Stress Analysis of Tee Pipe Junction

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1. ABSTRACT

In the present article, results of an investigation on the stress distribution at a typical Tee pipe junction in Primary Heat Transport system of Nuclear Reactors is presented. The Tee junction has been analysed when one end of the main pipe is fixed and unit external forces are applied at the other end of the main pipe and that of the branch pipe (Fig.1). The study has been made by the Finite Element Method using SAP IV general purpose package program. The unit external loads at the twelve degrees of freedom are applied in the form of equivalent stress distribution on the end cross section. Stress concentration factors (SCF) obtained from the investigation are presented.

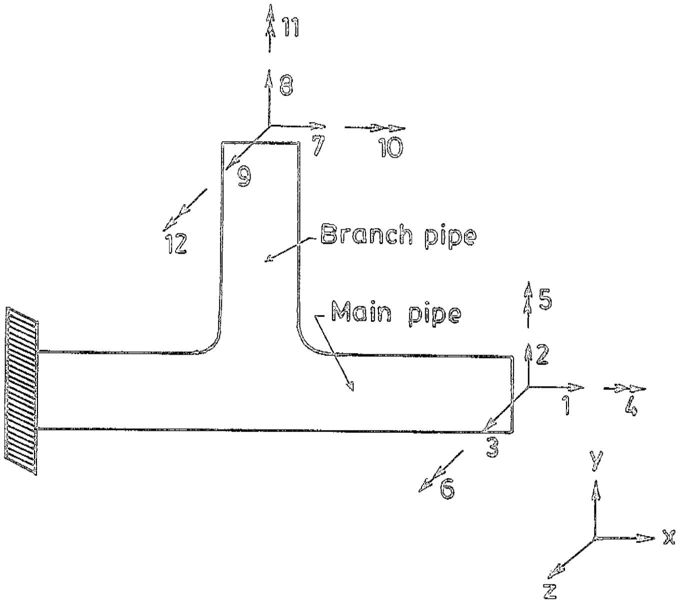

Fig.1 Tee pipe junction

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2. INTRODUCTION

The Primary Heat Transport (PHT) system is one of the major structural subsystems in nuclear power reactors. Tee pipe junctions are very common in PHT systems and they are the most critical regions from a design point of view, because of the stress concentration phenomenon.

The present article presents the results of an investigation on the distribution of stresses at Tee junctions when one end of the main pipe is fixed and unit external forces are applied at other end of main pipe and that of the branch pipe in all the six degrees of freedoms individually. The dimensions of the joint with extension pipes is shown in Fig.2.

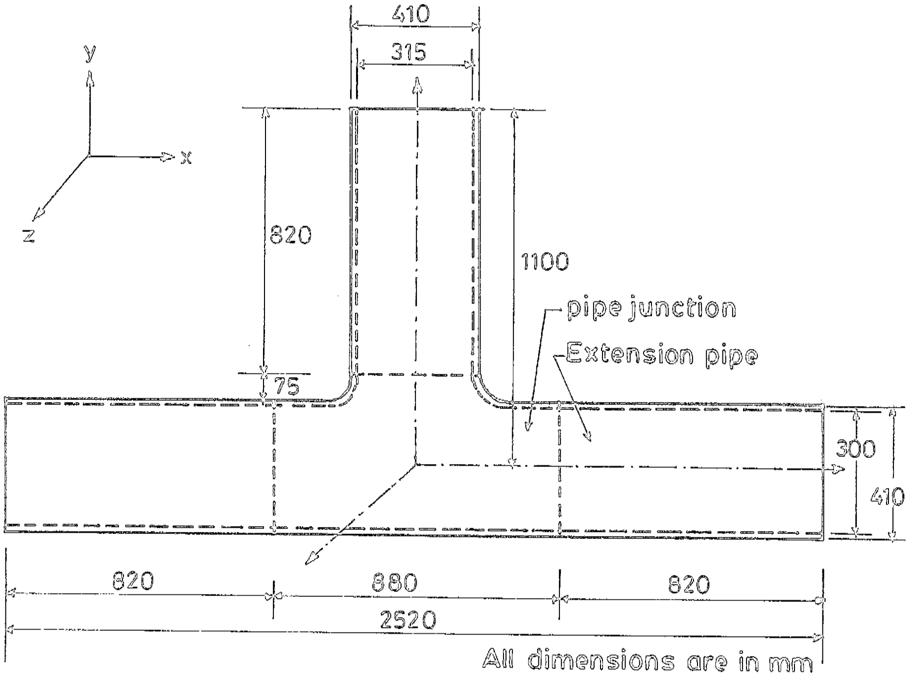

Fig.2 Model Dimensions

3. TEE PIPE JUNCTION

The monocast joint is made of carbon steel SA106 Grade B with material constants as follows:-

Young's Modulus of Elasticity (E) = 190000 N/mm^2 ,
Poisson's Ratio (μ) = 0.3
and Material density (ρ) = 7850 Kg/m^3 .

