ANALYSIS OF A SEGMENTED LOCKING RING FOR SHELL-BOTTOM CONNECTION IN PRESSURE VESSELS

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1. Introduction

An approximate structural analysis is presented of a shell-bottom connection in which a locking ring, partially protruding from an annular slot machined in the vessel wall, supports the bottom loaded by the internal pressure. The ring is segmented into four parts, to permit assembling. The contact pressure between the ring and the slot lower face may be conveniently approximated. Simplified expressions of the internal forces within the ring are obtained.

2. The modelling of the split ring

This paper presents a structural analysis of a shell-bottom connection in which a locking ring, partially protruding from an annular slot machined in the vessel wall, supports the bottom loaded by the internal pressure. The ring is segmented into four parts, to permit assembling, Fig. 1. In comparison to a flanged bottom, this shell-bottom connection may be more quickly disassembled and, therefore, it is preferred when frequent maintenance is needed.

Previous analytical, numerical, and photoelastic studies [1-4] have evidenced the presence of highly concentrated reaction force peaks between the ring and slot lower face and at the ring sector extremities. Another peculiar aspect is the possibility of a contact between the ring and slot upper surfaces, as a consequence of the rotation of the ring cross section; previous studies have shown that in a ring with a square cross section the above contact does not occur, [4], whereas it may take place in a rectangular, radially elongated cross section, [5].

Based on the available studies, a simplified model of the contact force between the ring and the slot is developed, and the ring maximum internal forces are evaluated.

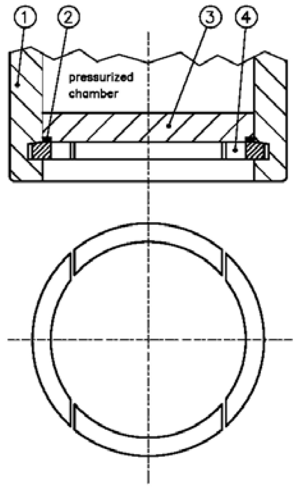

Fig. 1. The segmented locking ring.

3. Approximate analytical modelling

The segmented ring is loaded by a distributed pressure p_b (the index b stands for bottom) uniformly applied to the circular crown at the ring upper face, described by the radii R_i and R_p. The approximate contact reaction is assumed to be constituted by a) a distributed, constant, linear force F_c acting along the radius r_c defining the transition between the lower face of the slot and its filleted edge defined by R, and b) by two concentrated forces P_c applied to the contact extremities and at the radius r_c. Figures 2 and 3 clarify the meaning of the main symbols.

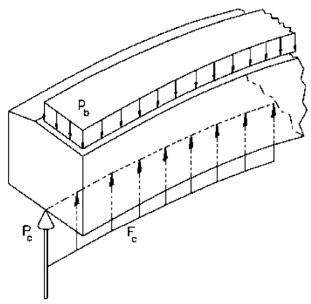

Fig. 2. The segmented locking ring.

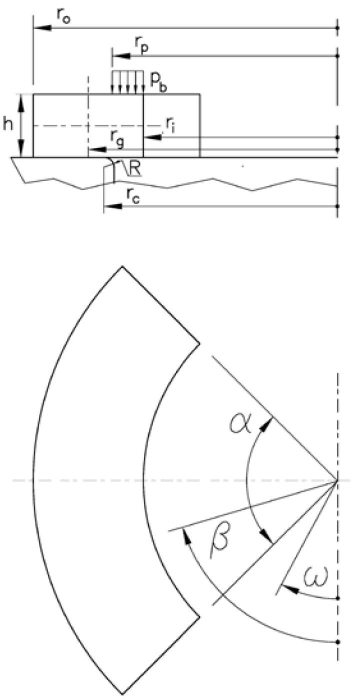

Fig. 3. The segmented locking ring.

The values of F_c and of P_c, Fig. 2, may be expressed in terms of the geometry of the locking arrangement, of the angular extent α of the ring sectors, and of the contact pressure p_b, by imposing the vertical and rotational equilibrium conditions for the ring sector.

The expressions for P_c and F_c are:

$$P_c = \frac{p_b\,\alpha\,\sin\frac{\alpha}{2}\left(r_p - r_i\right)\left[3\,r_c\left(r_i + r_p\right) - 2\left(r_i^2 + r_i\,r_p + r_p^2\right)\right]}{6\,r_c\left(2\sin\frac{\alpha}{2} - \alpha\cos\frac{\alpha}{2}\right)} \tag{1}$$

$$F_c = \frac{p_b\left(r_p - r_i\right)\left[4\sin\frac{\alpha}{2}\left(r_i^2 + r_i\,r_p + r_p^2\right) - 3\,r_c\,\alpha\cos\frac{\alpha}{2}\left(r_i + r_p\right)\right]}{6\,r_c^2\left(2\sin\frac{\alpha}{2} - \alpha\cos\frac{\alpha}{2}\right)} \tag{2}$$

Having computed P_c and F_c, it is possible to formulate the analytical expressions of the maximum bending moment and of the maximum torque in the ring. The maximum bending moment occurs at the sector centre, whereas the maximum torque occurs at an intermediate section, whose angular position may be determined analytically.

For instance, the expression for the maximum bending moment M_{max} is:

$$M_{max} = \frac{p_b\,\alpha\left(1 - \cos\frac{\alpha}{2}\right)\left(r_p - r_i\right)\left[3r_c\left(r_i + r_p\right) - 2\left(r_i^2 + r_i\,r_p + r_p^2\right)\right]}{6\left(2\sin\frac{\alpha}{2} - \alpha\cos\frac{\alpha}{2}\right)} \tag{3}$$

4. Conclusions

An approximate structural analysis has been carried out of a shell-bottom connection in which a locking ring, partially protruding from an annular slot machined in the vessel wall, supports the bottom loaded by the internal pressure. The ring is segmented into four parts, to permit assembling. The contact pressure between the ring and the slot lower face has been approximated in terms of a uniform contact pressure and of two concentrated forces acting at the ring-slot contact extremities. Approximate expressions of the internal forces within the ring have been obtained. The whole of the results indicates that, while the stresses in the segmented ring appreciably deviate from axisymmetry, the stresses in the vessel may be estimated with an axisymmetric model.

References

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