Experimentální Analýza Napětí 2009
Experimental Stress Analysis

PROFESSIONAL VERIFICATION OF CRANE TRACK BEAMS IN HEAVY METALLURGICAL OPERATION BY MEANS OF TENSOMETRY

Peter Bigos[1], Jozef Kulka[2] , Karol Kubin[3], Martin Mantic[4] & Melichar Kopas[5]

Abstract: There is always a topical question of money for purchase of new technologies, as well as for modernisation in various transformed and renewed industrial companies. Many machines were exploited during the whole operational time on a maximum level, but another machines were used only sporadically and therefore they don't need to be replaced. This situation is typical for crane tracks. In some intervals of the crane track was the crane travelling permanently, however in the rest part of the crane track it was only sporadically. By means of an experiment there can be selected beams designated for an urgent replacement, whereas other beams remain without any necessity of a change.

1. Introduction

This paper describes a professional verification of crane track beams, determination of residual durability of selected beams and suggestion of necessary measures with regard to possibility of future operation of the whole crane track. There were analysed the most seriously loaded beams in one of metallurgical plants in the framework of the company U.S.Steel Košice, Ltd.

2. Description of crane track

The analysed part of crane track consists of single „I“-shaped beams that are 1 800 mm high and 18 000 mm long. One of beams is different from all others; it is 3 296 mm high and 36 000 mm long. Every beam is reinforced vertically and bolted together with columns, as well as each other, up to one third of its high. There are also “braking portals” arranged in rows under some of simple beams with length 18 000 mm, Figure 1. Positioning of braking portals required a special adjustment of beams by means of metal sheets, which are welded crosswise to the lower flange of „I“-shaped beam in a certain small distance left and right from the middle of beam, in order to transfer braking forces, i.e. inertial forces (arising during braking of crane) from the main beam of crane track into the breaking portal.

There were analysed together 9 beam sections of crane track with 18 000 mm long beams (from this number 5 beams were equipped with braking portal) and one analysed beam section was different from all others; it was 36 000 mm long.

All experimental measurements were performed only from one side of crane track because of their accessibility, as well as due to very strong safety rules in the metallurgical plant. Thus, all data necessary for calculation were transformed suitably also to the opposite part of given investigated crane track.

[1] prof. Ing. Peter Bigoš, CSc.; Technical University of Košice, Faculty of Mechanical Engineering; Department of Machine Design, Transport and Logistics, Letná 9, 042 00 Košice, Slovak Republic, peter.bigos@tuke.sk
[2] doc. Ing. Jozef Kuľka, PhD.; jozef.kulka@tuke.sk
[3] doc. Ing. Karol Kubín, CSc.; karol.kubin@tuke.sk
[4] Ing. Martin Mantič, PhD.; martin.mantic@tuke.sk
[5] Ing. Melichar Kopas; melichar.kopas@tuke.sk

Figure 1: *Single beam 18 000 mm long with braking portal .*

3. Calculation analysis of crane track loading

The main purpose of this analysis was to calculate the time behaviours of dominant loadings arising during travel of crane with the 20 t lifting capacity. The crane was equipped with a load, which was equal to the crane's lifting capacity and in this way it was possible to compare measured data obtained from the tensometric measurement with expected calculated values.

There was applied the FEM methodology and as an instrument was used the software product COSMOS/M.

3.1. Geometric model

The used geometric model is created as a 3D-model, which is characterised by centre line surfaces of flanges, together with longitudinal and transversal stiffeners. All the important dimensions are obtained from measuring on the real crane track and they are given on the Figure 2.

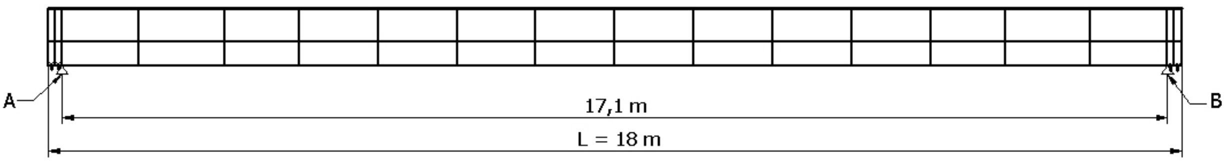

Figure 2*: The main dimensions of one crane track section with length 18 000 mm .*

3.2. Model of finite element network

There were applied next two kinds of elements for model of finite element network:

a) Shell 4T – shell thick-walled elements for simulation of web-plate, flange belts, longitudinal and transversal stiffeners,
b) Beam 3D – beam elements for simulation of rail and for clamping screws between crane track and columns.