The external diameter of the main and branch pipes are 410 mm with the thicknesses 55 mm and 47.5 mm respectively. Lengths of the limbs are 880 mm and 75 mm. At each end of the Tee junction extension pipes of same material, external diameter and respective wall thicknesses were considered to be welded to provide for St. Venant's effect. The length of each extension pipe was 820 mm.

4. FINITE ELEMENT DISCRETISATION

The Finite Element model has been developed using the variable number-nodes thick shell elment in the SAP IV element library. Half of structure shown in Fig.2 using the symmetry about xy plane has been considered. Fig.3 shows half of the descretised model. As the ratio of pipe wall thickness to radius is of the order of 1/4, two layers of elements along the thickness direction were considered. The discretisation consists of 1557 nodes and 916 elements. The element had nodes varying from 8 to 20. Each node will be having 3 degrees of freedoms (u,v,w). It may also be noted that the mesh is coarser at end regions and finer at the junction. Bandwidth minimisation technique was considered during discretisation.

The main frame computing system SIEMENS-7580E with operating system BS 2000 was used for the analysis.

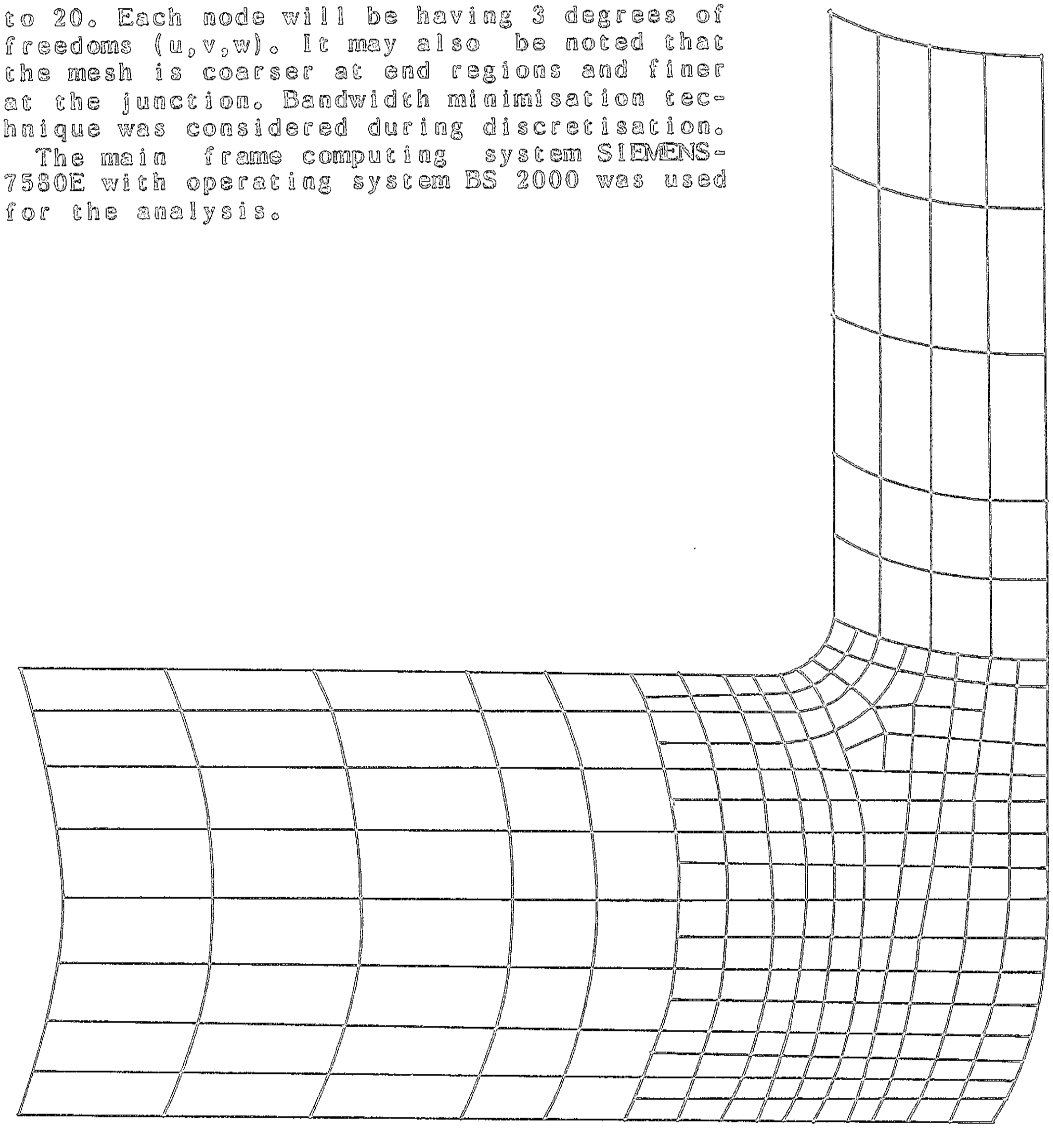

Fig.3 Discretisation of pipe junction (Quarter portion)

5. RESULTS AND DISCUSSIONS

The stress concentration factors have been arrived at as the ratios of the maximum stress obtained from the Finite Element Analysis to the nominal stress predicted by the Strength of Materials approach. Some of the critical locations in the junction region were identified for the different loading cases and are shown in the Figs. 4(a) through 4(g) along with the Stress Concentration Factors obtained from the analysis.

