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Experimental Stress Analysis

TORSION SYSTEM OF CONVERTERS ANALYSED BY FEM FOR FURTHER VERIFICATION OF LIFETIME BY EXPERIMENTAL METHODS

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Abstract: During demolition of converter's lining are some parts of the converter overloaded. In order to determine these excessive loads by experimental methods, it was necessary to assess by the finite element method the locations of extreme loadings, where were during demolition measured time-dependent charts of stress increments. By localization of such locations for measurement with the FEM was developed the base for application of sensors. Verification of lifetime was realized according to standards for the assessment of lifetime of carrying structures. One of the inputs for the assessment was time-dependent chart of stresses during process of demolition.

1. Introduction

After a certain operation period of two identical newly built converters it was found out that in one of them cracks developed in the supporting structure of the pedestal of the torsion system that ensures transfer of the tilting moments from the converter vessel to the converter pedestal. After carrying out repairs on the pedestal structure by the operator of the equipment the authors performed the numerical and experimental analysis of stress states in the torsion system with the aim to prevent initiation of cracks in the pedestal. This analysis was done at the time of the normal operation as well as during removal of the converter lining [1]. Overloading of the supporting structure could not be unambiguously quantified from the moments determined from the measurement of electrical quantities on the electro drives, because the system drive – gearbox – brake formed a closed force flow.

On the basis of the analysis carried out by the authors, three alternatives of modification of the torsion system pedestal were suggested, though they were not fully accepted by the producer of the equipment. After the subsequent approximately two-year operation period of the converters it was found out that in the supporting structure of the torsion system pedestals of both converters further cracks developed in the locations predicted by the authors. It invoked the need to perform a repeated numerical and experimental analysis of the pedestal support structure of the torsion systems in both converters with the emphasis on the assessment of their stress conditions mainly in the presence of extreme tilting moments of the converter vessel during demolition of the lining or during their operation with extremely big steel residues on the converter wall [2,3].

The paper reports the results of the numerical analyses of the causes of crack initiation in the pedestals of the torsion systems in both converters.

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2. Description of converter's torsion system and locations of the first cracks

Fig.1 illustrates the scheme of the converter. The torsion system model is shown in Fig.2.

