(b) show the variation of stresses for axial pull. The stresses tend to peak near centre of horizontal elbow while stresses near junction is maximum for vertical elbow.

Fig.5 shows a typical deformed mesh for h equal to 0.375 and subjected to internal pressure.

Table 1 shows the maximum stresses that occur in the elbow system under various loading conditions and for all three piping ratio values studied. Though in general the stresses are higher for centres of elbows, values of stresses are higher at junction compared to those at centre for some load dcases and piping ratios. There is also a change of nature of maximum stress from centre to junction. It may be noted that normalisation is done with respect to nominal stress values at the end where load is applied.

5 CONCLUSIONS

Elbow-elbow connections for three piping ratio values of 0.2423, 0.375 and 0.6795 are analysed using three dimensional finite element method. The stresses for junction and elbow runs are presented. Though in general stresses are maximum at centre of elbow, peak stress occurs at junction of elbows for some load cases and piping ratios. A table of maximum normalised stresses is presented.

REFERENCES

Karabin, M.E. etal. 1986 February. Stress component indices for elbow-straight pipe junction subjected to inplane bending. Jl of PV.Tech,Vol.108.

Thomson G, Spence J.1983 Nov. Maximum stress and flexibility factors of smooth pipe bends with Tangent pipe termination under inplane bending Jl Pr. Vessel tech.

Natarajan, R. etal. 1975. Stress analysis of curved pipes with ends restraints Computer & Structures. Vol.5.

Buragohain, D.N. SOLID-Computer code for finite element analysis of solids. IIT Bombay, India.

Table 1.

			Vertical Elbow			Horizontal Elbow		
	Piping Ratio		0.2423	0.375	0.6795	0.2423	0.375	0.6795
Inplane Bending	$\frac{\sigma_\phi}{\sigma_n}$	Junction(J)	1.35	1.35	1.20	1.35	1.35	1.20
		Centre (C)	1.62	1.65	1.57	1.15	-1.23	-1.11
$\sigma_n = \frac{MD_o}{2I}$	$\frac{\sigma_\theta}{\sigma_n}$	(J)	0.46	0.27	0.26	0.46	0.27	0.26
		(C)	0.68	0.60	0.43	0.28	0.36	0.15
Axial pull	$\frac{\sigma_\phi}{\sigma_n}$	(J)	-1.33	-1.44	-1.29	-1.33	-1.44	-1.29
		(C)	-0.67	-0.69	-0.64	-1.86	1.90	1.76
$\sigma_n = \frac{FRD_o}{2I}$	$\frac{\sigma_\theta}{\sigma_n}$	(J)	-0.42	-0.37	0.26	-0.42	-0.37	0.26
		(C)	-0.30	-0.27	0.35	-0.44	-0.38	0.24
Internal Pressure	$\frac{\sigma_\phi}{\sigma_n}$	(J)		0.44	0.33		0.44	0.33
		(C)		0.34	0.35		0.34	0.35
$\sigma_n = \frac{PD_o}{2t}$	$\frac{\sigma_\theta}{\sigma_n}$	(J)		0.88	0.72		0.82	0.72
		(C)		0.93	0.77		0.93	0.77

WALL THICKNESS .....t
PIPE MEAN RADIUS...r
ELBOW MEAN RADIUS· R
O.D.OF PIPE........ Do
MOMENT OF INERTIA...I

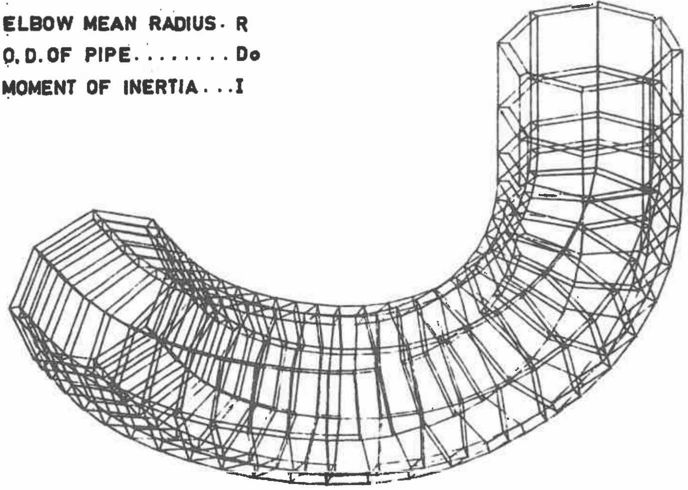

FIG.1 FINITE ELEMENT MESH OF ELBOW-ELBOW CONNECTION

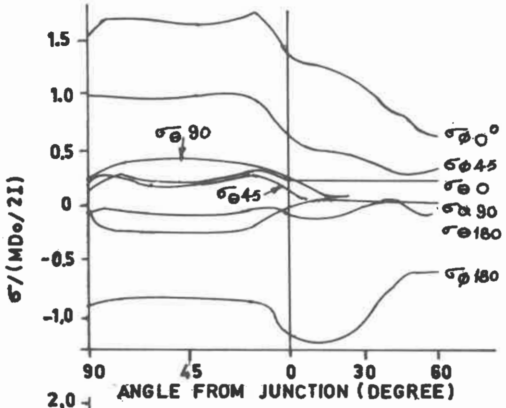

FIG 2 (a) STRESSES ALONG ELBOW RUN

IN-PLANE BENDING (h = 0.375)

