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Measurement of Response Distribution on Mass Crossbeams in Dependence on Load Position

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Abstract. The article deals with experimental measurement of three design variants of construction hoist masts. There is described methodology of measurement and marking of measured places. All three masts were experimentally tested by means of strain gauge measurement and results are discussed.

Introduction

There is a demand on higher load capacity of construction hoists due to increasing productivity of construction work. Manufacturers of hoists want to satisfy this demand by innovation of masts, but they are limited by connection dimensions of nowadays used masts so the old and new masts could work together. Usage of construction hoists is shown on Fig. 1.

Fig.1 Photos of construction hoists [1]

Variants Description

In earlier published article [1] is described FEM analysis of original mast (variant A) and modified masts (variant B and C). Selection of measuring points was made on base of this analysis. Reason for this measurement was getting information about distribution and magnitude of deformation of mast crossbeams in different operational modes.

The variant marked as A is original construction which started to lose its reliability due to increased load capacity of construction hoist (see Fig. 2). The variant marked as B is based on variant A. Middle crossbeam shape was changed so half of its length is C profile and half is L profile and it is made from bent sheet metal. Top and bottom crossbeam is closed by a second L profile from bent sheet metal and welded to original rolled L profile. The variant marked as C is based on variant B. Top and bottom crossbeam has been changed from closed shape to C profile from bent sheet metal. Middle crossbeam is same as at variant B [1].

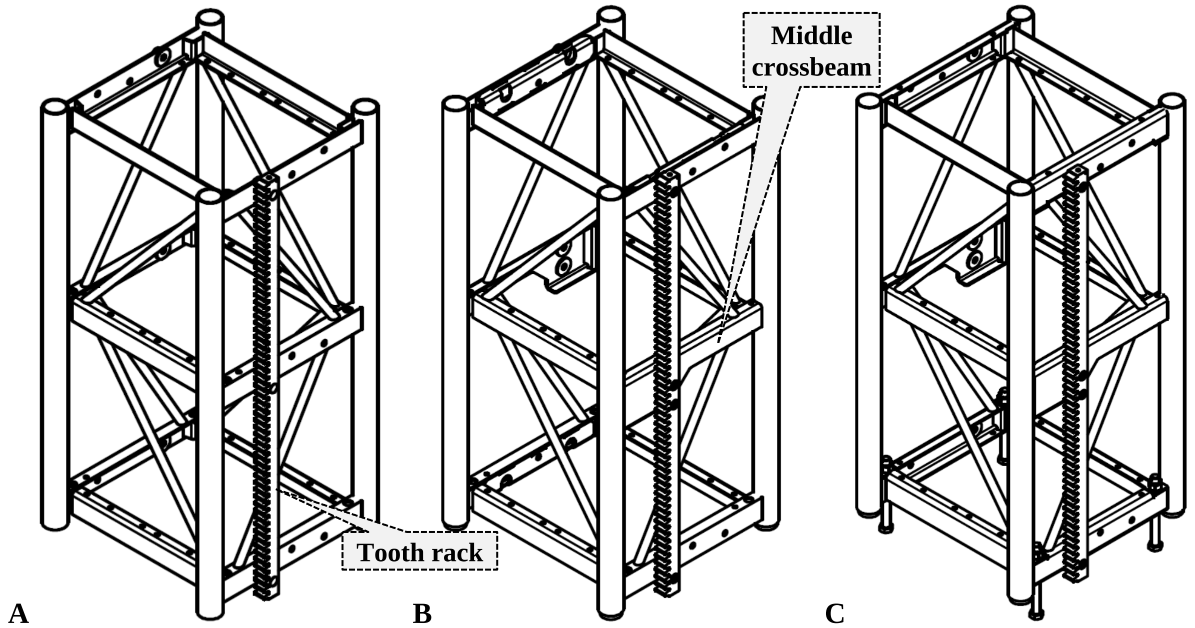

Fig.2 Mast variants (A – original, B – closed profile, C – C-profile) [1]

Measurement methodology

Relative deformation ε was chosen as measured magnitude to evaluate reaction of crossbeams on load.

