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STATIC ANALYSIS OF A CONVERTER VESSEL USING THE FINITE ELEMENT METHOD

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ABSTRACT

The paper presents static and fatigue strength calculations for a converter. Following common practice with liquid steel vessels, the calculations were evaluated in accordance with the 2007 edition of the ASME Boiler and Pressure Vessel Code, Section VIII.

KEYWORDS: finite element, mechanical structures, converter, mechanical stresses

1. General description of the calculation method

For all calculations, a finite element model of the converter system was generated [1-3]. The calculations focused on the removable part of the vessel (in particular, the suspension system). Therefore, only the vertical position of the converter (0° - Blowing) was analysed [3, 4].

The results of the static analysis were evaluated according to the ASME Boiler and Pressure Vessel Code. The stress evaluation showed that the vessel shell (i.e. the flange connection of the removable part) is adequately designed for the investigated loads in terms of static stresses and fatigue. Therefore, a fundamental prerequisite is that the requirements described below are fully met [5-7].

As with any welded structure, common maintenance practice requires regular inspection of the welded connections for crack initiation (VT and PT and/or MT/UT), typically performed every 1-2 years.

The following requirements can be deduced from the calculation results [8]:

- In the structural areas of the vessel shell with higher loads - i.e., the welds between the ribs and the flange of the upper part of the vessel - full penetration welds must be made, and these must be 100% non-destructively tested (VT, PT/MT, and UT/RT);
- Areas with higher loads must be inspected regularly;
- The calculation of the bolts and shafts must be carried out by a competent entity;
- The prestressing of the bolts was not taken into account in the FEM calculation.

In the calculation model, linear elastic stress-strain behaviour was assumed for all components. The corresponding material properties were based on data for comparable materials according to the SEW standard (Physical Properties of Steels) and were adjusted to reflect the temperatures of the components.

The material properties used are as follows:

- Vessel Shell (material: 16Mo3 / 400 °C);
- Young's modulus of elasticity E = 184 GPa;
- Poisson's ratio of elasticity; v = 0.3.

The maximum temperature of the vessel shell was specified as 400 °C. No equilibrium temperature calculation was performed.

2. Finite element analysis (FEM)

The computational model comprises the vessel, the converter ring, the ring shafts, the four lamellar suspension systems and the horizontal suspension (Figure 1). Due to the symmetrical design, only half of the model was used. The mass of the complete steel structure of the converter assembly, including the refractory, is 268 tonnes. The complete converter ring weighs 109 tonnes and the suspension system was assumed to weigh 9 tonnes. Thus, the total mass of the model (including deposits) amounts to 193 tonnes for the half-model.

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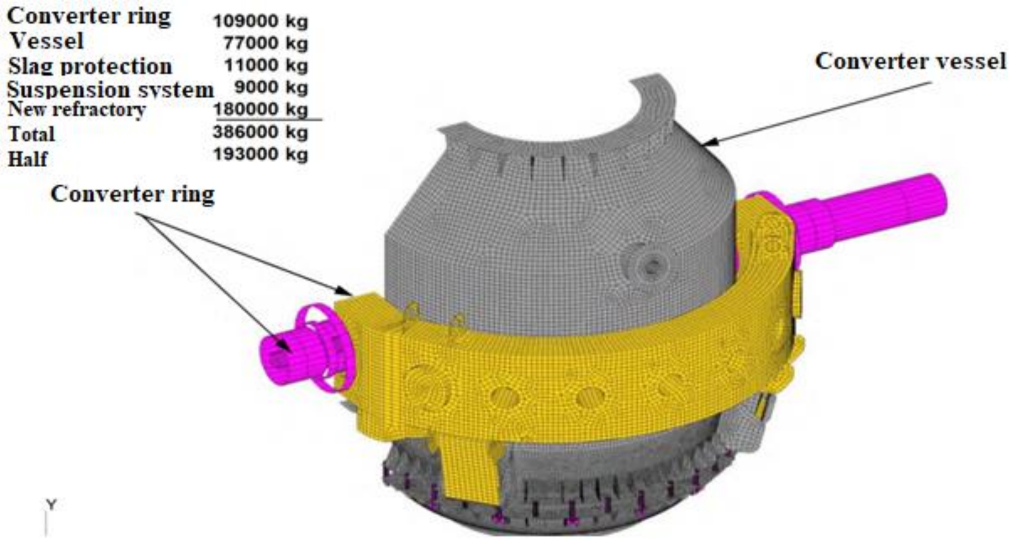

Fig. 1. Calculation model

2.1. Model discretization

The mesh was constructed with four linear nodes in the form of quadrilaterals for the vessel shell elements, using a bilinear extrapolation of the corner stresses.

