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EKSPERIMENTAL AND NUMERICAL ANALYSIS OF STRESS CONDITIONS ON TURRET

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ABSTRACT
Turrets or turntables are welded steel constructions used in process of continual casting, and present very important device in steel beams production. Two different types of turrets exist, and both are damaged. Some cracks were detected in the environment of basis. In order to define reasons of this state, it is necessary to define real stress distribution using numerical analysis of the stand structure and experimental analysis using strain gauges in real working conditions. This research should enable to determine the difference in stress conditions of two different variants of the turret and actual tension values at given locations during the operation, and possible cause of cracking too.
Keywords: turret, stress-strain analysis, FEM, strain gauges

1. INTRODUCTION
Turrets can rotate around a central column. On each turret, it is possible to put two ladles, where the max. weight of one ladle is around 1.8 [MN], Fig.1 There are two difference types of turrets, the first type is not vertically movable (Ladle Furnace-LF plants), while the second turret has the possibility of vertical movement of the traverse by using a hydraulic cylinder (Continual Casting Machine-CCM). Hollow shaft, traverse and stand in both options are identical from the design aspect.

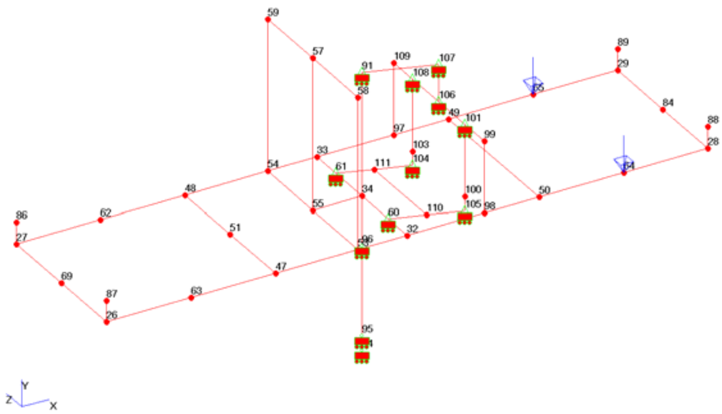


Figure 1. Turret - simplified model

2. DESCRIPTION OF TURRET

Turntables for receiving ladles vary in structural design of pickup arm used for force balancing. There are two variants, first with a hydraulic cylinder and the other with a rigid lever. Other structural elements are identical for both manipulators.

It should be noted that, based on the available technical documentation, it was not possible to determine the quality of the material of turret stand, as well as all the geometric details of the dimensions – section details. To determine the actual force that loads the stand bearing it is used the case in which the diameter of the stand inner ring D is approximately equal to the diameter of the outer ring bearing d, $D \approx d$, Fig. 2. In this case, the biggest contact pressure is determined by the formula [3, 4]:

$$p_{\max} = \frac{4 \cdot F}{\pi \cdot l \cdot d} \qquad \text{... (1)}$$

where:
F - support reaction in the radial direction,
l – the length of bearing,
d – the diameter of the outer ring of beds.

Operating force on the stand is:

$$F_n = 2 \cdot p_{\max} \cdot l \cdot d \qquad \text{...(2)}$$

This force (F_n) is used as an active load in the numerical analysis of stress-strain state of turret stand. Forces determined in this way correspond to the most extreme caseloads that are caused by 1.8 [MN] weight of load on one side of the turret. The assumption is that the load places on the platform without the impact.

