608. Experimental research of steel rope dynamic properties

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Abstract. This paper is intended to reveal possibilities to find defects in steel ropes using dynamic properties of tensed steel rope in special test rig. For this purpose special test rig was designed and build. During experimental test rope dynamic properties was estimated depending from excitation frequency, also including influence of frame dynamic properties. Finally, results are given and conclusions are made.

Keywords: rope, defects, diagnostics, dynamical properties.

Introduction

Steel ropes are frequent element in technical design and widely used as flexible link in transmission. Flexibility and one side force transmitting property enabling to use them in many various applications, but mostly they are used for lifting devices, load carrying. Human transporting equipment, like lifts, rope trains are types of transportation where only ropes can be used. Also ropes are used for static load transmitting – tensing towers, bridges, electric lines [1, 4].

Modern rope is consisting from 3 parts (fig. 1) core, strand and wire [1, 3].

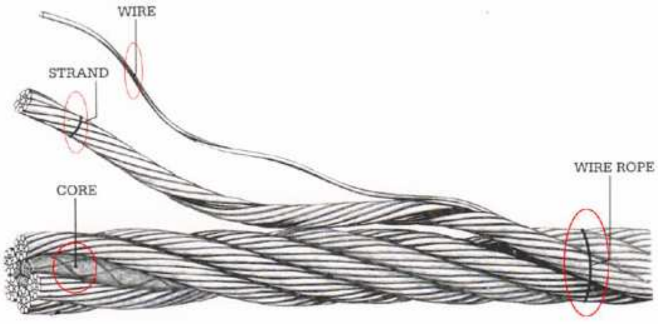

Fig. 1. Design of modern steel wire rope

Steel rope strands and wires have unified shape and are produced from high quality steel. Strands are wired in the same or in the contrariwise direction to wire rotation, depending on type of rope. Core of rope is produced of synthetic fiber and filled with lubricant, which lubricates wires of rope during tension and rope operation.

Steel rope are produced with high technology, but nevertheless during lifetime period from mechanical impact, chemical surrounding and temperature change rope material start deteriorating and defects start developing. Main rope defects are shown in fig. 2, which can be split into two classes – rope running defects (fig. 2 a – c) and rope material defects (fig. 2 – d). Both classes of defects are dangerous and should be detected on time.

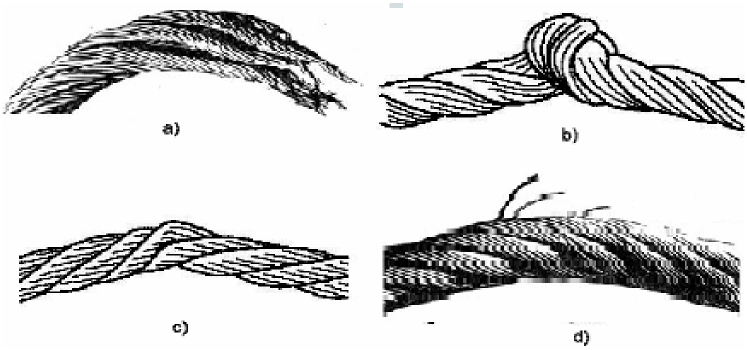

Fig. 2. Wire rope defects: a) – separated strand, b) – twisted rope, c) – kinked strands, d) – broken strand wires

Defect finding is sophisticated process, and there a lot of methods are used. Mostly popular and technically simple is optical observation method [2, 3], when experts evaluate quality of rope by observation, but this is costly and quite inefficient. Also, this method is not applicable for mounted ropes, where expert cannot access.

To modify such method is used electromagnetic method of rope control, which is presented in fig 3 [5] and tries detect of rope defect by evaluating electric signal from sensor system. Such methods use permanent magnets, which creates permanent magnetic field in the rope and measuring process senses for magnetic field change around the rope outer surface.

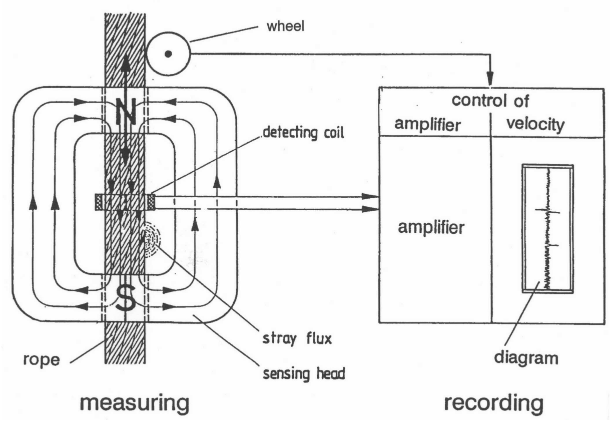

Fig. 3. Diagnostic electromagnetic inspection of rope

Method of magnetic flux method is based on three parameter measurements: a) magnetic flux change about broken wire (LF) and defects of strand, b) magnetic flux change in cross direction of rope (LMA), c) magnetic flux change in longitudinal direction. The last method is usable in whole rope testing and uses permanent magnets, and applicable in broken wire or corrosion made hole detection by magnetic flux or flux change detection.

