Transactions of the **13th International Conference on Structural Mechanics in Reactor Technology** (SMiRT 13), Escola de Engenharia - Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, August 13-18, 1995

Modelling study of sliding interface contact in pipe coupling

Chawla, D.S., Kushwaha, H.S., Mahajan, S.C.
Bhabha Atomic Research Centre, RED, Bombay, India

ABSTRACT: The FEM results are dependent on simulation of geometry and boundary conditions. The difficulties are faced while modelling the complex structures with number of interface contact where small relative movement can not be ruled out. The paper describes the 3-D interface sliding contact modelling study for pipe coupling.

1 INTRODUCTION

Safe operation of nuclear power plants is only possible if structural integrity of various components is maintained. To ensure the integrity the detail stress analysis is performed using FEM. The analysis will provide correct result if the structure is properly modelled and various boundary conditions are simulated correctly. The situation becomes quite complex if the structure is assembly of various components and there is scope of relative sliding at interface surfaces in different directions. To understand the effect of sliding, 3-D interface surface contact modelling study is carried out with special reference to pipe coupling (Chawla 1993).

2 GAP ELEMENT STUDY

The gap elements are required for modelling the interface. The typical gap element is a two noded element, one node lying on each of two surfaces. The gap element characteristic is such that two surfaces can have relative movement parallel or tangential to the surface, but the relative displacement normal to the surface depends on the actual gap. Once the gap is closed by application of load, the two surface make rigid contact in the normal direction. The gap element is validated by solving two sample problems (Berkol 1992). First sample problem considered is that of a cantilever beam uniformly loaded along the length againgst a rigid circular surface (Fig.1). The gap elements are used in between the cantilever and rigid circular surface. The cantilever is modelled using brick elements. The coumputed results (NISA 1990) as compared with published result is given in table 1. The shrink fitted pipes (composite tube) is considered as second sample problem. Inner and outer radius of composite tube is 5.0 and 13.0 mm. Each pipe is 4.0 mm thick. The radial interference is considered as 0.1 mm. Because of symmetricity, 1/4th geometry is modelled (Fig.2) using 640 brick elements and 99 gap elements at interface. The computed stresses (NISA 1990) show satisfactory agreement with analytical/published results.

3 INTERFACE MODELLING OF PIPE COUPLING

The interface sliding locations in pipe coupling are shown in figure 3. In the present study, the 3-D finite element model (Fig.4) is used. The amount of relative displacement is expected to be very small but this will change the stress scenario i.e. location of high stress point may shift. The relative sliding may be in radial, axial or circumferential direction at different locations. The amount of sliding depends on interface surface condition and material of components. It is very difficult to simulate the actual wedging and sliding action in a complicated structure. In the present study two extreme possible cases are studied by adopting two different modelling techniques for interface contacts. In the case 1, the two contact surfaces are assumed to be deformed together i.e. no relative sliding at interface is allowed. This is achieved by coupling corresponding nodes of two surfaces in contact for all degree of freedom. In the case 2 the friction-less relative sliding between the two surfaces is simulated by employing gap elements. Thus the case 1 considers hundred percent friction while case 2 assumes zero friction between two surfaces.

4 ANALYSIS FOR INTERNAL PRESSURE

Analysis of coupling due to internal pressure of 1.26 Kg/sq.mm is carried out. The stress intensity contours at section 1-1 for case 1 and case 2 are plotted in figure 5. High stress concentration is observed at junction of endfitting hub with endfitting tube in both the cases. Interface condition of sealring with two hubs plays important role during internal pressure loading. When full sliding is allowed (case 2) the sealring experiences higher stresses compared to no sliding case (case 1). This is also seen from figure 6, which shows the stress intensity in sealring at location R along the circumference for two cases. The peak stress intensity at centre of sealring is probably because of groove present in the clamp thereby causing flexibility at that location. The case 2 also has moderate stress concentration in the clamp near contact location at section 1-1 which is not present in case 1 (Fig.5).

