Elasto-Plastic Analysis of Seal Disc

H.S. Kushwaha, B.K. Dutta, A. Kakodkar
Bhabha Atomic Research Centre, Reactor Engineering Division, Trombay, Bombay 400 085, India

Abstract

Elastic and elasto-plastic axisymmetric finite element analysis of seal disc are done for four stages of loadings. A comparison of displacements and stress intensities obtained by elastic and elasto-plastic analysis along the radius of the seal disc is made and significance of elasto-plastic analysis is demonstrated.

1. Introduction

One of the most appealing features of a pressurised heavy water reactor is the provision for on line refuelling. To do this, special arrangements are provided at both ends of the each horizontal coolant channels. This arrangement consists of a seal plug for shielding purpose, followed by a final cover in the form of a thin disc, popularly known as seal disc/1/. The purpose of the seal disc is to provide necessary sealing to avoid any leakage of heavy water from the coolant channel and also to prevent seal plug and fuel bundles to come out of coolant channel which is under operating pressure.

A failure of seal disc during operating condition of the reactor may lead to a very serious accident. This necesitates a detail stress analysis to obtain a complete stress picture in the seal disc at various stages of loadings. Following sections describe an analysis method adopted to compute deformations and stresses at various points in the seal disc for different loading sequence. Since an elastic analysis shows a much higher stresses at some of the boundary points, an elasto-plastic analysis is also carried out. Results obtained from both the analysis are compared and importance of elasto-plastic analysis is demonstrated.

2. Geometry and Loading Sequence

Fig 1 shows typical geometry of a seal disc used in 235MW PHWR and also adopted for the present analysis. The main body of the seal disc is made of 17-4PH material. A circular nickle plating is done at the outer periphery which comes in contact with the end fitting and sees necessary sealing pressure to avoid any leakage of heavy water.

During installation of seal disc, a particular loading sequence is maintained by the fuelling machine, which can be divided into four stages. The first stage corresponds to the loading at the centre of the seal disc by a ram, till a difference in deflections between centre line of seal disc and at rocker radius becomes 0.021". In second stage beside centre loading, rocker point is also loaded in such a way so that deflection difference of 0.021" is maintained and sum of the both loads becomes 4000 lbs. The third stage corresponds to the locking of deflection at rocker radius and release of centre load. Whereas in the fourth stage of loading, coolant channel pressure is increased to 1600psi, which also corresponds to operating pressure of the reactor . In the present analysis stresses and deflections are computed at the end of these four stages of loadings by elastic and elasto-plastic analysis.

3. Finite Element Modelling and Material Properties

Fig 2 shows the finite element discretization of the seal disc. In all 187 elements and 678 nodes are used in the model. Large number of elements are used in the nickle plate where high stresses are expected due to support condition. In general it is difficult to establish theoretically width and location of contact surface. Hence in the present analysis this data is input by measuring the impression of the contact with End-Fitting obtained on an used seal disc. Young's modulus of 30E06 psi and poisson's ratio of 0.3 are used in the analysis. Yield stress of 125000 psi for 17-4PH material and 15000 psi for nickle plating are also used for elasto-pastic calculations. No hardening of the material is assumed for the stress computations.

4. Elastic and Elasto-Plastic Analysis

The seal disc is analysed first elastically. To obtain magnitude of loads correspond to stage 1 and stage 2 , which are deflection bound, seal disc is analysed for unit load at the centre and also for unit load at rocker radius. Deflections obtained at the centre and at the rocker radius for these two cases are then used to get magnitudes of loads for stage 1 and stage 2 by linear extrapolation, which is valid for elastic analysis only. Displacement obtained at the rocker radius for stage 2 is used as constant displacement boundary condition for stage 3. Whereas in stage 4, beside this constant displacement at rocker radius, channel pressure equal to 1600 psi is applied on the seal disc.

Elastic analysis of seal disc shows a much higher stresses than yield stress at nickle plating. Hence to obtain a better picture of deformation and stresses in the seal disc, an elasto-plastic analysis is carried out for all four stages of loadings. Since the concept of linear extrapolation used to obtain magnitudes of loads for stage 1 and stage 2 is not valid for elasto-plastic analysis, a new set of loads for different stages are to be found out to meet the deflection bound loading sequence. Von-mises yield criteria, Prandtl-Reuss flow rule and isotropic strain harening are used for the plastic formulation. Incremental tangent stiffness solution procedure is used to solve final set of nonlinear equations/2/.

5. Results

Fig 3 shows a list of forces which are to be used for elastic and elato-plastic analysis to meet the deflection bound loading sequence.Fig 4A through 4D show the comparison of displacements along the inner surface of the seal disc for elastic and elasto-plastic analysis.Similar comparisons of stresses are shown in fig 5A through 5D.