There is illustrated model of finite element network on the Figure 3 with coloured distribution according to stiffness constants.

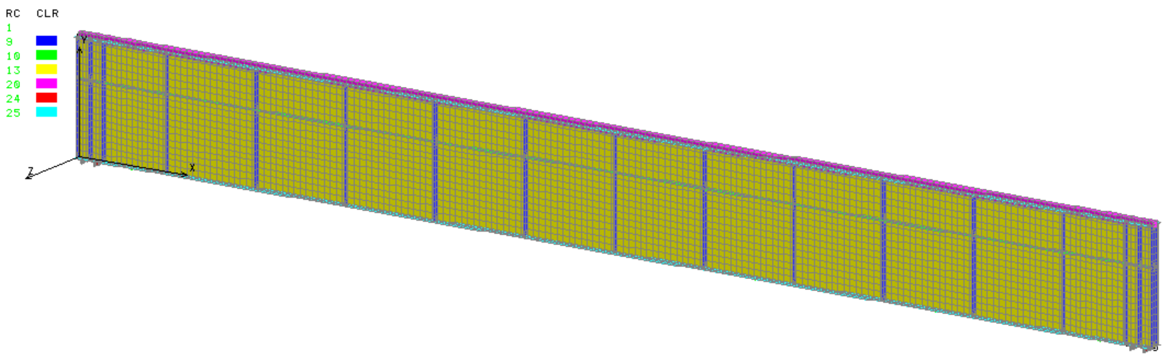

Figure 3: *Global view of the network model of a crane track section with length 18 000 mm .*

3.3. Bindings and loading

The bindings were defined in the supporting points of beam in vertical direction in the contact edge between beam and supporting column of the crane track, taking into consideration end of bolts with regard to the column in order to perform the correct calculations.

The loading was simulated as a fixed twin-force F1 and F2 corresponding to the crane wheel pressures with lifting capacity 20t.

3.4. Elaboration of results obtained from computational analysis

The results of calculation, by means of the FEM, were elaborated in the form of longitudinal normal stresses σ_x caused due to bending loading of the crane track according to the orientation of strain gauge sensors applied during the tensometric measuring.

4. Tensometric measuring

On the basis of previous computational analysis and visual inspection of crane track was suggested a methodology of experimental determination of deformation and afterwards also determination of stress state. The sensors were applied on individual beams with regard to their accessibility, as well as according to the foregoing theoretical analyses. There is an example of sensor layout on the beam sections with and without braking portal on the Figure 4 and Figure 5.

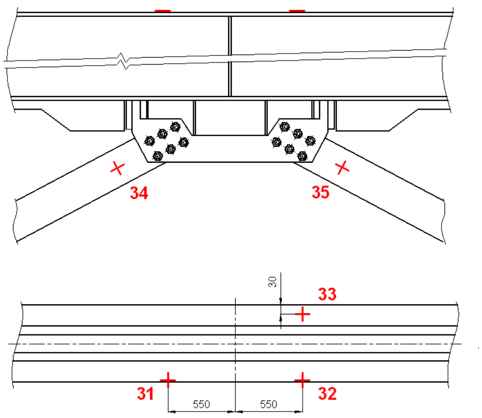

Figure 4: Arrangement example of stress gauge sensors on beam with braking portal .

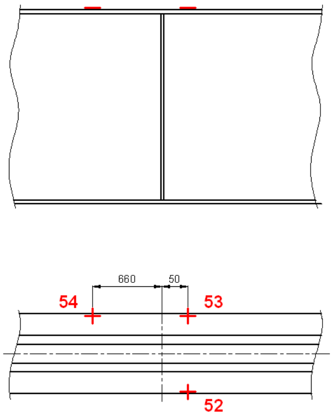

Figure 5: Arrangement example of stress gauge sensors on beam without braking portal .

There were applied stress gauge sensors HBM 6/120XY11 with ohmic value 120 Ω, with constant of deformation sensitivity 2,04 and by means of tensometric glue HBM X60. Interconnection between sensors and measuring apparatus was realized with a shielded transmission line. Assembly of measuring amplifier and measuring chain is arranged according to the Figure 6.