5 ANALYSIS FOR BOLT LOAD

Analysis of the coupling is carried out with bolt torque of 7604 Kg/sq.mm per bolt. The bolt load is simulated by temperature difference. Figure 7 shows the stress intensity contours for two cases sections 1-1. The interface condition of clamp with feeder hub and endfitting hub is more important for bolt pretightening torque. In the case 2 the relative movement at interface locations is allowed which causes reduction in rigidity and overall stiffness while applying bolt load. Therefore stresses generated in clamps are higher in case 2. The stress intensity distribution along the circumference in clamp and endfitting hub at location E is shown in figure 8. It can be seen that for most of the circumferentially length the stresses in clamp and endfitting hub for case 2 (with sliding) are higher than in case 1 (no sliding). Figure 8a shows discontinuity near 90 degree because of groove in clamp. Due to same reason the stresses in hub show dip at 90 degree, where there is no interface contact between hub and clamp. At extreme ends (near 0 and 180 deg) the case 1 (no sliding) shows peaking of stresses due to high distortion caused by bolt torque. While case 2 shows the peaking of stresses near 90 degree for clamp because of high contact pressure developed at interface. The contact pressure at interface reduces away from 90 degree location. Effect of Sealring interface condition with two hubs can also be seen (Fig.7). For case 1 (no sliding) trend of moderate stresses are seen in sealring as in two hubs. While sliding causes reduction in sealring stresses and increase of stress concentration in two hubs near sealring interface at section 1-1.

6 DISCUSSION AND CONCLUSION

Proper simulation of interface contact is very essential during finite element analysis. The possibility of small sliding can not be neglected. Due to sliding the location of high stresses may shift. Since the exact simulation of sliding interface contact in 3-D complex structure is very difficult, the two extreme cases can be analysed. If component is safe for these extreme cases, the component can be considered to be safe.

REFERENCES

Berkol, O. 1992. An algebraic algorithm to treat the contact with friction in linear static analysis of discretized systems. Finte element in analysis and design. 11.

Chawla, D.S. et.al. 1993. The stress analysis of feeder pipe coupling of 500 MWe PHWR. BARC/1993/E/033.

NISA, 1990. FE computer package. EMRC. Michigan. USA.

Table 1 Computed displacement as compared with published results for sample problem 1.

Distance from fixed end (mm)	displacement (mm) (Berkol 1992)	Computed
40.0	0.1	0.1
80.0	0.4	0.4
120.0	0.8797	0.8728
160.0	1.4520	1.4456
200.0	2.0503	2.0523

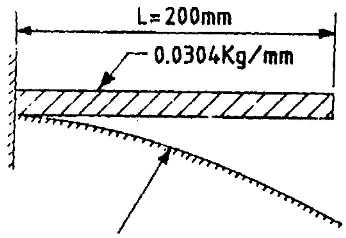

Fig.1 Sample problem 1

Table 2 Comparison of computed stresses with published result for sample problem 2.

	Loca- tion	Analy- tical	(Berkol 1992)	Computed
H	ID/IP	-142.6	-150.3	-153.0
	OD/IP	-93.3	-91.2	-88.9
	ID/OP	140.0	147.9	158.8
	OD/OP	90.7	88.7	93.7
R	ID/IP	0.0	-14.8	-13.8
	OD/IP	-49.3	-46.8	-44.0
	ID/OP	-49.3	-46.8	-36.2
	OD/OP	0.0	-3.5	-3.5

Note: ID=inner dia; OD=outer dia
IP=inner pipe; OP=outer pipe
H=hoop stress; R=radial stress