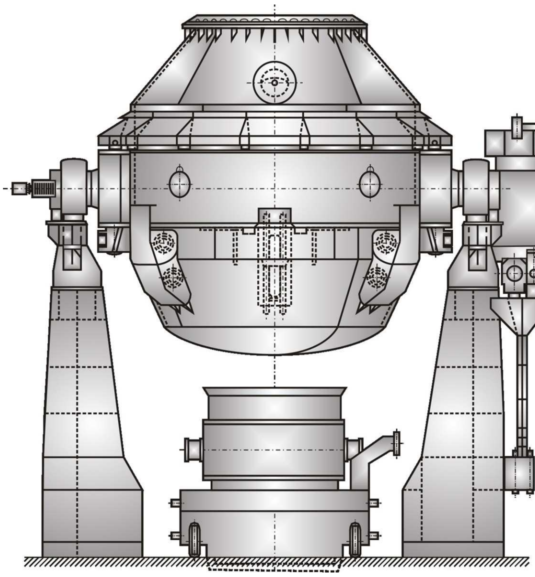


Figure 1: *Scheme of the converter.*

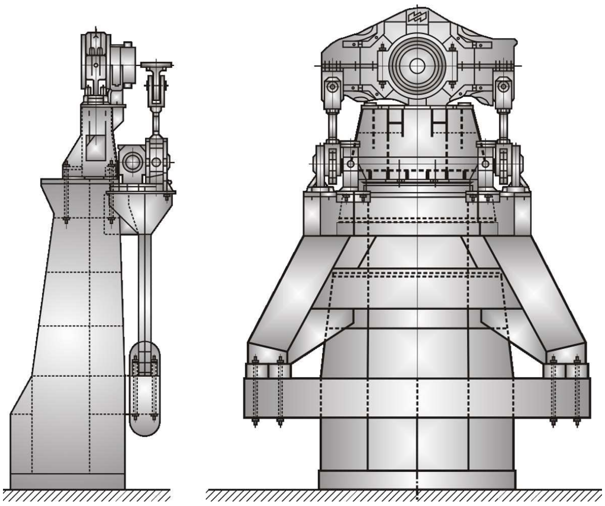


Figure 2: *Torsion system of converter.*

During operation of the converter the torsion system carries primary loading from tilting moments of the main gearbox of the converter drive and also secondary loading caused by vibration of the steel liquid during the fining process in the converter vessel. This loading (in Fig.3 represented by forces F) is transmitted by connecting rods from the gearbox to the torsion shaft and by vertical consoles (bearing house) to the pedestal (Fig.3).

During inspection of the pedestal there were found cracks in the welds between the vertical console, the stiffening rib and the flange of the pedestal's I-beam on the side of the tapping as well as in the I-beam´ web (Fig.4).

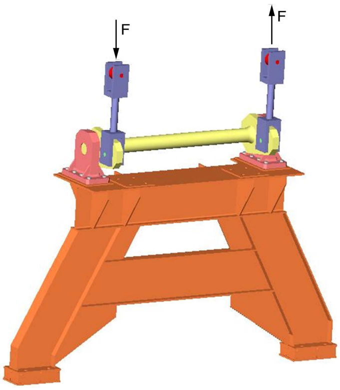


Figure 3: *Loading of torsion system of the converter.*

Figure 4: *Cracks in the pedestal of the converter's torsion system in the location of the weld between the vertical console and the flange as well as in the I-beam´ web.*

In order to ensure further safe operation of the converter the following measures were undertaken by the operator at the recommendation of the producer:

- cracked weld between the vertical console and the flange of the I-beam was repaired,
- in the location of fractures in the I-beam´ web two steel plates were welded from both sides by a fillet weld along the whole perimeter (Fig.5a).
- for the reinforcement of short welds between the vertical console (which connects the pedestal with the converter stand) and the flange of the I-beam two horizontal steel plates were welded on both sides (Fig.5b),
- in order to provide reinforcement, four sloping stiffeners between the converter pedestal and the lower flange of I-beam were added (Fig.5b).

a) b)

Figure 5: *Modifications carried out for ensuring further operation of the converter a) plates welded in the locations of cracks in the I-beam´ web, b) bracing by horizontal plate and slanted stiffener.*

According to the data of the converter producer maximum value of the tilting moment during the normal operation of the converter should not exceed 2000 kNm. During non-standard conditions of the converter (caved-in converter lining of cone, frozen bath in the converter) the magnitudes of maximum tilting moments are higher and they can reach 6322 kNm.

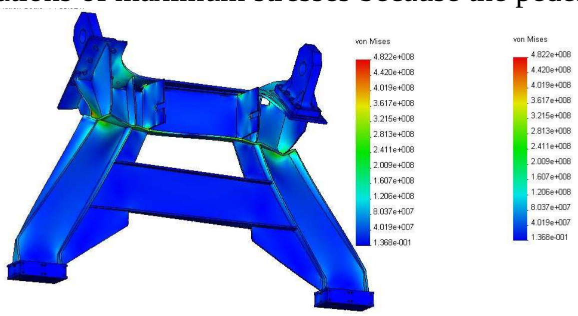
For this value of the tilting moment the forces in connecting rods (their length is 4 m) can reach the magnitude 1580.5 kN.

Through the analysis it was discovered that the system drive – gearbox – brake constituted a closed flow of forces. The forces from the drives in case of active brake are not transmitted to the torsion system. It is a reason why it is not possible to limit the safe operation of the torsion system by the moments determined from electrical quantities.

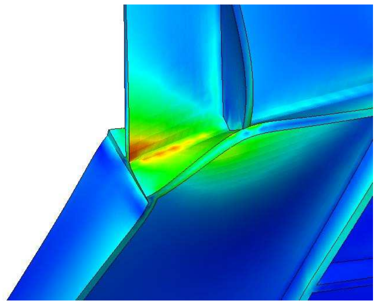
3. Analysis of Stress conditions in the torsion system pedestal by the finite element method

The finite element method was used for the analysis of stress distribution in the pedestal and other elements of the torsion system [4]. The computations were performed based on the assumption of linear elastic behaviour of the material. The areas of bolted joints were considered as a contact problem. Computations were performed for both original and modified structures [1]. In the computations the maximum tilting moment 6322 kNm was used which is given by the producer of the equipment.

