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Multi-sensors measuring system for geodetic monitoring of elevator guide rails

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ABSTRACT

The elevator guide rails geometry, which covers such features as rectilinearity, verticality, parallelism and span, is of key importance as uninterrupted, failure-free operation of elevators and safety of elevators' users are prerequisites. The geometric parameters have to measured and controlled periodically according to elevators industry standards. The paper discusses the construction and principles of operation of developed Multi-Sensors Measuring System (MSMS) in the control of geometric parameters of elevator guide rails. The system is made of laser rangefinders and two laser emitters with a collimation system. To detect and register the location of laser spots the system uses CCD/CMOS detectors. The elements of the system are deployed in the elevator shaft. This solution allows you to control the position of the laser beams in the external reference system and to determine the torsion angles of the guide rails in the elevator shaft. Algorithm and data processing chain are also provided in the paper. The experimental results demonstrate that the system ensure elevator check according to current industry standard.

1. Introduction

Elevators facilitate vertical communication in buildings (Fig. 1) between floors and are means of transport in mines. Depending on the size of the object, guide rails may be even a few hundred meters long. The geometry of elevator guide rails is affected by annual and seasonal (winter-summer) temperature changes and other environmental factors which include thermal, wind, dynamic and seismic loads, etc. To ensure safe use, elevators are subject of periodic control measurements.

The issue of measurement is regulated by legal and technical provisions included in the international [1], European [2–5], national [e.g. 6] and industry standards [7]. The standard EN 81-20/50 [3] will be adopted on a global scale, not only in Europe. This law was started from the 1st of September 2017 and is the only binding standard.

Professional literature broadly discusses measurements of mine shafts and elevators [8,9], rectilinearity measurements of elongated objects, in particular measurements of various types of guide rails: railways [10,11], crane rails [12,13], elevator rails (which are installed in buildings [14,15], in mine shafts [16] or in drilling platforms [17] and machines [18–20]. These measurements are performed to ensure safety and failure-free operation of devices that co-operate with guide rails [21]. Measurements are taken using both geodetic and non-geodetic methods, and professional equipment [12,15,20,22,23]. Parameters which describe correct location of guide rails include: rectilinearity in the horizontal and vertical plane, parallelism, span and verticality [11,14,15].

Measurements are typically taken in the local coordinate system which should allow for obtaining high accuracies of establishing positions of survey points which represent the measured elongated elements. In accordance with the applicable regulations [2,7], the measurement accuracy depending on the type of guide rails averages between a few millimeters (e.g. for railways, crane rails and elevator rails) and thousandths of a millimeter (for machines).

The measurements methods incorporate methods that rely on orthogonal measurements (e.g. constant straight method, mono-photogrammetry) [14,22], methods that apply polar measurements (e.g. measurements using a theodolite or a total station, terrestrial laser scanning) [11,12,13]. Depending on the size and object accessibility, the applied methods may be direct if there is a contact with survey points [11,12] or indirect – if there is no contact with survey points [15,24].

The constant straight may be realized using the laser beam, the axis of optical geodetic instruments and guide invar wires [23].

The photogrammetric method may be used as an independent measurement method [15]. It can also be used jointly with orthogonal and polar geodetic measurements [24]. Integration of measurement

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Fig. 1. Panoramic elevators, Ottawa, Ontario, Canada (https://pl.wikipedia.org/wiki/Winda).

results depends on location of the measuring equipment on the surveyed object [14,15,22,24].

In order to ensure safe operation of elevators various control-survey systems were designed and built. Their elements are located in various places of the elevator shaft [15,25].

Currently available on the market digital measuring techniques (e.g. CCD camera, laser rangefinder) and wireless data transmission (e.g. WiFi, Bluetooth) shape the possibility to create and configure a dedicated measuring control system. Such a system can be easy deployed on a control object in order to measure defined parameters.

The first part of this paper (Section 2) discusses the application of a well-known **M**easuring **S**ystem of the **E**levator **G**uide-**R**ails (MSEGR) in the control of geometric parameters of guide rails [14,16,25]. In the second part of this paper (Sections 3) we introduce **M**ulti-**S**ensors **M**easuring **S**ystem (MSMS) developed by the authors, which has been designed for measuring of geometric displacement parameters of elevator guide rails. We describe the configuration of the system, sensors used and the deployment of sensors in the elevator shaft. Then the georeferencing issue is discussed and finally results of experimental study are given.

2. Measuring System of the Elevator Guide-Rails

Measuring **S**ystem of the **E**levator **G**uide-**R**ails (MSEGR) [14,16,25] consists of five laser rangefinders (e.g. Leica DISTO), one laser emitter with the collimation system and one CCD/CMOS receiver for digital registration of laser spot location at individual observation levels (Fig. 2). The control-survey equipment is located on the top of the elevator cabin (Fig. 2-B) and in the upper part of the elevator shaft (Fig. 2-A).