Measurement was carried out via strain gages 1-LY11-6/120 (HBM). Position of load (position of cage pulleys) was sensed with strain gages placed on tooth rack for all measurements (see Fig. 3).

Measurement was carried out for these load levels: empty cage, cage with set of weight 3 200 kg and cage with set of weight 3 900 kg. Sample rate was set at 10 kHz. Measurement was carried out during following operational modes: going up and down, braking via instantaneous safety gear, loosen tooth rack and not adjusted pinions. There were used 6 strain gages on each variant of mast on crossbeams and 3 strain gages at tooth rack near tooth root.

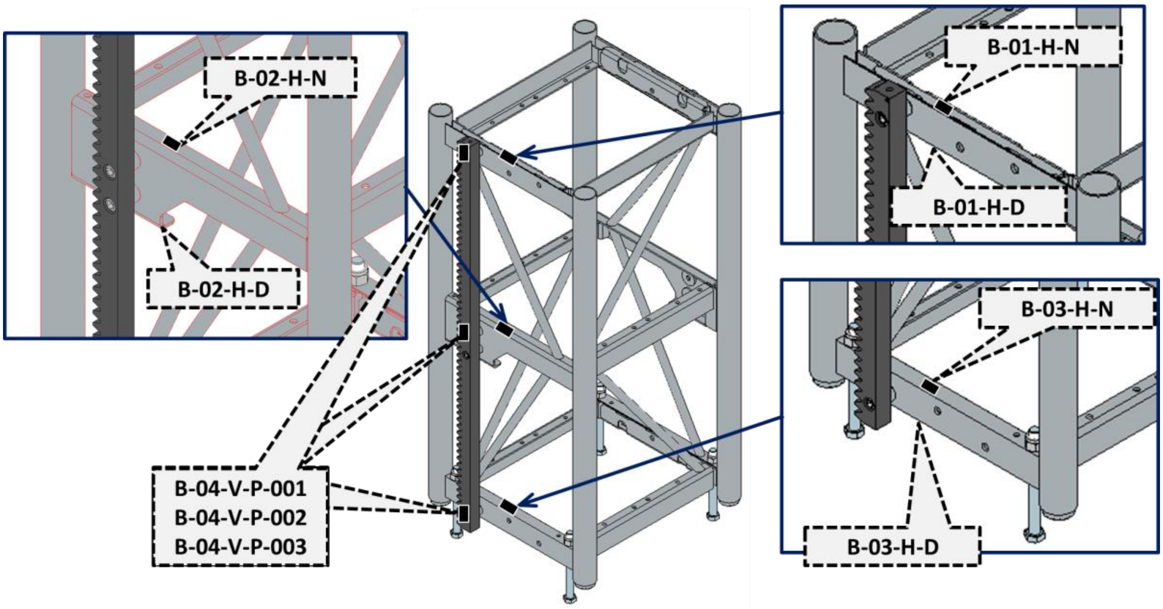

Fig.3 Indication of strain gages placed on tooth rack and on hoist variant B

There are in bellow mentioned examples represented measured data from middle crossbeams, specifically from upper strain gages marked as (A-02-H-N; B-02-H-N and C-02-H-N). First letter determines hoist variant, two digits determines position of crossbeam, letters H and V determines orientation (H – horizontal or V – vertical) and last letter determines upper (N) or lower (D) flange.

Measurement example 1 – Going up and down with full speed and maximal set of weight 3 900 kg

There is shown time behavior of relative deformation at middle crossbeam (Fig. 2) in Fig. 4 for variants A, B and C. Measured values of individual variant were for going up and down following: ε_A = 288.5 / 139.0 μm/m; ε_B = 380.2 / 319.5 μm/m; ε_C = 212.9 / 253.6 μm/m.