Fig.6a shows the fields of equivalent stresses in the pedestal of the original structure without modifications. From the figure it is obvious that plastic deformations develop in the locations of maximum stresses because the pedestal is made of steel sheets grade S235.



a)



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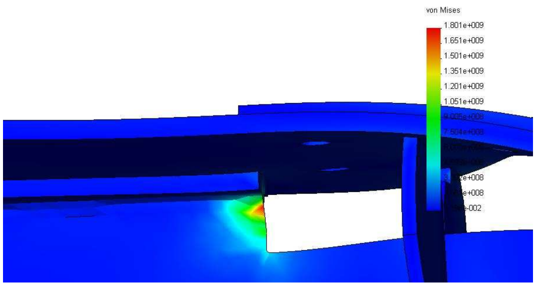

c)

Figure 6: *a) Equivalent stresses in the original structure of the pedestal for the tilting moment 6322 kNm, b) Location of extreme loading at the end of I-beam´ web, c) Location of extreme loading near the weld between the vertical console and the upper flange of I-beam (computation for a model with artificially developed a crack).*

The locations of extreme loading appear at the ends of I-beam´ web in the area of its joining to the legs of the pedestal (Fig. 6b) and in the location of the weld between the vertical console and the upper flange of I-beam (Fig. 6c), i.e. in the location where a crack was initiated and spread further. In Fig.6c is computation for a model with artificially developed a crack in order to study its influence to web. Further computations carried out on a model with artificially modelled crack in this location showed that secondary cracks initiated in the I-beam´ web due to normal stresses developed after failure of the weld between the flange and the vertical console (Fig.4).

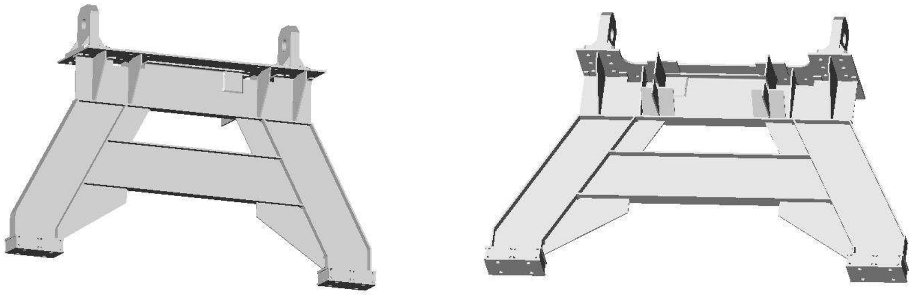

Figure 7: *Model of the pedestal after modifications performed according to section 2.*

Fig.7 gives a computational model of the pedestal after modifications described in section 2 (lapping of locations with cracks by plates, welding of two horizontal plates between the vertical console and the flange of I-beam as well as welding of four slanted plates between the stand of the converter and the bottom flange of I-beam – see Fig.5).

Fig.8 gives distribution of equivalent stresses in the pedestal of the torsion system after its modification for the tilting moment 6322 kNm.

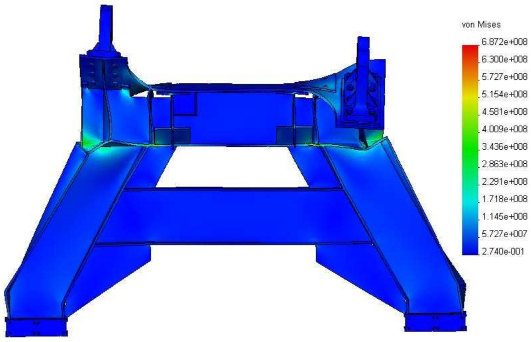

Figure 8: *Equivalent stresses in the modified pedestal of the torsion system for the tilting moment 6322 kNm.*

As Fig.8 shows due to realization of the suggested improvements the stresses were decreased in the locations of cracks, but at the same time the stresses were increased in the location of joining of the pedestal leg and I-beam (Fig.9). The maximum stresses were higher by 43% than maximum stresses before the improvements.