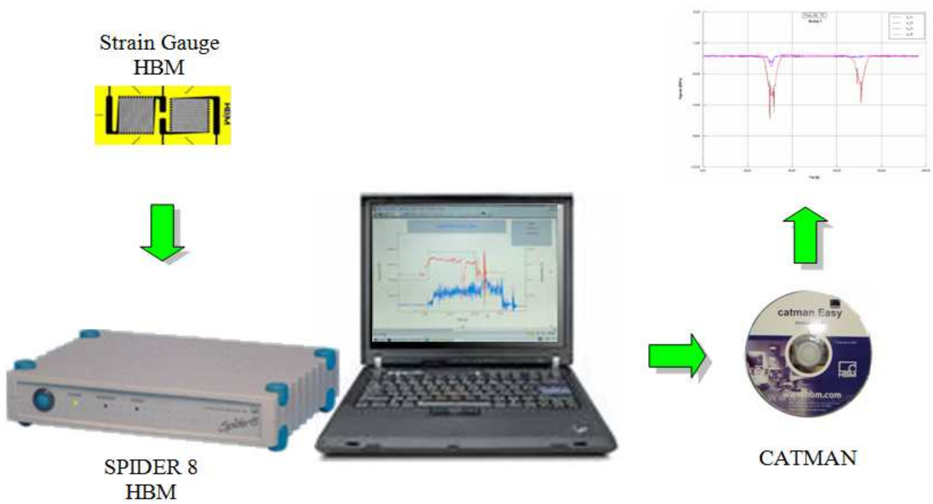

***Figure 6:** Measuring amplifier and measuring chain .*

The used amplifier with A/D converter is the SPIDER 8 from the HBM company. After balancing of the measuring device were all sensors coated with the protecting film SG 250 (from the HBM company).

The time behaviours of normal stress increments were obtained and evaluated by means of the CATMAN software from the measured values of relative deformation increments in the given measuring points during individual operational regimes. There were performed 3 measuring regimes for each of analysed beam section, i.e. 124 graphical records of time behaviours were obtained totally. The Figure 7 presents time behaviour of normal stress increments in the case of one analysed beam section of the crane track.

