1. INTRODUCTION

The development of gantry cranes of a coating structure, as an evolution of steel box-structure cranes, started in the fifties of the previous century. Such gantries are characterised by a high rigidity and slenderness, while their drawback constitutes much smaller lifting capacity than the cranes of truss structures of similar dimensions as well as an increased susceptibility to mechanical vibrations. Considerations were performed for three scoop gantry cranes of a lifting capacity of 350 kN, operating in one of the Polish steelworks. The bearing element for these cranes constituted the span, 133 m long, of the coating structure, made of steel plates strengthened by axial and transverse ribbing (Fig. 1).

2. NONDESTRUCTIVE BRIDGE TESTS

Complex non-destructive investigations of gantry cranes were performed due to finding in them fatigue cracks after
several immediate repairs (Ładecki et al. 2005, 2009, 2010). These examinations contained visual tests of all outside surfaces in order to estimate areas of inadmissible defects of the bearing structure, such as: tears, cracks, permanent deformations etc. They also contained defectoscopic examinations, estimations of corrosion decrements progressing with an ultrasound technique application, analysis of span permanent deformations on the basis of cyclic geodesic measurements of the vertical profile shape of the beam truck crane pad (Ładecki et al. 2010).

The performed non-destructive tests revealed several areas of crack occurrence (the most often of a fatigue character) and other damages of crane structures. The most intensive occurrence of fatigue cracks was found for the beam truck crane pad, for which identified types of damages are illustrated in Figures 2, 3 and 4.

Apart from sporadically detected cracks of type „A”, „C” and „G”, for various examination series, it was found that there are: 42–47% type „Z” cracks, 13–42% type „O” cracks and 8–25% type „B” cracks, in the total number of detected cracks.

The occurrence of fatigue cracks were also detected in other areas of cranes, out of which the most dangerous were found near the long support (Fig. 5), and in the short support tube buffet (Fig. 6).

Apart from the discussed above fatigue effects in the exploitation of the cranes the maintenance in good condition of truck railways, where troubles are related to loosening and cracking of screws and periodical cracking of rails, is also a serious problem.
In order to explain the existing situation the proper strength analysis, FEM, was performed and verified by extensometric measurements of deformations.

3. STRENGTH ANALYSIS

Altogether 17 cases of loading was considered for the developed discrete model of the crane structure (Matachowski, 2004). The FEM analyses revealed that for the most disadvantageous conditions of structure loading the extreme shearing forces for the span occur in the support areas, while the extreme bending moment values in the support areas and in the middle of the span length between supports (Fig. 7). These areas are compatible with the areas of the highest intensity of fatigue cracks in crane beams.

Examples of the results of the reduced stresses obtained – in accordance with the Huber – Misses hypothesis – for the
span and crane beam, for one of the loading variants are presented in Figures 8 and 9. The selected FEM results for the crane beam elements are listed in Table 1. Extreme values of the reduced stresses for the crane beams being equal 65 MPa, were obtained for the area of the cracks of the fillet joints of type „B“ and „Z“.

![Fig. 8. FEM analysis – distribution of the reduced stresses in the span – load variant 2](image)

![Fig. 9. Distribution of the reduced stresses in the crane beam – load variant 2](image)

**Table 1**

Selected FEM results for crane beam elements

<table>
<thead>
<tr>
<th>Crane beam element</th>
<th>Stresses [MPa]</th>
<th>Reduced stresses for the loading variant:</th>
<th>Fatigue category (PN-90/B-03200)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 – Truck on the short support</td>
<td>2 – Truck in the middle of the span</td>
</tr>
<tr>
<td>Side strips</td>
<td>60</td>
<td>53</td>
<td>160</td>
</tr>
<tr>
<td>Membranes</td>
<td>65</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>Cracks type „B“ &amp; „Z“</td>
<td><strong>65</strong></td>
<td>57</td>
<td><strong>57</strong></td>
</tr>
</tbody>
</table>
4. EXPERIMENTAL PART

In order to verify the obtained FEM analysis results the extensometric measurements of deformations were carried out. These measurements were made for two work cycles of the bridge (Badura et al. 2009, Ladecki et al. 2010). The first cycle comprised driving: of an empty truck, of a fully loaded truck and after its unloading at the arrested bridge. The second cycle comprised of driving of the whole bridge with an empty truck parked on the short support. Three strain gauge rosettes marked R1, R2, R3 type TFxy-4/120 were used in measurements, and measurements were carried out after zeroing the instrument at the work cycle beginning. The location of the measuring sensors placed at the western side of the bridge between frames No. 14 and 15 within the crane beam area and on the coating behind the bridge long support are illustrated in Figure 10.

Examples of the results of the reduced stresses obtained – in accordance with the Huber–Misses hypothesis – for the span and crane beam, for one of the loading variants are presented in Figures 8 and 9. The selected FEM results for the crane beam elements are listed in Table 1. Extreme values of the reduced stresses for the crane beams being equal 65 MPa, were obtained for the area where the cracks of the fillet joints type „B” and „Z” occur.

The highest values of reduced stresses recorded in the work cycle 1 and bridge cycle 2 listed together with the FEM analysis results (corresponding to cycle 1) are shown in Table 2.

5. CONCLUSIONS

Non-destructive investigations of cranes indicated an occurrence of several fatigue cracks, which sources were not eliminated at immediate repairs.

On the basis of the FEM analysis, verified by extensometric measurements of deformations, the most endangered areas of crane structure, corresponding to places of the fatigue cracks occurrence were determined. Extreme values of the reduced stresses for crane beams of 65 MPa, were obtained for the occurrence areas of the fillet joints

<table>
<thead>
<tr>
<th>Sensor No.</th>
<th>Reduced stresses $\sigma_1$ [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cycle 1</td>
</tr>
<tr>
<td>R1</td>
<td>18</td>
</tr>
<tr>
<td>R2</td>
<td>20,5</td>
</tr>
<tr>
<td>R3</td>
<td>16,5</td>
</tr>
</tbody>
</table>

Examples of diagrams of stresses variability recorded by rosette R2: for the work cycle 1 is shown in Figures 11a, while for driving of the whole crane (cycle 2) in Figures 11b. Results shown in Table 2 indicate good compatibility of the calculation results and measurements.
cracks type „B” and „Z”, while the source of often detected cracks of type „O” is probably their vicinity to cracks of type „B” and „Z”, from which type „O” cracks the most often were developing.

The exploitation history of the discussed objects is not known, however when taking into consideration the fatigue category, for the crack occurrence area, determined as 57 MPa (PN-90/B-03200), exceeding of the fatigue strength of the welded joints can be indicated as the reason of forming and progressing the fatigue cracks. The presented calculations and measurements can be used for more accurate fatigue strength analysis. They constituted the bases for performing the relevant strengthening of crane structures.

References

PN-90/B-03200 Konstrukcje stalowe. Obliczenia i projektowanie.