This method find defect when rope with defects passes magnetic head and create signal change. There are used various type of sensors [2, 4, 5].

Purpose of research

This research was intended to find dynamic characteristics of rope and rope test rig in order to create method and experimentally prove possibility to find rope defects using dynamical property change. As a basis for such research is used stiffness change in transversal and longitudinal direction, and, as a result, change of natural frequencies of the system [6, 7].

$$y_1^* = \sum_j a_{ij} p_{Hj} \tag{1}$$

$$p_{Hj} = \sum_i b_{ij} y_i^* \tag{2}$$

$$w_k = \delta_k j + w_{k0} \sqrt{1 - \left(\frac{\delta_k}{w_{k0}} \right)^2} \tag{3}$$

Where δ – overall k system stiffness

j – Complex index

w – Frequency of the system k degree of freedom

As stated in formula (3), state of system will be defined by parameters, expressed as experimentally defined frequencies.

Research test rig and methodic of research

To perform this research was designed and build test rig, which is shown in fig. 4. This test rig has massive body, made from cast iron and has mass approx 200 kg. Body is placed on the concrete floor through flexible support, which enables to filter out vibrations from the floor and surrounding.

Fig. 4. Test rig for rope dynamical properties experimental research: 1 – test rig body, 2, 3 – rope supports, 4 – rope, 5 – sensor frame

Steel rope of 4 mm is attached to rope supports 2, 3, which can only free vibrate in transversal direction, longitudinal direction is restricted. Transversal vibration of rope was measured by inductive contactless relative vibration sensors„Hottinger Tr4, which was mounted on sensor frame 5. Rope was excited through frame by harmonic oscillation of prescribed frequency by electro dynamic exciter, running from generator through amplifier.

For experimental research of steel rope properties was used equipment of Danish firm "B&K" vibration measurement toolbox (fig. 5), which was used to excite system and collect data from mounted sensors.

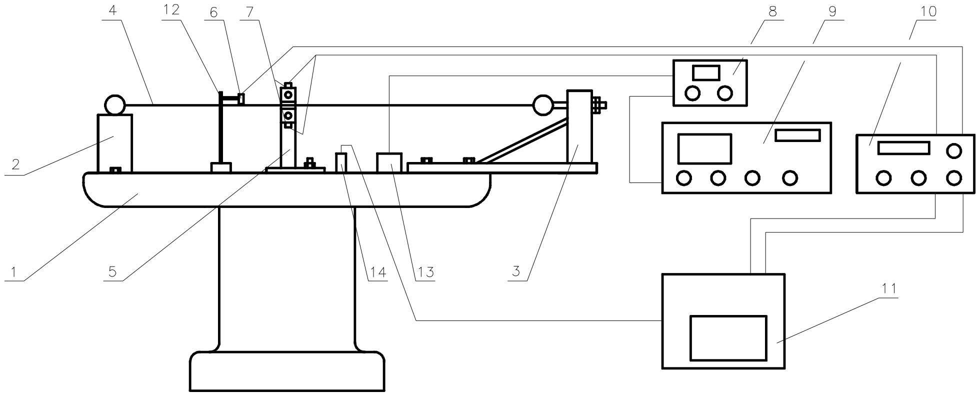

Fig. 5. Test rig vibration measuring diagram: 1 – test rig body, 2 – rope support, 3 – rope support, 4 – test rope, 5 – sensor TR4 frame, 6 – linear displacement transducer „Hottinger Tr102“, 7 – linear displacement transducer „Hottinger Tr4“, 8 – exciter amplifier 2706, 9 – generator for electro dynamic mini exciter type 1027, 10 – amplifier „Hottiger KWS 503 D“, 11 – machine diagnostics toolbox Type 9727“with laptop DELL, 12 – sensor TR102 frame, 13 – electro dynamic mini exciter type 4810, 14 – accelerometer type 8341

During experimental research rope (4) was fixed between supports (2) and (3) and tensed with 200 N forces. Dynamic excitation of this system was performed by exciter (13) tightly fixed to the frame (1), which was driven by generator 1027 (9) through amplifier 2706 (8). When vibrational exciter (8) was on, vibrations of test rig body (1) was measured by accelerometer 8341 (14) and test rope (4) vibrations was measured using linear displacement transducers „Hottiger Tr102“(6) and „Hottiger Tr4“(7), which was fixed in sensor supports (5) and (12). Signal form linear displacement transducers (6) and (7) through amplifier „Hottiger KWS 503 D“ (10) was send to portable measuring processing toolbox „Machine Diagnostics Toolbox Type 9727“ (11).