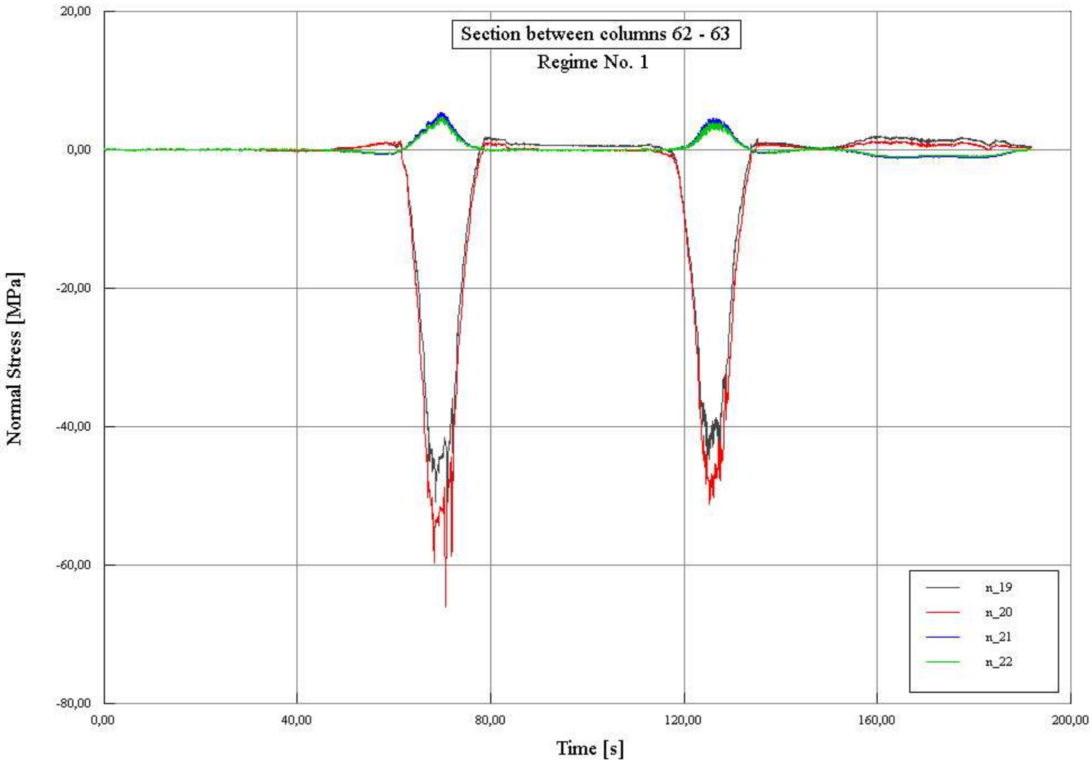

Figure 7: *Time behaviour of changes of normal stress increments .*

5. Cumulation of fatigue damage – residual durability

For determination of fatigue damage is decisive the technical standard STN 73 1401. The main purpose of verification process of construction with regard to the fatigue limiting state is to ensure, with an acceptable probability, in order that the construction will not be damaged or cracked due to fatigue during the time period of projected durability.

Important input information for calculation of residual durability is the total number of loading cycles of beams during the whole operational life of the crane track, i.e. during the long time period of years 1966 ÷ 2007. The results of loading cycles analysis of the given crane track is summarized in the Table 1. Theses results are distributed according to the individual beam sections among columns. This table creates a base for estimation of residual durability.

Table 1: *Number of cycles according to the beam sections among columns .*

Beams among columns	**Number of cycles during years 1966 ÷ 2007**	
	Operation of cranes with average load 11 000 kg (n_1)	**Operation of cranes without load (n_2)**
50 ÷ 58	146 848	146 848
58 ÷ 68	3 181 705	3 181 705
68 ÷ 75	1 566 378	1 566 378
Totally	4 894 931	4 894 931

Important input for determination of residual durability of selected crane track beams were results obtained from the measured time behaviours of normal stress increments, as well as there were used calculation performed according to the standard STN 73 1401. With regard to this technical standard it is necessary to select number of detail ČD 206 with the detail's category KD 125 for a single beam of the crane track without a braking portal. In the case of beam with the braking portal it is ČD 403 and KD 50. There are given in the Table 2 data for determination of fatigue durability for the KD 50 and KD 125

Table 2: *Numerical values of used fatigue curves .*

<table>
<tr><th rowspan="3">Loading of detail</th><th rowspan="2">Category of detail CD</th><th colspan="3">Stress amplitudes for</th></tr>
<tr><th>$N_{M,KD}$</th><th>$N_D = 5.10^6$</th><th>$N \geq N_L = 10^8$</th></tr>
<tr><td>$\Delta\sigma_C$ (MPa)</td><td>$\Delta\sigma_{M,KD}$ (MPa)</td><td>$\Delta\sigma_D$ (MPa)</td><td>$\Delta\sigma_L$ (MPa)</td></tr>
<tr><td rowspan="2">Normal stress</td><td>50</td><td>452</td><td>37</td><td>20</td></tr>
<tr><td>125</td><td>232</td><td>92</td><td>51</td></tr>
</table>

Next step was calculation of total cumulation of fatigue damage due to manipulation with load and without load according to the STN 73 1401. The results for individual beams are summarized in the Table 3.

Table 3: *Summarized results for individual beams .*

Analysed beam section	**Beams among columns**	**Cumulation of fatigue damage**
1	50 -51*	0,870
2	55 – 56*	0,667
3	62-63*	7,700
4	69-70*	5,838
5	74-75*	0,890
6	58-60	infinite
7	66-67	1,300
8	68-69	1,245
9	72-73	infinite
10	73-74	infinite

Note: index * is marking for beams with braking portal

6. Conclusion and suggestion of measures

There are next relevant final results and conclusions based on performed measuring, as well as taking into consideration valid technical standards and experimental data obtained from expert verification of actual technical state of the given crane track steel construction (see Table3):

- Single beams in the sections 3 and 4, that are supported with braking portals, have already exhausted totally their fatigue durability with survival probability 95% in the points of maximum loading or in the points of unfavourable notch case, for the given cadence of cycles. The visible fatigue cracks on the lower flanges, as well as on the web-plates, confirm this statement, see Fig.8. The prompt replacement of given beam section is necessary.