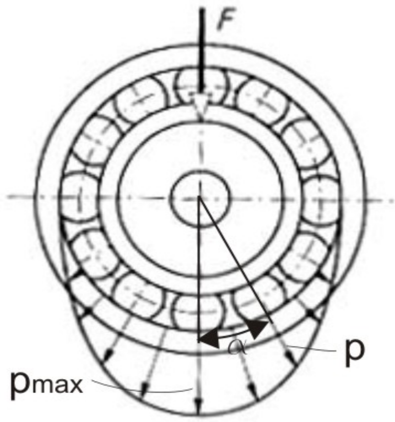
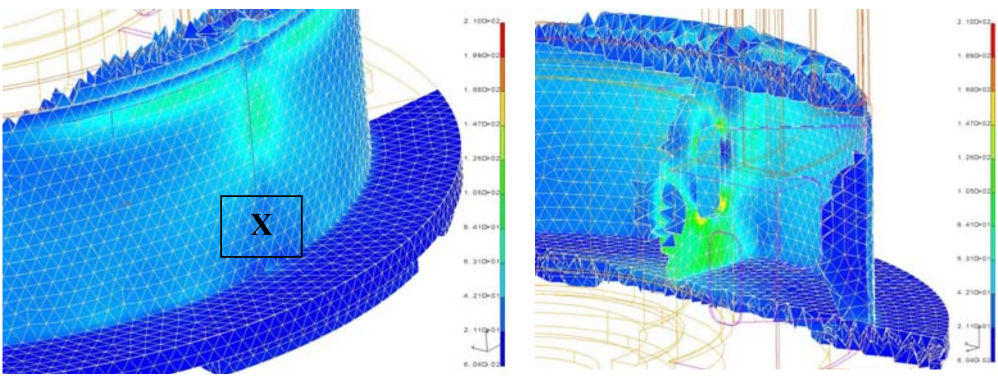


Figure 2. Pressure distribution for case $D \approx d$

3. NUMERICAL ANALYSIS OF STRESS

Finite element method (FEM) is used for numerical analysis. By application of FEM, the distribution of load and deformation on the stand for one of the cases in the experimental analysis should be obtained. The specific case is chosen where one full ladle with approx. weight of 1530 [kN] is settled on turret. The stand has got a form of an axisymmetric structure, so an analysis of stress-strain state of ½ the overall structure is made, whereby the time needed for calculation is reduced, Fig. 3.



a) Exterior *b) Interior*

Figure 3. Stresses on the stand (Von Misses)

Details of stresses distribution on the inner and outer side of turret podium, where the maximum calculated stresses (von Misses) are about 48 [MPa], are shown on Figure 3. On the cylindrical part of the stand body, the highest stress is calculated on the inner side. Equivalent stresses according to von Misses are about 210 [MPa] and appear in the zones of stress concentration, what should be taken with certain amount of reserve because some structural details were not known.

In areas where measurements were carried out (220 mm from the bottom flange plate - marked with “X” on Fig.3), stresses obtained by numerical analysis did not exceed 50 [MPa].

4. EXPERIMENTAL TEST

Measurement points were selected in that way that the test results can be compared on both turrets and determine the influence of hydraulic cylinders (the case with CCM) in relation to the rigid vertical lever (the LF) on the stress-strain conditions.
Measurement starts from zero condition, what implies the construction is loaded only with its own weight. First load is introduced gradually adding an empty ladle with approx. weight of 510 [kN], then turret is rotated for 180º and on the other side of the turret is put the full ladle with approx. weight of 1530 [kN] is positioned. Turret loaded in this way rotate again for 180° and after that, the raising of empty ladle is done in order to provide the extreme case of eccentric loads.

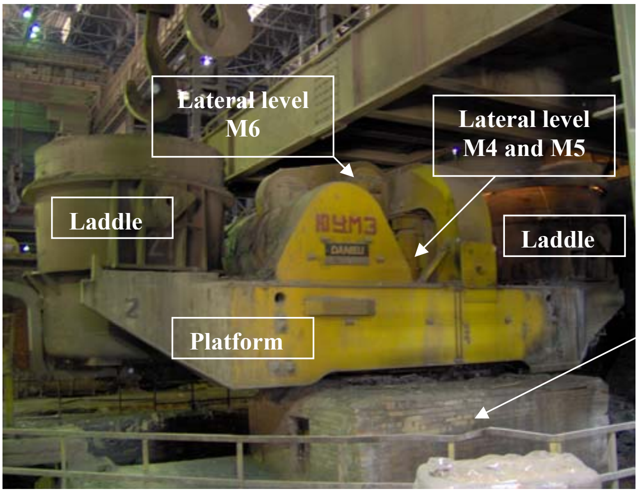


Figure 4. LF turret loaded on both sides (two ladles)