6. Conclusions

An axisymmetric finite element analysis of seal disc is done for 235MW pressurised heavy water type reactor. Elastic calculations show very high stresses at the nickle plate because of support condition. Whereas elasto-plastic calculations show the yielding of the whole nickle plate in first stage of loading. This analysis also shows the requirement of only 85 percent of central ram load corresponds to elastic calculations to obtain 0.021" of deflection difference between centre and rocker radius during elasto-plastic calculations. Hence load sharing between centre ram and rocker point changes significantly at the end of stage 2 of loading. A plot of displacements and stresses show a significant change in deflection magnitudes in case of elasto-plastic calculations. Also there is a slight increase in stresses of the main body of the seal disc due to redistribution of stresses during plasticity analysis.

7. References

/1/ Lindsay,R.I.,"Design Manual-Sealing Plugs",RAPP 31140,October,1968

/2/ Dutta,B.K.,Kushwaha,H.S.,"Elasto-Plastic Analysis of Plane Stress/Plane Strain and Axisymmetric bodies by FEM ",BARC Internal Report , BARC-1146,1982

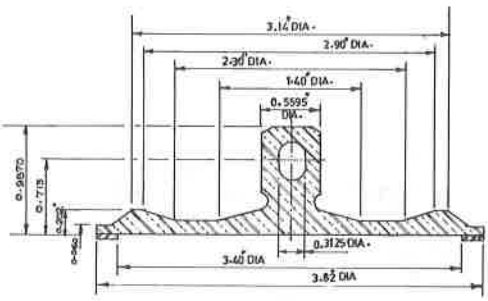

FIG.1 A SEAL DISC CONFIGURATION FOR 235MW REACTOR

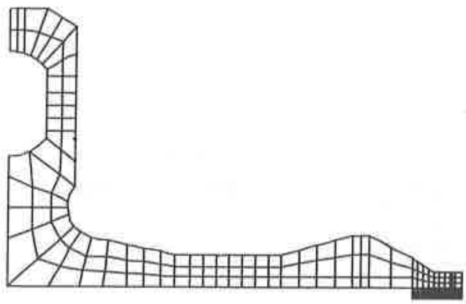

FIG 2 FINITE ELEMENT MESH OF SEAL DISC

LOADING STAGE NUMBER	ELASTIC ANALYSIS				ELASTO-PLASTIC ANALYSIS			
	CENTRAL LOAD (lb)	LOAD AT ROCKER RADIUS (lb)	ROCKER DISPLACEMENT (in)	CHANNEL PRESSURE (lb/in^2)	CENTRAL LOAD (lb)	LOAD AT ROCKER RADIUS (lb)	ROCKER DISPLACEMENT (in)	CHANNEL PRESSURE (lb/in^2)
1	2455.8	—	—	—	2163.95	—	—	—
2	2112.12	1887.88	—	—	1615.51	2384.49	—	—
3	—	—	.00851	—	—	—	.010659	—
4	—	—	.00851	1600	—	—	.010659	1600