Results of such measurement were processed using packages Origin 6.1 and Pulse. There were defined spectrums of vibrations, its distributions and statistical parameters (arithmetic mean, the standard deviation and the standard deviation of the mean) (4):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i, \quad S_X = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}, \quad S_{\bar{X}} = \frac{S_X}{\sqrt{n}} = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}, \tag{4}$$

where n – number of measurement results, x_i – ith measurement result.

Results of experimental research

Results of measurements and data processing are presented below.

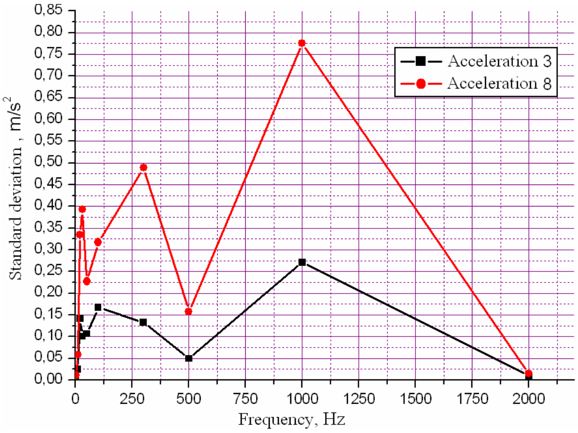

Fig. 6. Dependency of acceleration from accelerometer 8341 and standard deviation of acceleration Sx from exciting frequency, when gain is equal to 3and 8

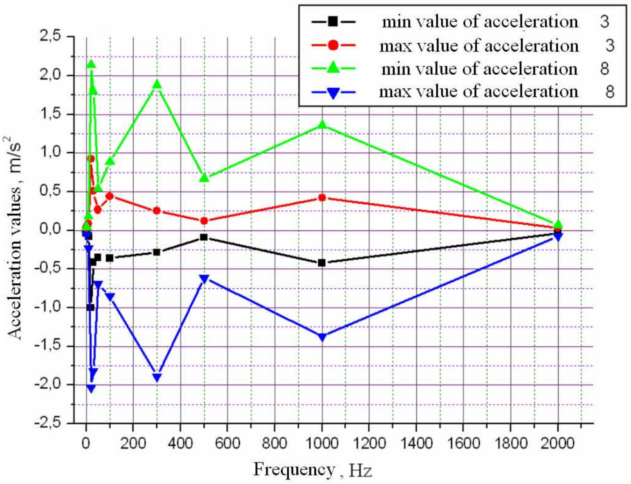

Fig. 7. Minimal and maximal acceleration values from accelerometer 8341 dependency to different excitation frequencies, when gain is equal to 3and 8

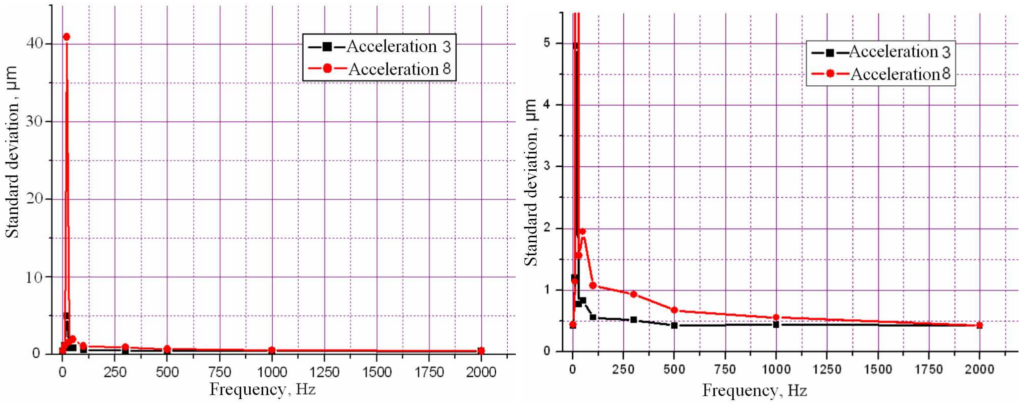

Fig. 8. Inductive displacement transducer Tr4 signal and standard deviation of it Sx dependency to different excitation frequencies, when gain is equal to 3and 8

