Finite Element Analysis of Contact Stress on Parting Flange of Small Steam Turbine Casing

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1. Introduction

For assembly and maintenance, outer casings of industrial middle or small sized nuclear steam turbine are usually split at a horizontal parting plane for upper and lower casings, and a vertical parting plane for HP and LP casings. These parting planes have bolted together. The effectiveness of a bolted joint is related to both the bolt and flange design.

In this paper, the contact stress on parting plane causing is calculated to investigate the flange parameters by 2- and 3-dimmensional finite element analysis. Finally, for turbine casing flange of SMART-P, 3-dimmensional finite element analysis is performed to evaluate contact stress on the casing flange, and sealing design.

2. 2D analysis

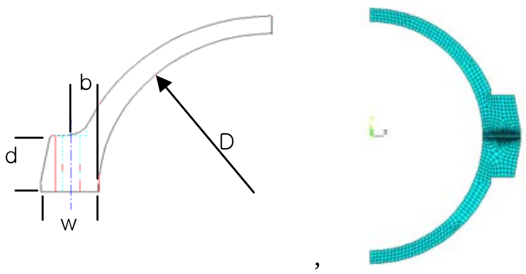


Figure 1. Parameters and mesh shape of 2D plane section flange

Figure1 shows flange geometry and parameters for horizontal plane section of HP turbine casing. No account could be taken of the bolt holes in this model. Selected flange parameters are flange width w, and depth d. At first, the effect of flange parameter d/D is investigated for constant w/D. Second, the effect of w/D is calculated for constant d/D.

Applied boundary conditions are internal pressure and bolting pressure which is equivalent to the bolt pre-loading. To investigate the effect of thermal loading, two cases are studied. Case1 is considered only pressure and bolt loading and Case2 is added temperature distribution.

Table 1 represents the minimum contact stresses on parting plane with d/D in the case of Case1 and Case 2.

The contact stress is increased with in the increase of flange thickness, and the thermal effect increases the contact stress on the parting plane.

Table 2 shows the minimum contact stress on parting plane with w/D. The wide flange decreases contact pressure on the parting plane for plane section of casing, and the thermal loading has the same effect as above analysis.

Table 1. Variation of the minimum contact stress(psi) on parting plane with flange parameter d/D when w/D=0.17

d/D	0.125	0.150	0.175	0.200	0.225	0.250
Case1	40	-122	-445	-574	-605	-611
Case2	-748	-1337	-1275	-1649	-1727	-1722

Table 2. Variation of the minimum contact stress(psi) on parting plane with flange parameter w/D when d/D=0.175

w/D	0.15	0.17	0.19	0.21	0.23	0.25
Case1	-813	-444	-48	4	63	46
Case2	-2061	-1275	-1085	-596	-177	331

3. 3D analysis

3.1 3D analysis of horizontal plane flange

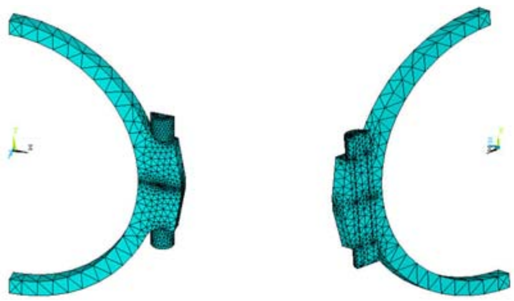
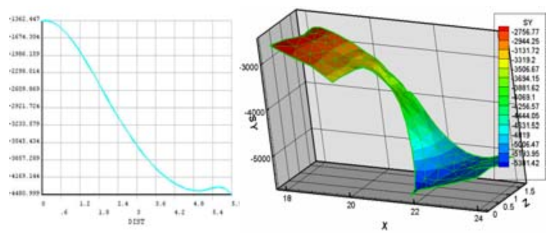


Figure 2. Mesh shape of 3D horizontal plane flange model

Upper and lower casings are joined by flanged and bolted joints. To investigate bolt holes, 3-dimmension finite element analysis (see Figure 2) is preformed.