FIG. 3 COMPARISON OF LOADING FOR ELASTIC AND ELASTO-PLASTIC ANALYSIS

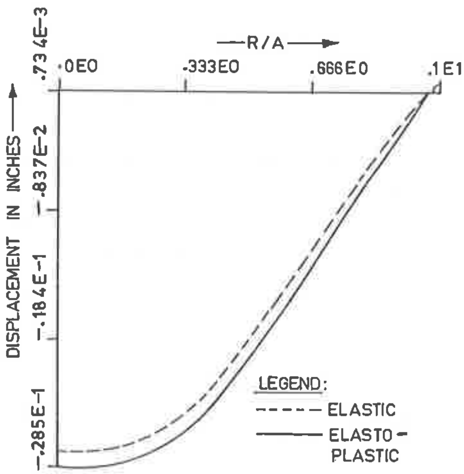

FIG. 4A: DISPLACEMENT COMPARISON AT END OF STAGE-1 LOADING

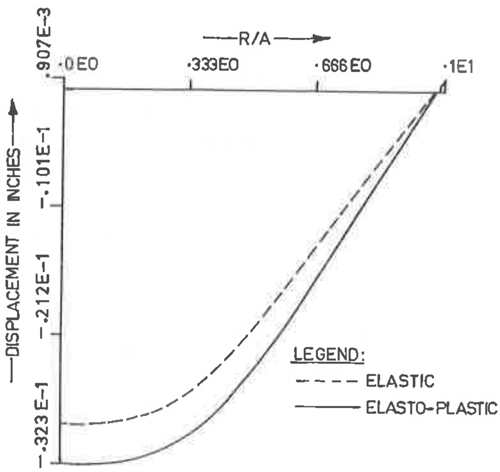

FIG. 4B: DISPLACEMENT COMPARISON AT END OF STAGE-2 LOADING

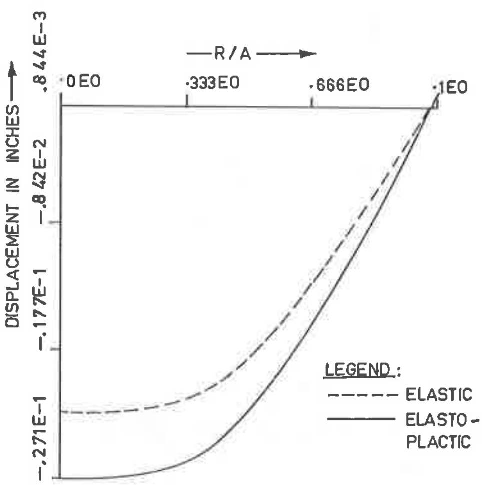

FIG. 4C: DISPLACEMENT COMPARISON AT END OF STAGE 3 LOADING

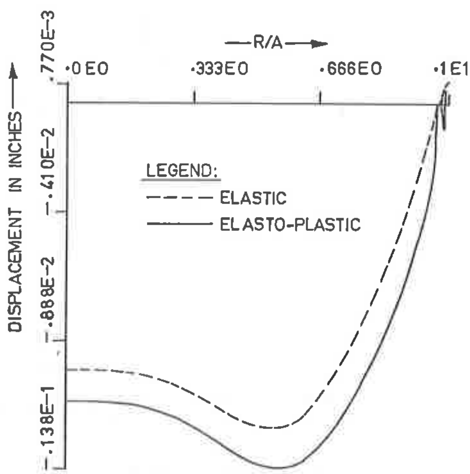

FIG. 4D: DISPLACEMENT COMPARISON AT END OF STAGE-4 LOADING

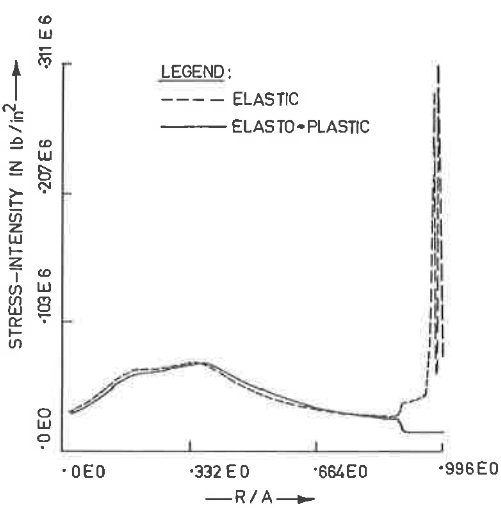

FIG. 5A : STRESS - INTENSITY COMPARISON AT THE END OF STAGE 1 LOADING.

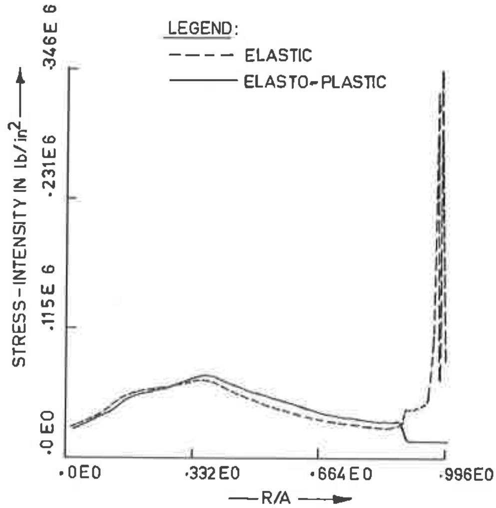

FIG. 5 B : STRESS INTENSITY COMPARISON AT THE END OF STAGE 2 LOADING.

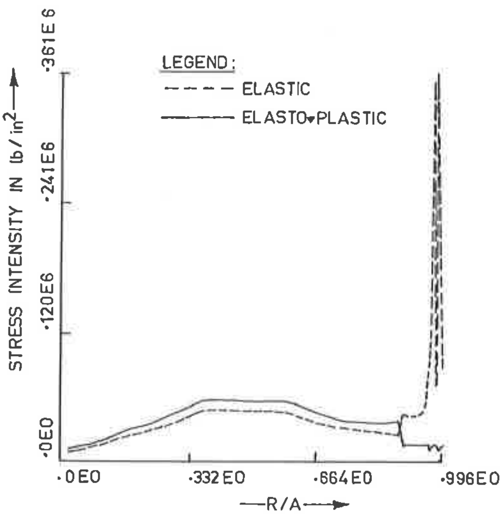

FIG. 5C : STRESS INTENSITY COMPARISON AT THE END OF STAGE-3 LOADING

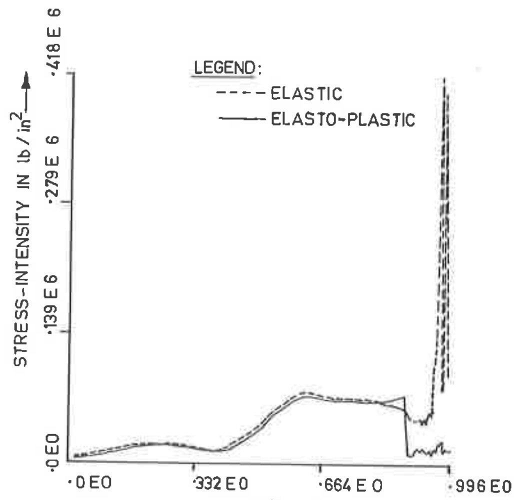

FIG. 5D : STRESS-INTENSITY COMPARISON AT THE END OF STAGE 4 LOADING