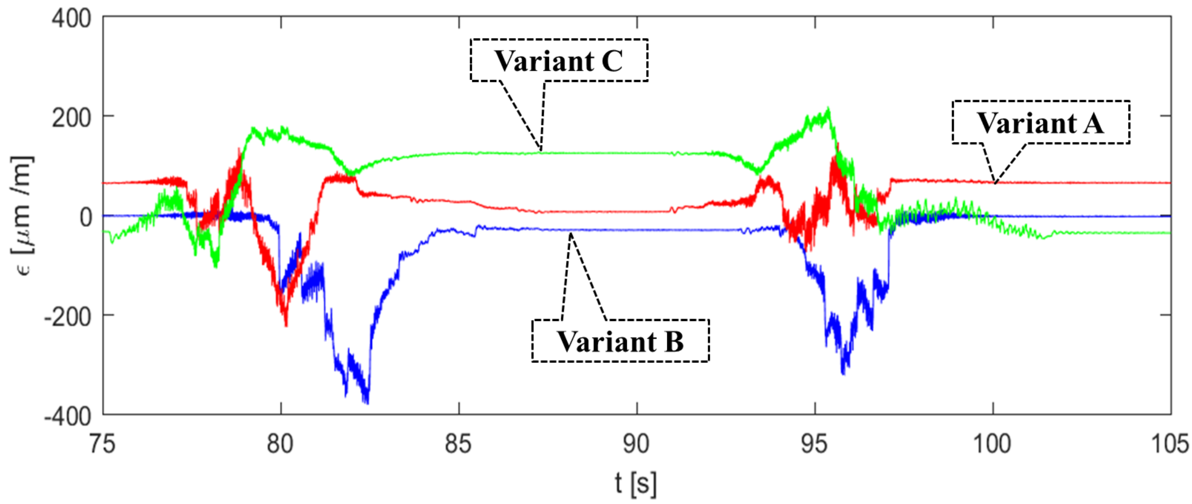

Fig.4 Deformation behavior at middle crossbeam for variants A, B and C – Going up and down with full speed and maximal set of weight 3 900 kg

Measurement example 2 – Going up and down with full speed and empty cage

There is shown time behavior of relative deformation at middle crossbeam in Fig. 5 for variants A, B and C. Measured values of individual variant were for going up and down following: ε_A = 166.6 / 81.8 µm/m; ε_B = 191.8 / 157.2 µm/m; ε_C = 126.2 / 81.8 µm/m. Behavior is of a same shape as with maximal set of weight (Fig. 4), but with lower amplitude values.

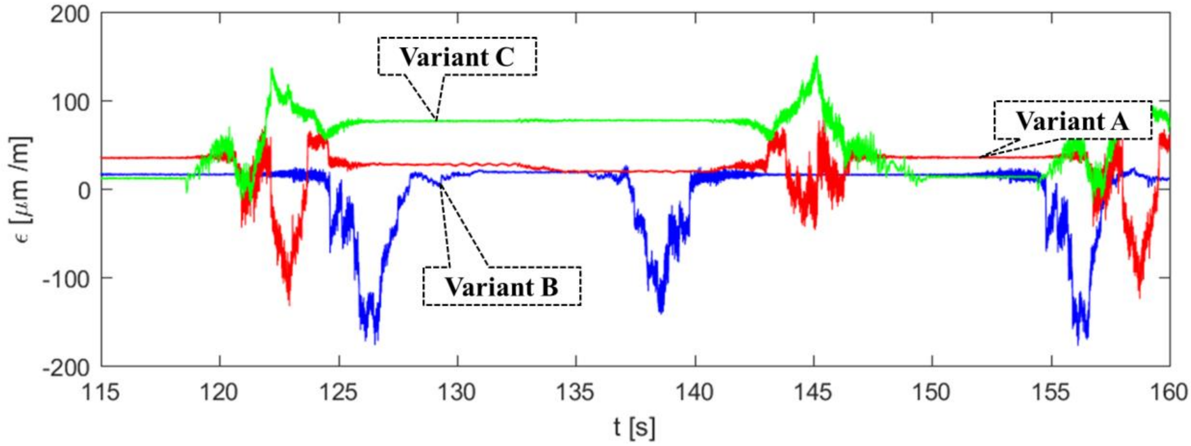

Fig.5 Deformation behavior at middle crossbeam for variants A, B and C – Going up and down with full speed and empty cage