In this method, the reference system comprises a laser light beam which is directed vertically, down the elevator shaft. The position of the laser spot during measurements is recorded continuously on the CCD matrix in the form of the film, which has a set frequency – a number of frames per second. In order to determine deviations from rectilinearity for both guide rails at the same time, with a fixed frequency that depends on the elevator speed, five distances are measured: four horizontal (laser rangefinders: D_1, D_2, D_3 and D_4) and one vertical (rangefinder D_5) at subsequent observation levels. Vertical distances between observation levels depend on the height of the shaft and the elevator speed (e.g. 0.5 m/s). The results of the measurements,

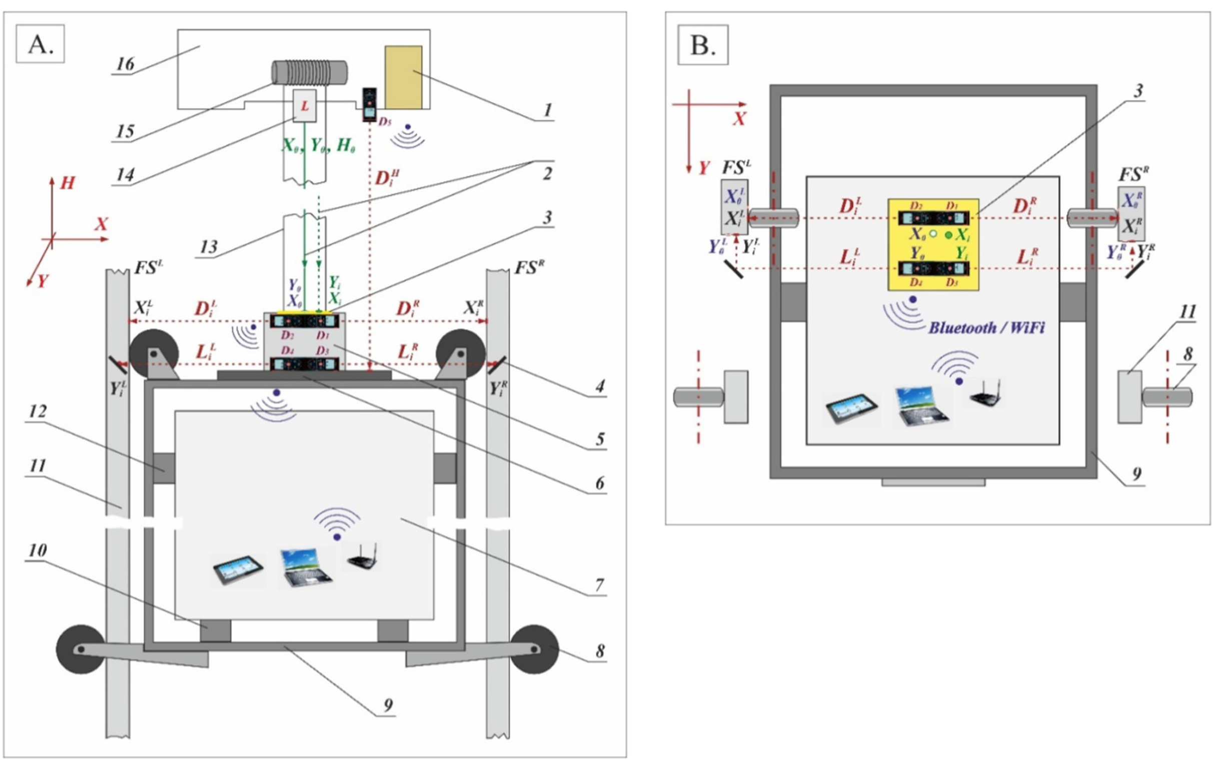

Fig. 2. Diagram showing the location of the control-survey system components [14]: (A) vertical cross-section; (B) horizontal cross-section through the elevator shaft. Symbols: 1 – electric engine; 2 – laser beam; 3 – CCD sensor; 4 – adjustable mirrors; 5 – CCD receiver housing with attached DISTO S910; 6 – the base of the measuring apparatus; 7 – cabin, 8 – rubber roller guides; 9 – frame; 10 – rubber buffers; 11 – elevator guide rail; 12 – crash sensor (oil, spring, etc.); 13 – hoist cable; 14 – place for mounting the laser transmitter; 15 – hoist cable drum; 16 – machine room; X, Y, Z–coordinates of the local Cartesian coordinate system; D_1, D_2, D_3, D_4 and D_5 – Leica DISTO S910 Laser Rangefinders; X_0, Y_0 – coordinates of the laser spot center in time t_0 (zero position); X_i, Y_i – coordinates of the laser spot center in time t_i (current position); FS^L – left guide rail; FS^R – right guide rail; X_0^R, Y_0^R, X_i^R, Y_i^R – survey points coordinates of the right rail; X_0^L, Y_0^L, X_i^L, Y_i^L – survey points coordinates of the left rail.