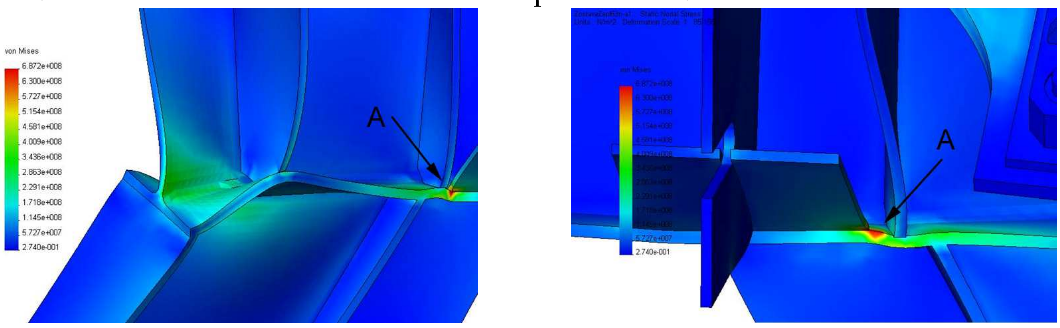

Figure 9: *Equivalent stresses in the connection of the pedestal leg and I-beam – pedestal after modification (tilting moment 6332 kNm).*

In the location of extremal loading were applied resistance strain gages [5] and the measurements have comfirmed the levels of stresses determined by numerical analysis. However, it have to be mentioned that due to smaller tilting moments during operation (cca 2000 kNm) were the extremal stresses adequately smaller. In spite of warnings that there can arise cracks in torsion system during further operation, the producer allowed the operation with converters with the pedestals modified according to previous description.

The lifetime of the converter linings is defined by the number of melting cycles. After the specified time of operation of both converters it was necessary to remove the old lining and replace it by a new one. As there were big steel residues on the converter wall and they were arranged asymmetrically, it was decided that the measurements of forces and stress conditions in the torsion systems of both converters would be carried out during lining demolition.

After visual inspection of the pedestal of the converter's torsion system before application of strain gages it was found out that there were significant cracks in locations of extreme stresses, which were identified by finite element computations in the previous stage of solution (location A, Fig. 9). The cracks occurred in the pedestals of the torsion system of both converters in the bottom flange of I-beam, always on the inner side of the stand on the side of the converter pedestal (Fig. 10).

The length of cracks reached 120 mm and the inclination of cracks to the surface was invoked by high shear stresses. As it was necessary to finish demolition of the converter lining, holes with diameter 6 mm were drilled in the crack tips to prevent further crack growth.


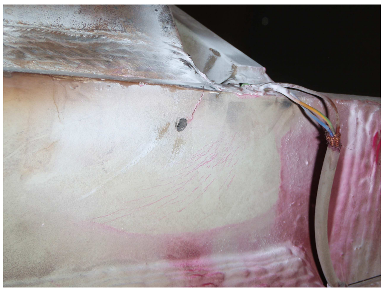

Figure 10: *Cracks on the bottom flange of I-beam in locations identified by the finite element computations (location A, Fig. 10).*

Consequential experimental measurements realized on the pedestals of torsion systems of both converters confirmed high levels of stresses in locations that were identified by numerical computations with FEM. It allowed real verification of lifetime of pedestal with recommendations concerned to necessary structural modifications [2,6].

4. Conclusions

For the lifetime assessment of structure is necessary to know time-dependent relations of stresses in the most loaded elements. Real charts of stresses during operation can be often determined only by experimental measurement. For the application of resistance strain gages it is suitable to identify such locations by numerical analysis with FEM.

In the contribution is by example of analysis of torsion system pedestals documented advantage of combination numerical and experimental procedures for the solution of such tasks.

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