Measurement example 3 – Going up and down with full speed and maximal set of weight 3 900 kg, loosened tooth rack

There is shown time behavior of relative deformation at middle crossbeam in Fig. 6 for variants A, B and C. From comparison of Fig. 4, Fig. 5 and Fig. 6 follows, that if there is change (not significant) of load distribution among individual crossbeams, it is given by lowering of bend stiffness of tooth rack and crossbeam. Not enough measuring channels were available during measurement (they were used for measurement of other strain gages), so data for middle crossbeam of hoist variant B is missing. Measured values of individual variant were for going up and down following: ε_A = 336.9 / 135.8 µm/m; ε_C = 208.6 / 262.9 µm/m.

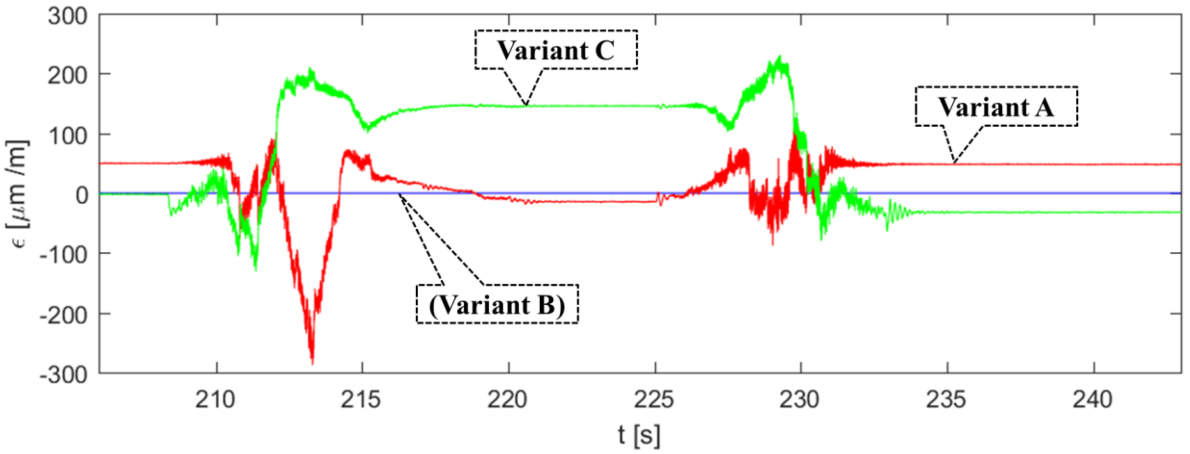

Fig.6 Deformation behavior at middle crossbeam for variants A and C – Going up and down with full speed and maximal set of weight 3 900 kg, loosened tooth rack

Measurement example 4 – Activation of instantaneous safety gear in upper half of hoist A

This measurement was carried out for mapping transient performance, which can came during instantaneous safety gear activation. Hoist variants were placed at each other in order from top: B, A, C. Fig. 7 shows as expected swing of measured strain behavior with following

damping to static load from cage weight. This dynamic impulse caused crossbeams of hoist B to oscillate. Hoist C has minimal oscillation.
Measured values were following: ε_A = 488.7 µm/m; ε_B = 247.1 µm/m; ε_C = 101.3µm/m.

