Determining the condition of material for tension bar bucket wheel excavator operating under dynamic working conditions

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Abstract

Since the bucket wheel excavator SRs 1200 had crashed with bucket wheel boom heavily damaged, there was an opportunity to analyze the real structure that-was in operation for past 40 years. As there are 4 more SRs 1200 bucket wheel excavators in RB Kolubara, obtained results can be of great benefit for 4 running bucket wheel excavators, as well as the revitalization of the damaged one.

The following results were acquired:

State of bucket wheel excavator's tension bar fatigue, operating under dynamic working conditions. This was managed by the determination of chemical mechanical properties, fracture mechanics and permanent dynamic strength parameters (Weller curve).

Based on acquired results, an evaluation for remaining life assessment of materials was determined, allowing predictions for further bucket wheel excavator exploitation performance.

1. Introduction

During the regular repair, and after 35 years of the bucket wheel excavator operation, it is stated that it was necessary to estimate the stress and deformation conditions of the complete bucket wheel excavator [1], as well as, separately some of its vital parts (bucket wheel boom and its tension rods), using an adequate tests [2]. Considering that there are 4 more excavators of the same type, it is necessary to estimate remaining age of is supporting structure, in order to estimate what should be done with the machinery: operation up to the end of structure safety, revitalization or depreciation [3]. Namely, due to many years of the BWE operations, has been occurred many damages and failures. All those has resulted in weakening of the steel structure at the vital parts of the excavator,

and in some cases, it resulted in significant damages. Those damages were especially noticed within the area of the bucket wheel boom as shown on the figure 1.
In order to obtain valid assessment of the situation and behaviour of the supporting steel structure, it is necessary to perform the excavator calculation by the final elements method, and then based on the critical points, obtained by calculation to perform surface tension measurements, and afterwards to compare those two methods in order to make in compliance obtained results. Considering that operation conditions of the excavator for the previous 35 years are rather unknown, it is necessary to establish the remaining age of the structure at the critical points, based on the obtained parameters, and also based on the working conditions experiments simulating at the sample.

Figure 1 Bucket wheel Excavator SRs 1200

For the purpose of the complete tension conditions review within the steel structure of the bucket wheel excavator, calculation is made by the final elements method [4, 5, 6]. The main goal of this calculation is to, based on technical documents and load - which is the result of its own weight and coal excavation, define points with the maximum loads, that is, to define potential new measuring points for the surface tension tests.

Surface tension tests within the bucket wheel excavator steel structure are performed for the purpose of:

- Defining of deformation and load conditions within the bucket wheel excavator steel structure only by its own weight
- Defining of deformation and load conditions within the bucket wheel excavator steel structure loaded by its own weight and coal excavation with the bucket boom lowered at approx. to -15˚.

As in this moment, laboratory examinations are not completed; the results shown within this paper would be obtained by calculation and measurement procedure at the structure itself.

2. Calculation

The calculation is performed by the final elements method, using MSC-NASTRAN program. Obtained graphics results review are given in the figure 1.

For all structure elements within the calculation, figure 2, it has been used steel S 355J2G, which has the following characteristics according to the standard:

- Yield stress $R_{p0,2}$ = min. 335 MPa
- Tensile strength R_m = 510 - 610 MPa
- Flexibility module E = 210 000 MPa
- Poisson coefficient $\nu = 0.3$
- Density $\rho = 7850\ kg/m^3$

In this case, tension rods as a one of the most critical parts of structure has taken into account [7].

There are specially selected obtained results on the tension rods model at the figure 3.