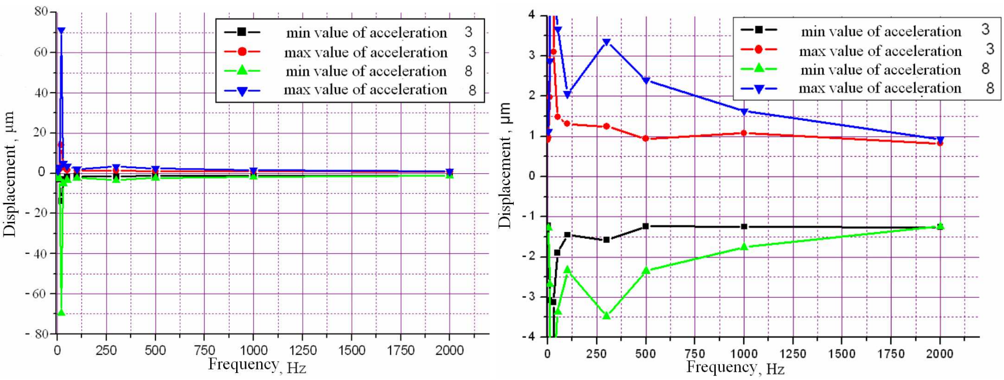

Fig. 9. Minimal and maximal acceleration values from displacement transducer Tr 4 dependency to different excitation frequencies, when gain is equal to 3and 8

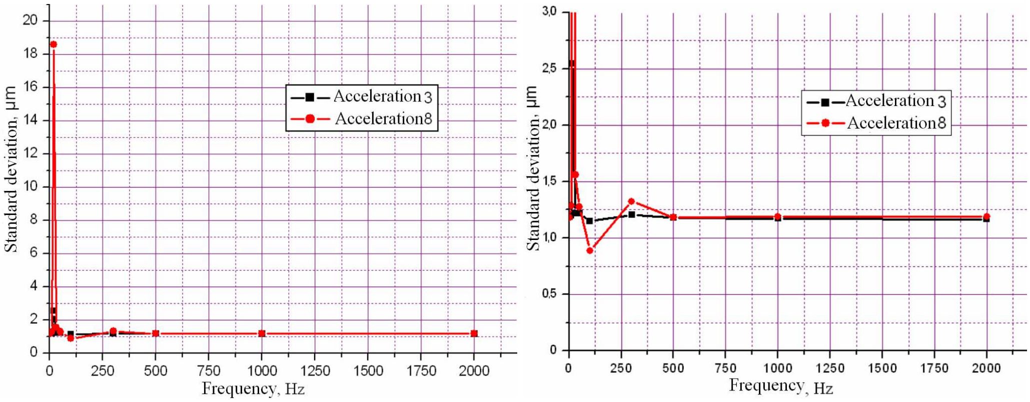

Fig. 10. Inductive displacement transducer Tr102 signal and standard deviation of it Sx dependency to different excitation frequencies, when gain is equal to 3and 8

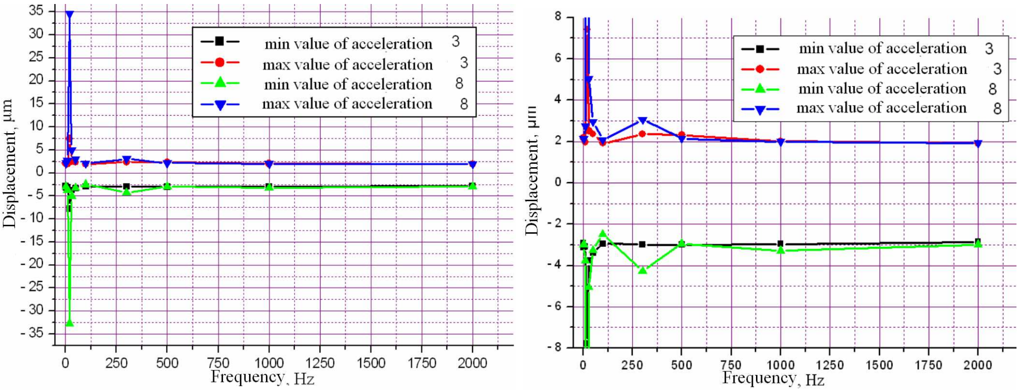

Fig. 11. Minimal and maximal acceleration values from displacement transducer Tr 102 dependency to different excitation frequencies, when gain is equal to 3and 8

Conclusions

Performed experimental research brings some information about dynamic properties of tensed rope system. Such system diagnostics initial step shows:

1. Rope system is excitable via harmonic excitation of test rig frame and sensitive in desired area of frequencies.
2. Relative vibration of rope to sensor support is significant and big enough to measure and analyse.
3. Natural frequency of test rig not prevents rope system analysis.

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