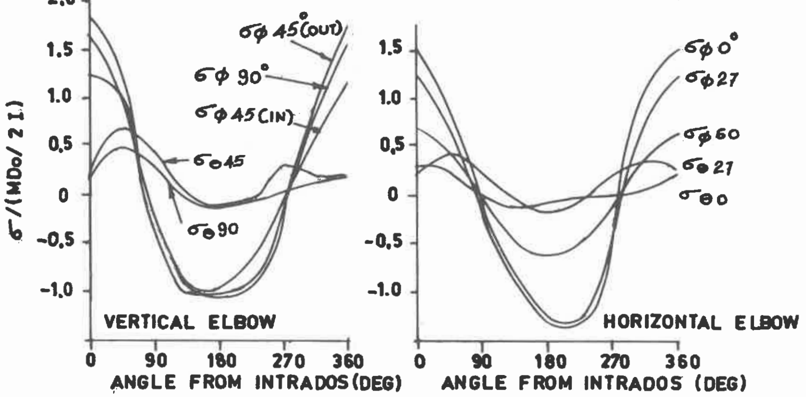

FIG 2 (b) STRESSES ALONG CIRCUMFERENCE

INPLANE BENDING (h=0.375)

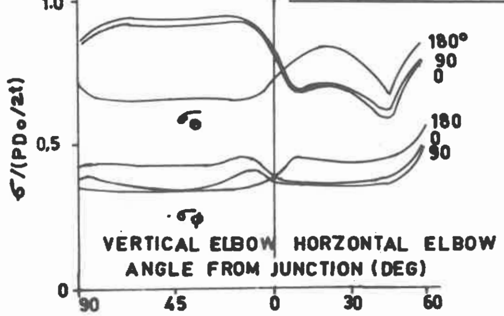

FIG 3 (a) STRESSES ALONG ELBOW RUN

INTERNAL PRESSURE (h=0.375)

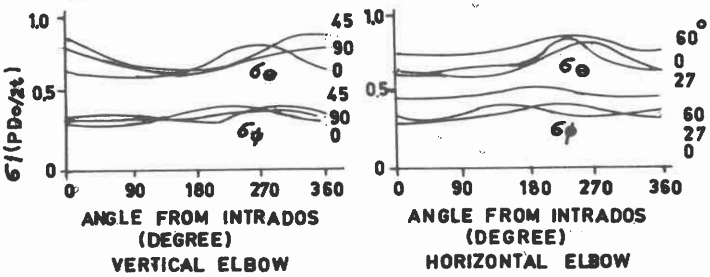

FIG 3(b) STRESSES ALONG CIRCUMFERENCE

INTERNAL PRESSURE (h= 0.375)

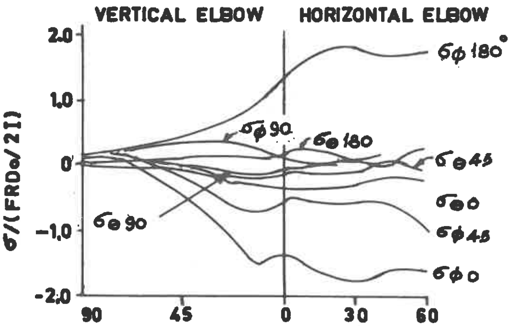

FIG 4 (a) STRESSES ALONG ELBOW RUN

AXIAL PULL (h=0.375)

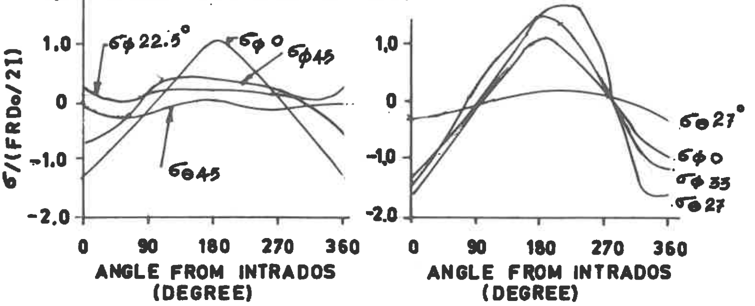

FIG 4 (b) STRESSES ALONG CIRCUMFERENCE

AXIAL PULL (h=0.375)

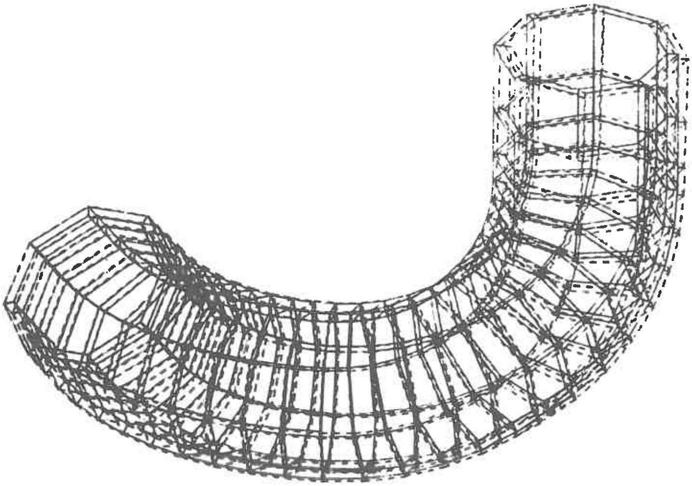

FIG. 5 DEFORMED SHAPE FOR INTERNAL PRESSURE

(h=0.375)