Technical information

FEM analysis of a 4" Class600 flange connection with soft iron octagonal RTJ seal

1. Goal of the FEM analysis

The FEM analysis is intended to analytically check the sealing widths of RTJ seals used in practice, e.g. according to ASME VIII Div.1, App.2 Table 2-5.2, Sketch 6.

2. Introduction

The flange design for RTJ seals is generally based on sealing widths that are not easily traceable. The seal width is usually specified at the widest sealing point of the RTJ seal, dimension A (Fig.1), divided by a factor (ASME) or a width (AD 2000 Rules B7:2010).

Fig. 1: Dimensions of ring joint seals, source: ASME B16.20

The difference to real conditions is that there is a contact sealing surface on the inside of the groove and one on the outside of the groove. Furthermore, the bilinear material behaviour of the seal and the friction on the seal faces are not taken into account. The FEM analysis performed takes these parameters into account.
3. Load cases

As load cases, the mounting prestressing of the threaded bolts was selected using 70 % of the yield strength ($R_{p0.2}$) of the screw material, then the design pressure of 100 bar (10 MPa) is applied.

4. Materials

The materials used are SA 105 for the flanges, 42CrMo4 for the threaded bolts and nuts, and Armco soft iron for the oval RTJ seal. In addition, bilinear material properties are assigned to the seal to take plasticizing into account in the calculation. A friction value of 0.15 was considered as friction on the seal contact surfaces.

5. Geometry import

The flange connection was modelled with flangevalid System Designer, imported into ANSYS Design Modeler and subsequently imported into ANSYS Mechanical.

Figure 1: Geometry import of the entire flange connection, flangevalid System Designer in ANSYS Design Modeler
Figure 2: Cross-linking of the octagonal RTJ seal

Figure 3: Cross-linking of the entire flange connection
6. Calculation results

Figure 4: Static mechanical model of the entire flange connection

Figure 5: Max. equivalent stress on the entire flange connection, sectional model
Figure 6: Max. equivalent stress on the octagonal RTJ seal, 368 MPa at the contact surfaces of the seal, in contrast to 1,189 MPa according to the usual regulations.

Figure 7: Max. equivalent strain on the contact surfaces of the octagonal RTJ seal (1.2% elongation).
Figure 8: Max. equivalent stress on the octagonal RTJ seal

Figure 9: Max. surface pressure on the contact areas of the octagonal RTJ seal, averaged
Figure 10: Max. surface pressure on the contact areas of the octagonal RTJ seal, not averaged

The contact surface width is approx. 4.5 mm on both the inside and the outside, i.e. approx. 9.0 mm compared to 1.39 mm according to ASME VIII Div.1, App.2 \( (w/8 = 11.11\,\text{mm}/8 = 1.39\,\text{mm}, \) where \( w = A \), i.e. the real contact surfaces are 6.5 times larger than ASME VIII Div.1, App.2.

Figure 11: Contact areas of the octagonal RTJ seal with the RTJ grooves on the flanges
6. Summary

The conventional analytical calculation according to ASME VIII Div.1, App.2 differs significantly from the numerical calculation according to the FEM. According to the AD 2000 regulations, the seal face is not specified for octagonal RTJ seals. Reference is made to the information provided by the manufacturers.

<table>
<thead>
<tr>
<th>Rules/calculation</th>
<th>Seal face width</th>
<th>Deviation from FEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD 2000-B7</td>
<td>Not specified</td>
<td>-</td>
</tr>
</tbody>
</table>
| ASME VIII Div.1, App. 2 | 1.39       | 6.5                | 650%
| FEM               | 9.0             | 1                  |

The table (Table 1) clearly shows the seal face widths for the RTJ seal.


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I will be happy to provide personal technical consulting, even on short notice.

Best regards from Bremen

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