6. CONCLUSIONS

i) In the case when axial load acts at the main pipe end the stress concentration factor at the two point of junction of main and branch pipe is 1.7 as shown in Fig.4(a). It may also be seen that a small compressive stress (with SCF 0.3) develops at two diametrically opposite points as shown in Fig.4(a).

ii) Comparison of Figs.4(b) and 4(d) shows that the nature of stress distribution is same but the moment about z-axis at main pipe end causes more stress concentration than the load along y-axis at main pipe end. In both of these cases it may be noted that -ve stress concentration develops at the intersection.

iii)Comparison of Figs. 4(c) and 4(d) shows that the in-plane bending involves greater stress concentration than out of plane bending.

iv) The values of SCF in Fig. 4(c) are less than 1.0 because of the stiffening effect provided by the branch pipe.

v) Figs. 4(e), 4(f) and 4(g) shows that stress concentration factors due to in-plane bending caused by loads and moments at the branch pipe end. The location of critical stress in all of these cases is same but the axial force at branch pipe end causes severe stress concentration of the order 3.0 where as in other cases it is of the order 1.1 to 1.6.

It may also be noted that the SCF at the branch pipe face towards the fixed end is more than that at the other face.

7. REMARKS

In the investigation reported above the plane of symmetry about xy plane has been utilised. This caused limitation for the application of loads and moments which cause torsion in the pipe. Hence the results of those cases have not been discussed here and will be reported in a subsequent study.

8. ACKNOWLEDGEMENT

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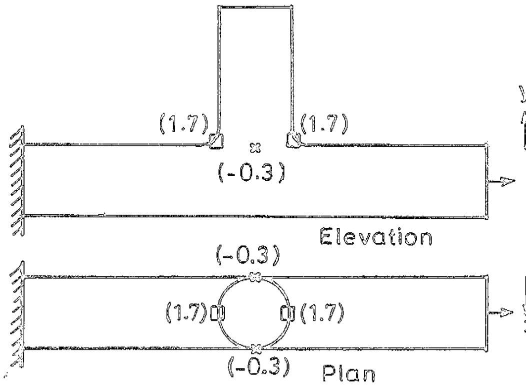