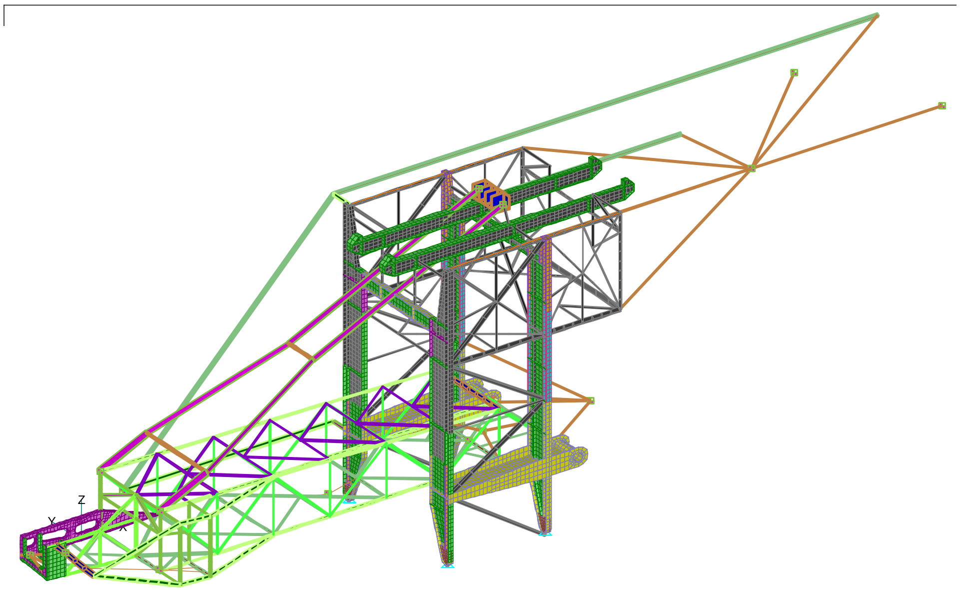

Figure2. Bucket wheel excavator SR 1200; Final elements model

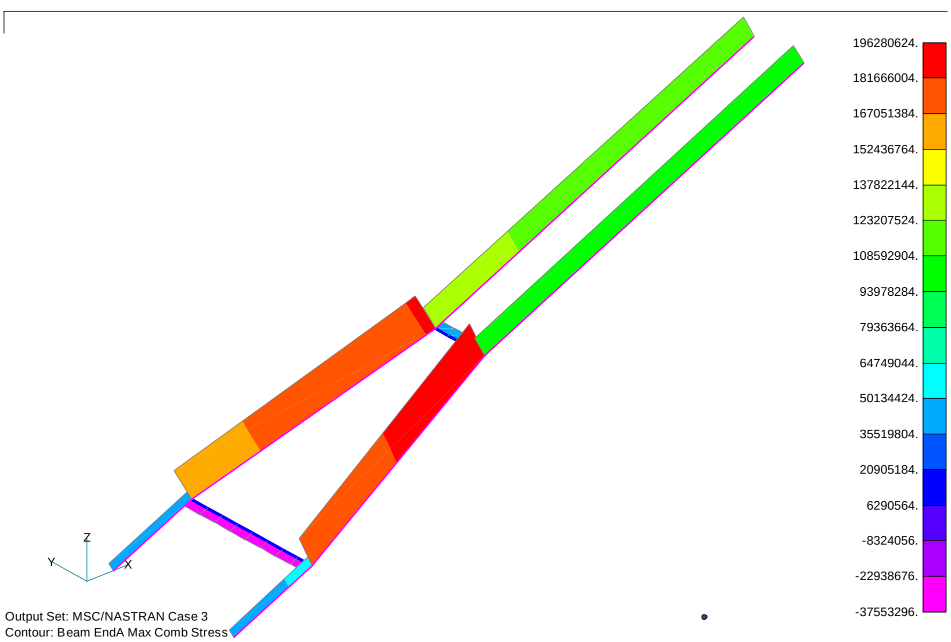

Figure3. Tensions at tension rod; case of load –own weight + load

At the tension rod can be noticed very high stress value [8].

3. Examination

For data collection and processing from the measurement belts (rosette), the following electronic equipment has been used:

- Multichannel measuring device UPM-40 with the auxiliary equipment;
- PC (personal computer);

For the measurement points feeding and conditioning, it has been used 40 channelled measuring amplifier UPM-40, manufacturer HBM. Measuring device UPM-40, i.e. measuring bridge, is the modern device for deformation measurement from the measuring belts. Subsequent data acquisition has been performed by connection of device with the personal computer. Measurement scheme is given within the figure 4 bellow.

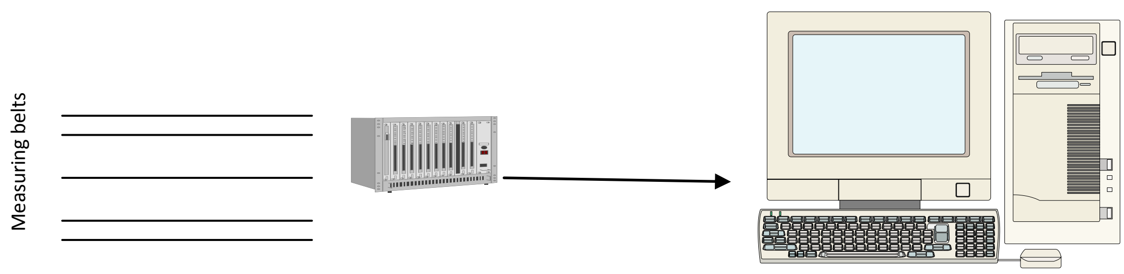

Figure 4. Measurement scheme

As it has been said within the introduction, the purpose of these examinations was to calculate an actual deformation and tension condition at the characteristic point of the bucket wheel excavator, which are, according to experts' experiences from OCMs, and based on technical technological documents, the most loaded (figures 5, 6 and 7).