Figure 8: *Photo-documentation of failed single beam with braking portal .*

- Single beams in the sections 7 and 8, however without braking portals, have also exhausted, more or less, the fatigue durability with survival probability 95% in the points of maximum loading, for the given cadence of cycles. There are also visible fatigue cracks on the lower flanges of beams, as well as on their web-plates, Figure 9. Replacement of these beams is necessary in the nearest future.

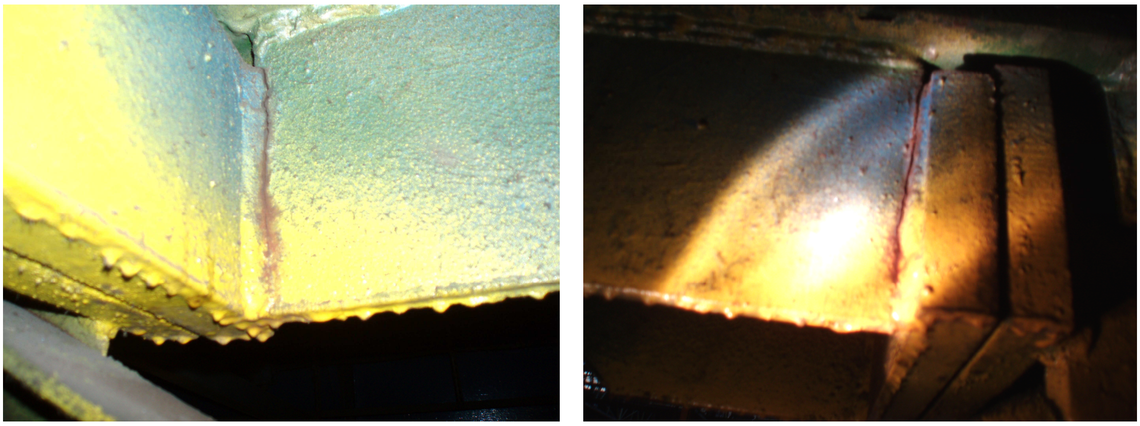

Figure 9: *Photo-documentation of failed braking portal .*

- Single beams in the sections 1, 2 and 5, that are supported with braking portals, haven't exhausted yet their fatigue durability with survival probability 95% in the points of maximum loading or in the points of unfavourable notch case, for the given cadence of cycles. The residual durability is about 10 ÷ 30%, i.e. approx. 4 ÷ 12 years of operation with present cadence of loading cycles

- The fatigue durability with survival probability 95% in the case of the last sections of single beams without braking portals (one of them is also beam with length 36 000 mm) is unlimited (near to infinity). These beams require only a common operational maintenance.

References

[1] Trebuňa, F., Bigoš, P.: Intenzifikácia technickej spôsobilosti ťažkých nosných konštrukcií. Košice, Vienala, 1998, 345s.
[2] Haibach, E.: Betriebsfestigkeit. VDI-Verlag GmbH Düsseldorf, 1989, 481 s.
[3] Haibach, E.: Die Schwingfestigkeit von Schweißverbindungen aus der Sicht einen örtlichen Beanspruchungsmessung. LBF – Bericht Nn. FB 77 (1968)
[4] Oliver, R., Ritter, W.: Wöhlerlinienkatalog für Schweißverbindungen aus Baustählen. DVS – Berichte Band 56 I bis V, Deutscher Verlag für Schweißtechnik, Düsseldorf (1979-1985)
[5] Haibach, E., Oliver, R.: Streuanalyse der Ergebnisse aus systematischen Schwingfestigkeit Untersuchungen mit Schweißverbindungen aus Feinkornbaustahl. Materialprüfung 17(1975)Nr.11, 399-401 s.
[6] STN 731401: Navrhovanie oceľových konštrukcií. 1998, 181 s.
[7] Bigoš, P., a kol.: Tenzometrické meranie žeriavových dráh v lodiach C-D, D-H stĺpy č.14 – 40 v prevádzke Narážacie pece a príprava vsádzky na DZ TV. Košice, TU SjF KKDaL, 2002, 74s.
[8] Bigoš, P., a kol.: Tenzometrické meranieUSSK žeriavových dráh v lodi B-C stĺporadie B, Stĺpy č.69 – 70 na prevádzke Expedícia TVa na DZ Teplá valcovňa. Košice, TU SjF KKDaL, 2006, 84s.