As can be seen from Figure 2, the computational model was generated with a relatively high mesh density, which allows a good degree of discretization and, therefore, produces quite accurate stress results.

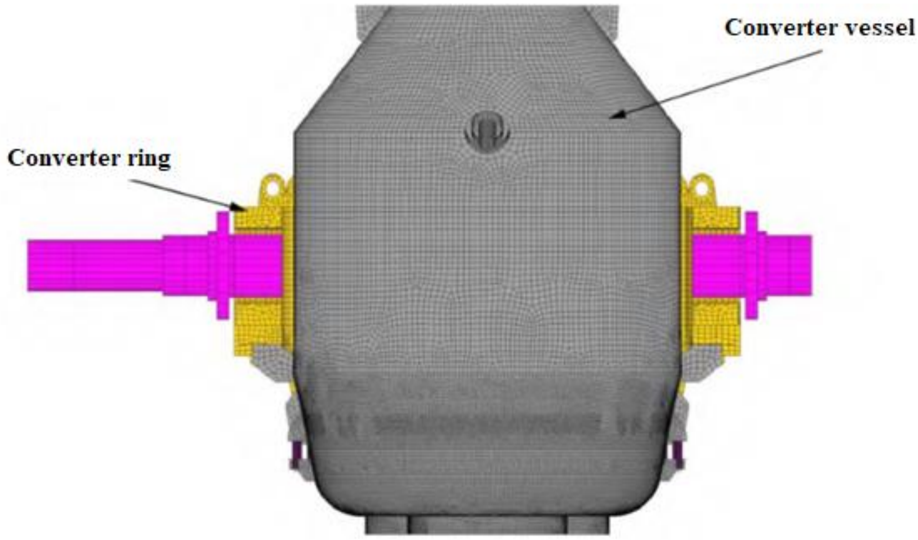

Fig. 2. The network of nodes and elements – mesh

2.2. Applying restrictions and constraints – Figure 3 [8]

The entire model is fixed to the converter ring shafts. In addition, the boundary conditions were applied symmetrically in the section plane.

2.3. Specification of the demands

The loads considered for the blowing are represented in Figure 4. In addition to the static load of 1893 kN for half of the converter, the liquid content of 387 kN (liquid steel, slag, and deposits) was considered as ferrostatic pressure.

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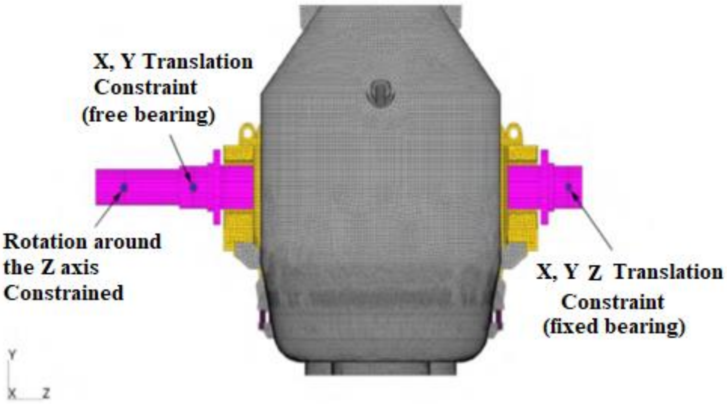