Figure 5. Bucket Wheel Boom with the tension rod

Figure 6. Strain Gauges

The very examination, i.e. defining of the deformation condition has been performed in several phases:

Phase A – Zero position; position when the bucket wheel steel structure was on the structure supports, and when the bucket wheel boom was lowered to the zero position and rested at the structure support.

Phase B1 - Structure without the structure support, loaded by its own weight, and lowered bucket wheel boom to -15˚.

Phase B2 - Structure without the structure support, loaded by its own weight, and horizontal bucket wheel boom position.

Phase B3 - Structure without the structure support, loaded by its own weight, and lifted bucket wheel boom to+18˚.

Phase C – Defining the deformation and tension conditions within the bucket wheel excavator steel structure loaded by its own weight, and coal excavation with the lowered bucket wheel boom to approximately -15˚.

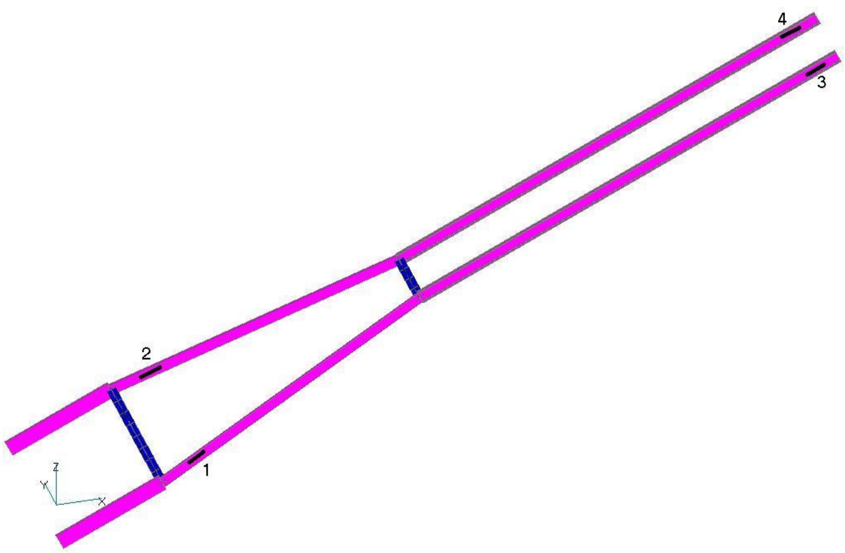

Figure 7. Disposition of measuring points on the tension rods

4. Examination Results

For the purpose of defining deformation and tension conditions within the bucket wheel excavator steel structure it has been used rosettes 10/120 RY 11, and individual measuring of belts 10/120 LY 11 and 10/350 LY 11. Measuring belts are glued together as it can be seen in the figure 4. In order to eliminate side effects during the procedure, like temperature changes, compensation measuring belt has been used. Compensation of temperature changes has been performed by measuring of belts 10/120 LY 11 and 10/350 LY 11. Measuring points on which belts has been located have been protected against atmospheric influences, as well as against mechanical damages, which should enable tension check to be performed as well after a certain period of time.

Measuring points has been selected based on design-technical documents submitted by the Investor, as well as based on the previous calculation, which is in accordance with the adopted methodology, i.e. has been selected to provide insight into the tension state at particular points of the bucket wheel excavator steel structure. Due to their disposition via steel structure, measuring points has been collected within groups and as such connected to the multichannel device UPM 40.

Measured micro deformations at the strain gauges on the tension rod of the bucket wheel boom, and calculated tension indicate that yield stress has not been exceeded not even at the single measuring point, that is, tension are at the linear flexibility area. The highest calculated main tension on the rod of the bucket wheel boom is on the measuring point 1 (178,1 MPa, figure 8). This point is located near to the bucket wheel axis, that is, gearbox and bucket wheel own weight have more load on the left then on the right side of tension rod. Other calculated tension values are relatively high, but still within linear flexibility area.