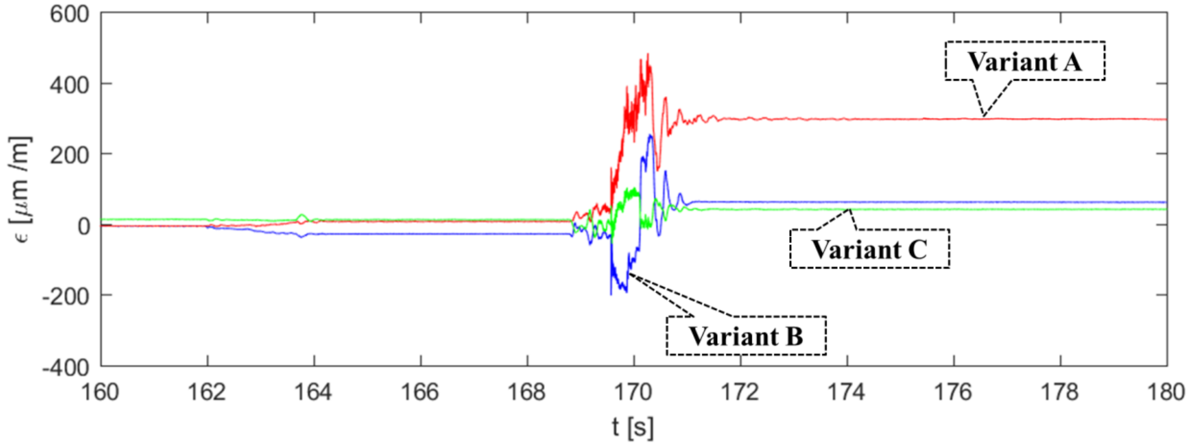

Fig.7 Deformation behavior at crossbeam for variants A, B and C – Activation of instantaneous safety gear in upper half of hoist

Discussion

Fig. 4 shows maximal values of amplitudes and time behavior of relative deformation during run. It is obvious that crossbeams reacts on cage passing differently (different crossbeams design and different tooth rack interaction with crossbeams).

Important fact is oscillation of some signals around zero value. This is not detected at crossbeam variant B (see Fig. 4 – 6), that has top and bottom crossbeam from closed profile. These profiles shows stability and do not vibrate. Moreover the stepped load from 3 pinions during cage passing is very well visible. It is most important for dynamical analysis evaluation of crossbeams, that load has pulsation cycle character i.e. from zero to maximum. When there is oscillation of signal around zero value, it is usually asymmetrical oscillating cycle.

Table 1. contains maximal values of relative deformations, which were measured with strain gages during different load levels (Example 1 – 4).

Tab. 1 Comparison of measurement results of individual variants

Variant	Example 1		Example 2		Example 3		Example 4
	up	down	up	down	up	down	
A	288.5	139.0	166.6	81.8	336.9	135.8	488.7
B	380.2	319.5	191.8	157.2	-	-	247.1
C	212.9	253.6	126.2	139.4	208.6	262.9	101.3

Strain gauges shows deformation in longitudinal direction of flange, which most corresponds with bend of crossbeams. Diagrams in Fig. 8 and Fig. 9 shows, that lowest bending stiffness shows hoist A. The highest bending stiffness shows hoist C.

Influence of loosened tooth racks and not adjusted pinions in not significant. Loosened tooth racks fit closely to bolts at all places similar, so the load is distributed equally analogously as with properly tightened tooth racks.

Important information from measurement with activation of instantaneous safety gear is that dynamical load to hoist is approximately twice as much as during service run. However activation of safety gear is not common during service run.

Diagrams in Fig. 8 and Fig.9 show proportion of relative deformations among hoists A, B and C.