Fig. 3. *Restrictions and constraints*

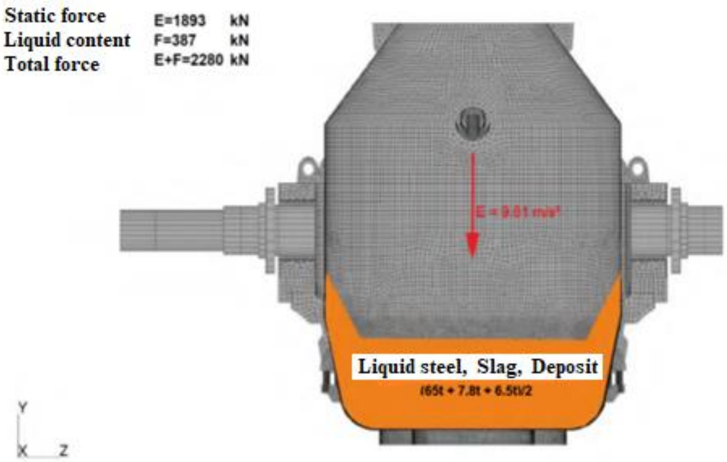

Fig. 4. *Requests*

3. Results obtained

3.1. Static resistance assessment

The main results of the finite element calculations are the displacements and stresses. Representative displacements understatic loads are shown in Figure 5. A maximum vertical displacement of 3.07 mm was calculated. The maximum distance between the two parts of the vessel amounts to 0.13 mm without tightening. This gap must be overcome by adequate tightening of the bolts.

The static stresses are represented in Figures 6 and 7. As already mentioned, the assessment focuses mainly on the suspension system of the lower part of the vessel.

The stresses in this area are shown in detail in Figure 7. The maximum stress in this region amounts to 104 MPa at the edge of the cutout of a suspension bolt. This value is safely below the limit of 127 MPa (valid for 400 °C). Therefore, it can be stated that the suspension of the lower part of the vessel is sufficiently designed with respect to the primary and secondary (static) stresses.

Fig. 5. *Displacements*

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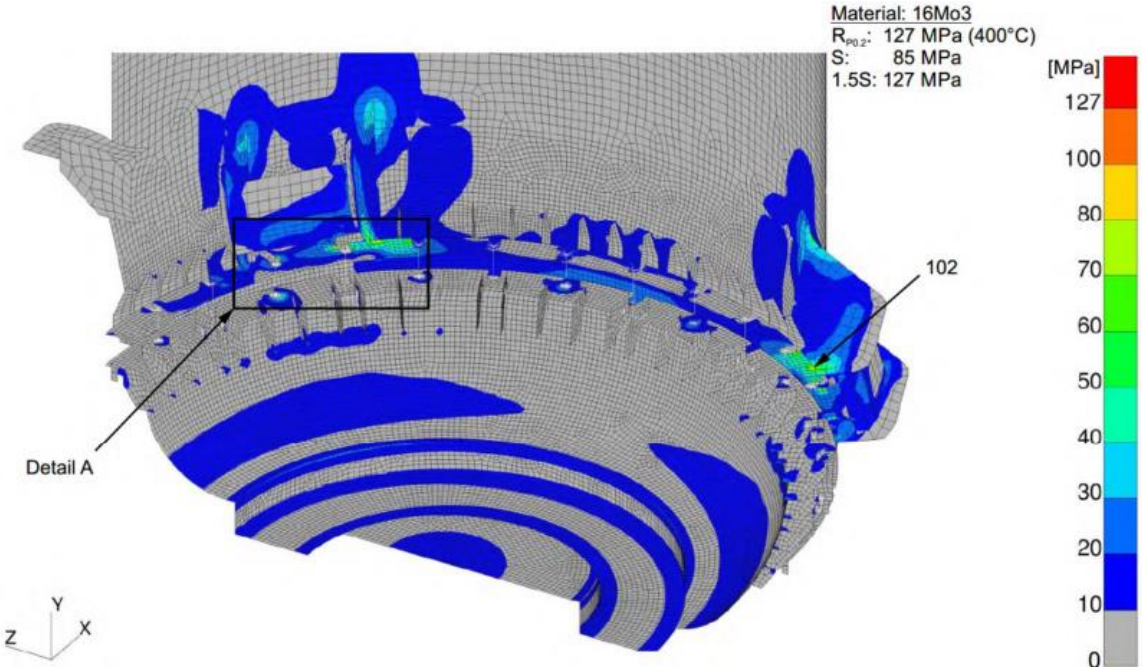