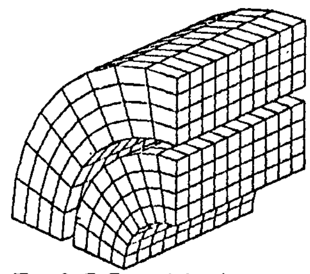

Fig. 2 F E model of sample problem 2

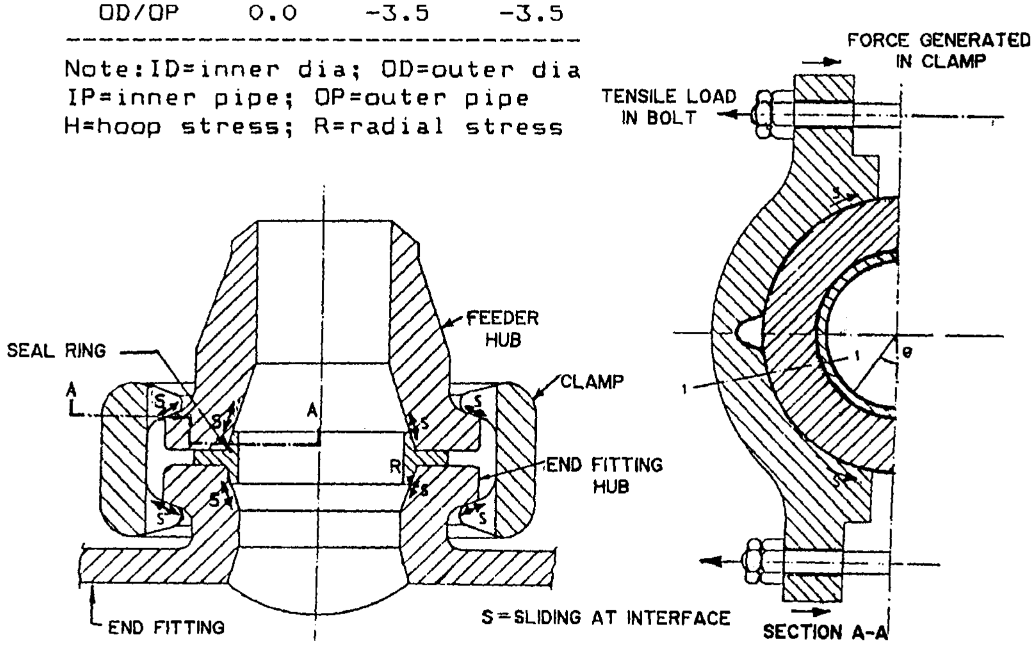

Fig. 3 Various interface sliding location in pipe coupling configuration.

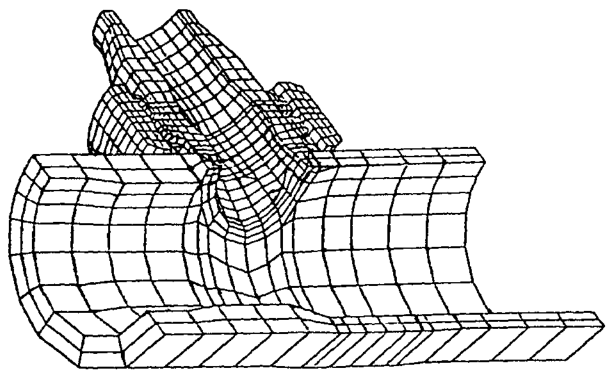

Fig. 4 Finite element model of pipe coupling

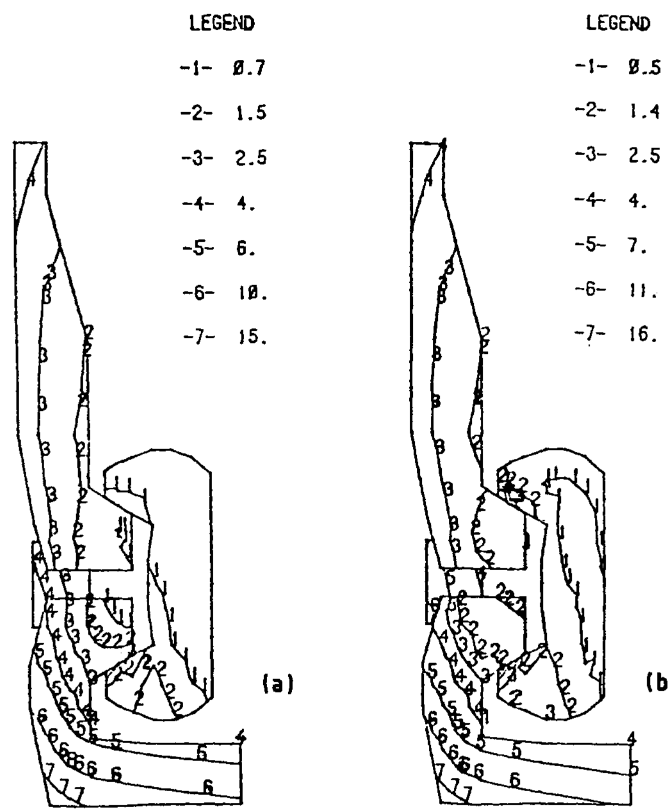

Fig. 5 Stress intensity (Kg./sq. mm.) contours due to internal pressure at section 1-1 for (a) Case 1 - no sliding (b) Case 2 - sliding allowed.