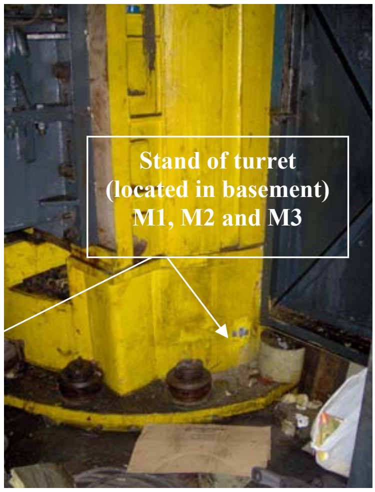


Figure 5. Stand of turret

4.1. Selection of measurement points

Strain gauges are installed on measuring places as follows:
- M1 - on the stand in a vertical direction,
- M2 - on the stand in the horizontal direction,
- M3 - on the stand in a vertical direction, as opposed to M1,
- M4 - a vertical column, 400 mm above the turning joint, side of the vertical lever,
- M5 - a vertical column, 400 mm above the turning joint, side of the lever system,
- M6 - middle point of the upper lateral lever.

On the turret with hydraulic cylinder installed for vertical movement of platform, lifting and lowering of the ladle during the continuous casting, measurement points were selected to match measuring points on LF turret. Measurement of deformation on turret construction is performed by using strain gauges of uniaxial type 10/120 LY11 produced by HBM Darmstadt, [2]. Data acquisition is performed by using 8-channel devices Spider 8-30 and software Catman 5.0 Professional, produced by HBM Darmstadt.
As useful load an empty ladles approx. weight of 510 [kN] and ladles full approx. weight of 1530 [kN] are used. The load is introduced in three phases as follows:

- Zero phase - empty turret;
- Eccentrically load on one side with empty ladle, 510 [kN]**;**
- Loaded on the one side with 510kN and other side of the turret with full ladle of 1530 [kN];
- Eccentrically load on one side of the turret with full ladle, 1530 [kN]**;**

Between each phase the rotation of turret platform for 180° is performed.

4.2. Results of experimental analysis

The measured values of deformations i.e. re-calculated value of stress on LF and CCM turret stands are approximately equal to stress values obtained by numerical analysis in same load conditions, [1].

Table 1. Comparison of the absolute stress values obtained by measuring

Turret	The maximum absolute value of the measured tension, [MPa]									
	M1		M2		M3		M5		M6	
Load, kN	LF	CCM	LF	CCM	LF	CCM	LF	CCM	LF	CCM
One side-510	8,8	11	4,4	1,1	9,4	6,7	9,6	12	20	-
Both sides 510 + 1530	21	65,8	5,2	7,6	18,8	27	15,3	28,8	21,8	-
One side-1530	40,6	42,9	5,9	7,8	26	55,3	32,9	39,5	41,8	-

Measurements of the measurement point M4 were interrupted due to severe working conditions.

5. CONCLUSIONS

The static analysis shows that changes of the platform vertical position do not affect the reactions in the supports of the vertical column-shaft. Numerical analysis for the extreme load case and the worst case of load distribution in the bearing's zone shows that the stresses are quite uniformly distributed on the mantle stand and do not exceed 50[MPa] in areas where stress-strain measurements are performed.

It can also be concluded from results that stresses on the stand of the LF turret have a lower value than CCM stand (Tab. 1), as a result of installed reinforcement on LF turret stand (vertical and horizontal stiffeners).

Based on performed analysis it can be concluded that:

- Turret stand from design aspect is correct.
- Hydraulic cylinder has no influence on construction stresses.

As possible causes of created damages on turret stand can be noticed:

- Poor quality of welding joints (no adequate technology and inadequate work quality),
- Overloads caused by strokes occurred during lowering of the full ladle – incorrect manipulation
- Instability of stand due to poor supporting on the ground - poor foundations.

6. REFERENCES

[1] Vukojević, D. (1998.) Elasticity theory with experimental methods, Mechanical Engineering in Zenica.

[2] Hoffmann, K. (1987.), Eine Einfürung in die Technik des Messens mit Dehnungsme βstreifen, Hottinger Baldwin Messtechnik GmbH, Darmstadt.

[3] J. Brnić, G. Turkalj (2006.), Strength of Materials II, University of Rijeka.

[4] A group of authors (1992.) Mechanical Engineering-manual, Institute for Textbooks and Teaching Aids, Belgrade.