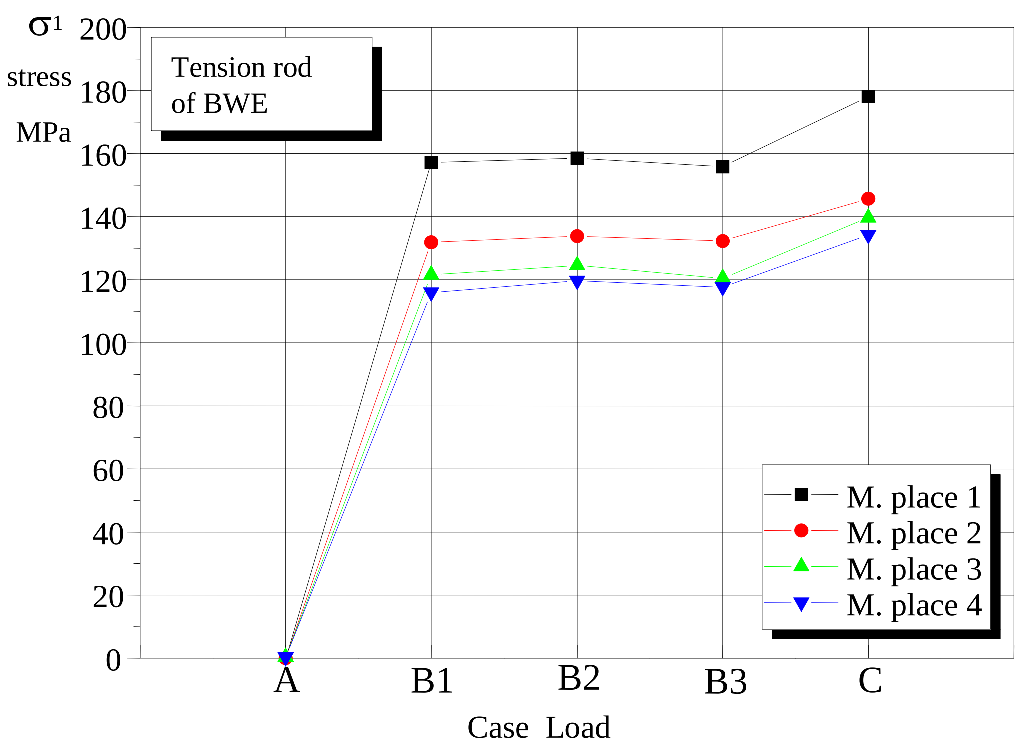

Figure 8. Tension dependence – load case for measuring points on the bucket wheel boom clamps

In general, all measuring points on the left side indicate higher load value, that is measured deformations and calculated tensions are higher than on the right side. This is directly related with the gearbox position and the bucket wheel boom position.

5. Discusion

In order to obtain as much as it is possible clear condition and behaviour insight of the support structure operation, it is necessary to adjust calculation model (final elements method) with performed measurements by strain gauges during operation according to the appropriate load cases [10].

The bucket wheel boom tension rods are used as a critical structural part for the analysis.

Calculation by the final elements method has included complete upper excavator superstructure, in order to have more realistic impact on the tension rod. Tension analysis has been performed by simulation of load by own weight as well as excavator loads during operation, according to DIN 22 261-2 [11]. The procedure has comprised several phases:

- Development of the bucket wheel excavator complete steel structure final elements model,
- Referent load case analysis, where the impact of own weight on disposition of deformation and tension conditions has been analyzed,
- Operation load impact analysis, including the impact of the own structure weight on disposition of deformation and tension conditions.

6. Conclusion

Tension analysis has shown that tension values obtained by calculation of final elements method, are on the lower level compared with the experimentally obtained tension values by the surface tension measurements method. The certain difference is evident, regardless the calculation with the actually measured thickness on individual points of the steel structure.

Evident from the submitted results is that tension rod structure causes a high tension level and potential dynamic "bad" structure points. Examination on used material durability should be done as well. On the other hand, even before obtained results for the remaining material age of tension rod, it may be asked for tension rod replacement, due to high operational loads during 35 years of exploitation, and installation of the new ones. It is certainly desirable for new tension rod to be repaired, in order to avoid high level of tension condition, by which the structure operational life would be extended.

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