Fig. 6. *The von Mises stress field*

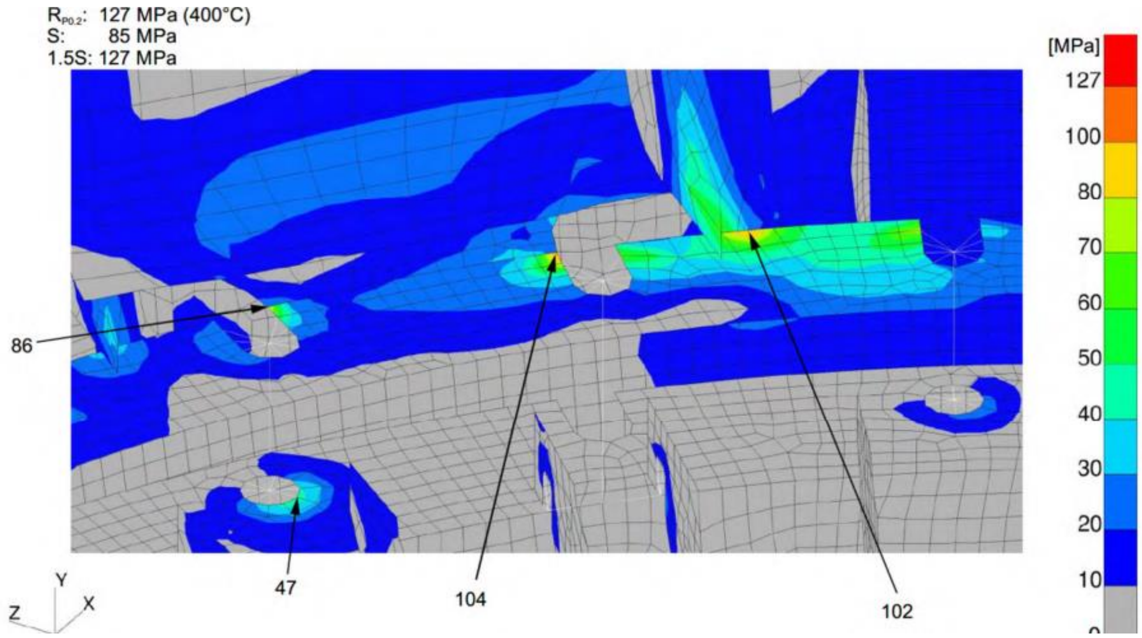

Fig. 7. *Stress field – detail A*

3.2. Fatigue resistance assessment

For the 65-ton capacity converter, normal operation with new refractory insulation was evaluated. Furthermore, a total number of operating cycles for the converter system of N = 210000 was specified. This number of cycles corresponds to 30 loads per day, 350 days per year, and 20 years of life. The number of equivalent load cycles for the vertical suspension amounts to 312000. This number was calculated using the operating scheme of a similar converter.

The permissible stress range, in terms of fatigue for different types of welds and for the actual number of load cycles, is given by the following values:

- Permissible stress amplitude for the unwelded material and for a fully penetrated machined weld: 105 MPa.

- Allowable stress amplitude for a full penetration weld: 88 MPa.

The static stresses for the 0° - Blow position were assumed to be the stress amplitude, which results in a larger stress range than in reality. The total maximum of 104 MPa is below the limit Sa=105 MPa. The maximum stress in the welded areas amounts to 76 MPa, which is below the limit of 88 MPa (full penetration weld). Therefore, these ribs must be welded with a full penetration weld on the flange. No machining is required.

4. Conclusions

To sum up, it can be stated that the investigated components of the converter system meet the requirements of the applicable standards (ASME Standard) under the considered operating load conditions.

Therefore, the fundamental conditions are that the strength properties of the applied components reach at least the evaluated data and that the manufacture of the converter components is carried out in strict accordance with the design drawings.

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