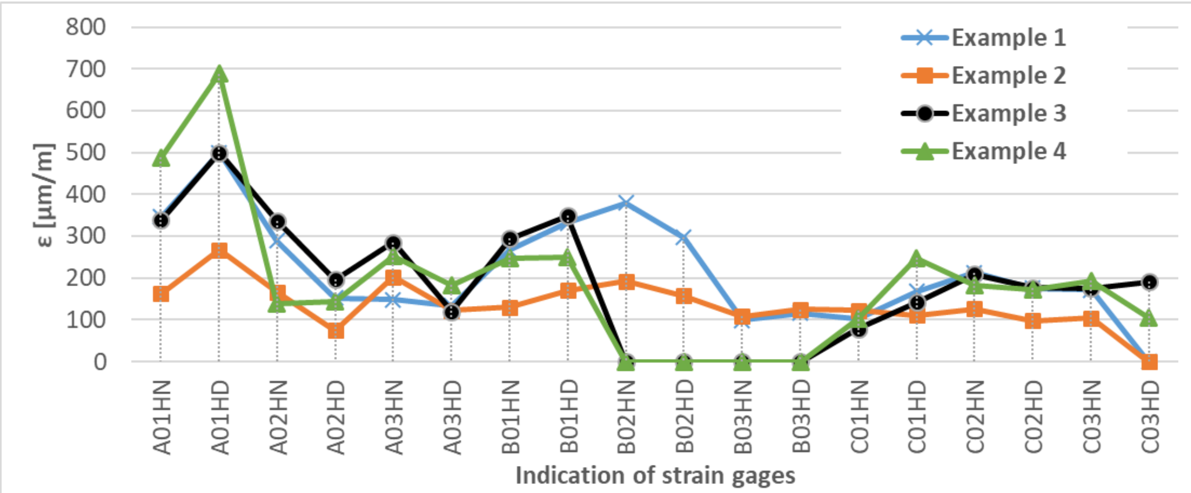

Fig.8 Review of measured relative deformations during different service runs – going up

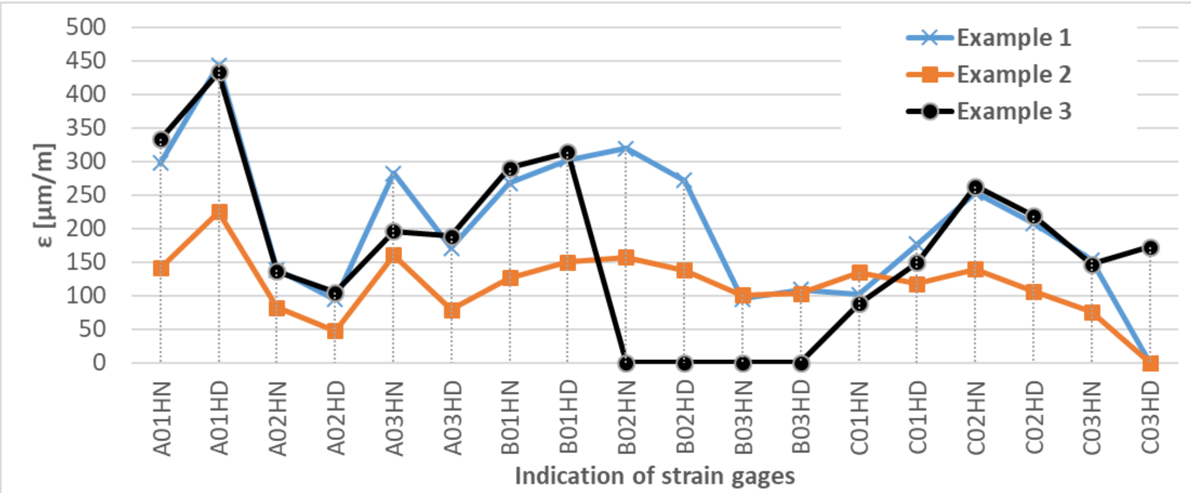

Fig.9 Review of measured relative deformations during different service runs – going down

Conclusions

One of important crossbeam property was their attenuation behavior after cage passing. Best attenuation results had crossbeam B, which has closed profiles. It´s top and bottom crossbeams reacts only by increasing of relative deformation during cage passing and it´s dropping to zero after unloading – it had character of pulsating cycle. Other variants of crossbeams oscillates around zero values – they had character of oscillating cycle.

Simulated assembly mistakes (loosened tooth racks and not adjusted pinions) did not influence load of hoist significantly. Load is distributed in similar way as when the assembly is correctly done.

References

[1] STARÝ, F., PETR, K., DUB, M., et al. Comparison of Different Construction Hoist Masts by FEM Analysis. In: Proceedings of 58th International Conference of Machine Design Departments – ICMD 2017. 58th International Conference of Machine Design Departments. Prague, Horoměřice, 06.09.2017 - 08.09.2017. Prague-Suchdol: Faculty of Engineering. 2017, s. 344-347. ISBN 978-80-213-2769-6.