Figure 3 shows the distribution of the contact stress on parting plane by 2D plane strain analysis (Figure 3(a)) and 3D solid analysis (Figure 3(b)). This figures show the similar distribution of the contact stress, but the value of the stress in 3D analysis is higher than that of 2D analysis. It can be explained that the contact area is reduced with bolting holes.

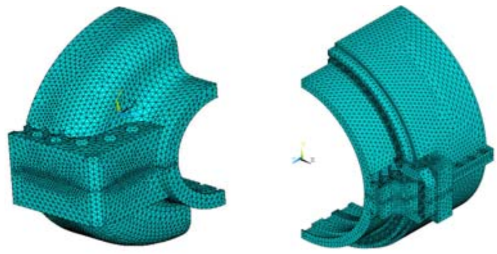


(a) (b)

Figure 3. Distribution of the contact pressure on parting plane

3.2 Front and vertical flange for HP turbine casing

For turbine model for SMART-P, 3-dimmensional finite element analysis has performed. Figure 4(a) is finite element model for front horizontal flange of HP turbine and Figure 4(b) is horizontal and 4-way joint flange. In these cases, bolt holes were considered, but bolt is not included in modeling.

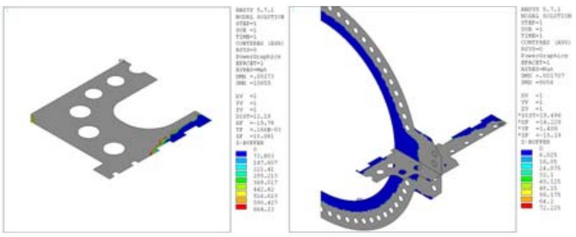


(a) (b)

Figure 4. Mesh shape of front and vertical flange

For sealing design, experience shows that contact stress is higher then 1.5 times of internal pressure in most applications. The flange must be designed for the minimum value of $^{\sigma}/_{P}$, called by Moch Number.

Figure 5 shows the distribution of contact stresses on the contact surface of the model. In this figure, gray region represents that Moch number is higher than 1.5.



(a) front flange (b) vertical and 4-way flange

Figure 5. Distribution of contact stress

In front flange, the contact stress is much higher than internal pressure in shown as Figure 5(a). But, the contact stress on vertical and 4-way flange is relatively low. Thus, the analysis model is modified to investigate the effects of the thermal loading and the flange thickness.

Temperature distribution is calculated by heat transfer analysis using steam temperature data. Figure 6 shows the result of analyses. Temperature distribution is negligible to contact stress of the vertical flange.

In other to increase the contact stress, flange thickness is increased about 30%. Region of effective contact area that Moch number is higher than 1.5, is increased as shown in Figure 7.

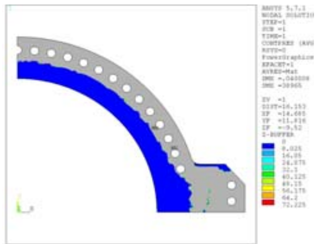


Figure 6. Distribution of contact stress on parting plane for thermal loading

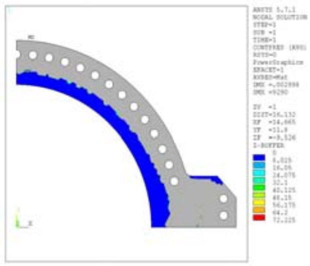


Figure 7. Distribution of contact stress on parting plane for thick vertical flange

4. Conclusion

Two dimension plane strain analysis was performed for two flange parameters, such as flange depth and width. Contact stress is proportionally increased with flange thickness, but decreased with flange width inversely. Temperature distribution increases the contact stress on parting horizontal flange.

Results of 2D plane strain analysis and 3D analysis show similar distribution of contact stress, but the value in 3D analysis is much higher because of difference of contact area.

The turbine casing for SMART-P is analyzed for front, vertical and 4-way joint flange. To increase contact stress on vertical flange, thick flange is more effective. The geometry used in analysis is satisfied with design criteria.

5. References

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