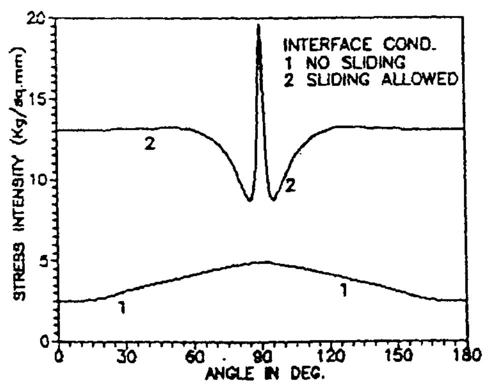

Fig. 6 Stress intensity distribution along the circumference at location R in Sealring.

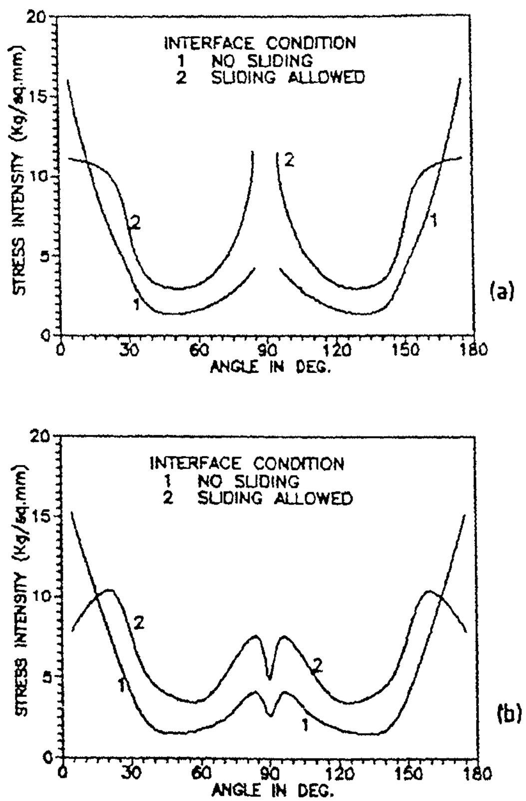

Fig. 8 Stress intensity distribution along the circumference at location E in (a) Clamp (b) End fitting hub.

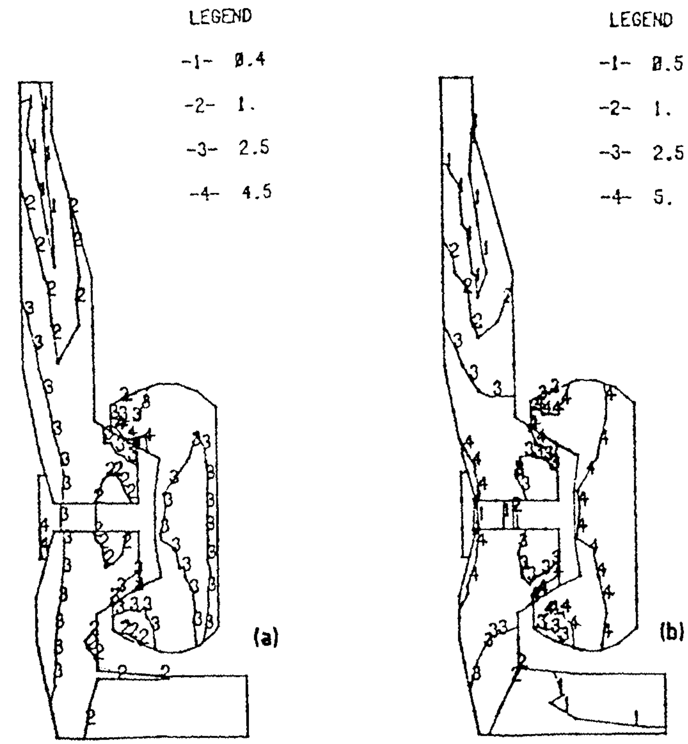

Fig. 7 Stress intensity (Kg/sq. mm.) contours due to bolt pretightening torque at section 1-1 for (a) Case 1 – no sliding (b) Case 2 - sliding allowed.