Fig. 4(a) Load at main end along x - axis

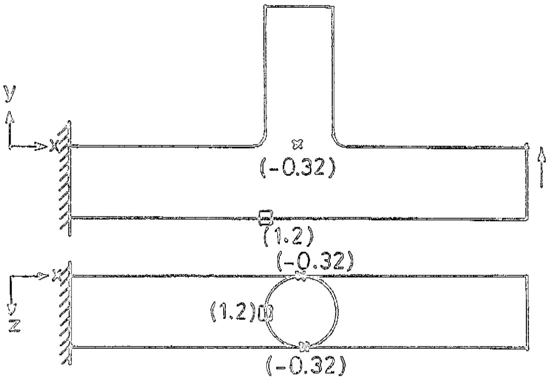

Fig. 4(b) Load at main end along y - axis

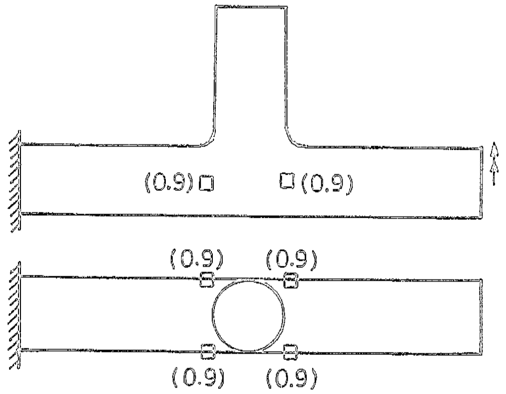

Fig. 4(c) Moment at main end about y - axis

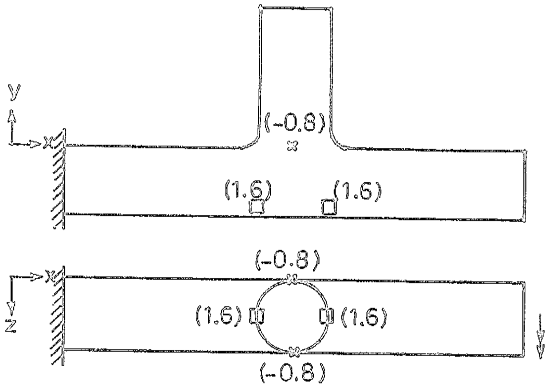

Fig. 4(d) Moment at main end about z - axis

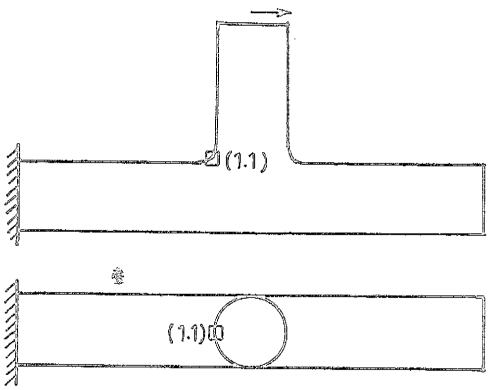

Fig. 4(e) Load at Branch end along x - axis

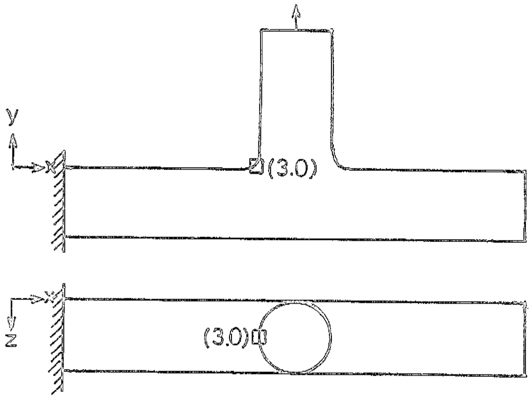

Fig. 4(f) Load at Branch end along y - axis

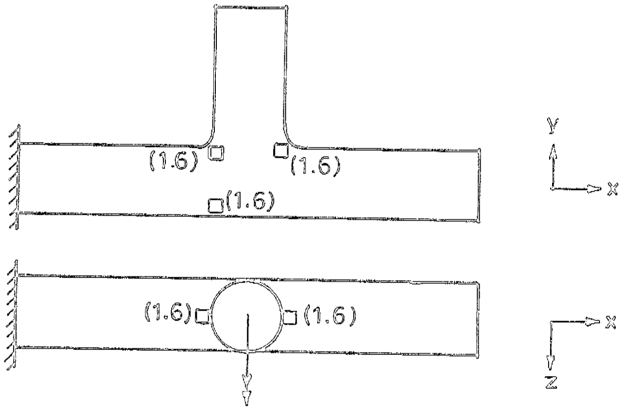

Fig. 4(g) Moment at branch end about z - axis

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