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Research paper

Track planarity and verticality of the warehouse racks for the quality assessment of further operation

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Abstract: The content of this paper is dedicated to the analysis of the flat planarity of forklift stacker's track and cross sections of lanes between racks in a warehouse. These results will serve as a basis for a possible reconstruction of the track and racks and shall contribute to the overall reduction of costs related to an unexpected bad technical condition. The contribution aims to assess the geometric parameters of warehouse racks at the selected company operation in terms of their suitability for further use. The choice of the selected topic represents a relevant issue, which can be possibly encountered in daily practice related to the storage and transport processes of products. The measurements and processing of longitudinal profiles and cross-sections were made in the local coordinate and local vertical system. Points on the lower, middle and upper level of racks were measured for good and correct interpretation of results. Testing the measured positional change of poles is on the end of this paper. The immediate readiness of interest groups of subjects for adopting necessary actions to ensure the stability and safe operation of the whole network of lanes of the warehouse spaces is the expected contribution of the presented results.

Keywords: longitudinal profiles and cross sections, poles of racks, regression analysis, safety of warehouse racks

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1. Introduction

Racks (industrial storage systems) are structures used to store manufactured products. They were first introduced around 1930 (Godley, 1991) and range from small, manually loaded shelves, to structures over 30 m tall. Methods of 1st or 2nd order elastic analysis for rack design of braced frames, depending on the deformability of the racks under horizontal loads, were developed by Bernuzzi et al. (2015a; 2015b), taking into consideration the limit states of resistance and stability of the frames. Bonada et al. (2016) studied the influence of bending moments on the load bearing capacity of rack uprights. Experimental investigation of the behavior of steel storage racks with perforated columns under axial compression is presented in (Elias et al., 2018). Seismic impact on racks stability is presented in (Kanyilmaz et al., 2016).

Producers and distributors of products are widely trying to store their products in the best possible way and the most suitable and safest area for operation. In this context, it is necessary that the business, or organisation for the sustainable functionality of the logistics system, should also deal with the issue of safety inspection of racks designed for storage. From the perspective of the service provider, it is necessary to regularly inspect the technical condition and quality of racks in storage facilities and supermarkets in order to ensure the continuity between the safe and smooth operation. Small changes in geometrical parameters of racks, which occur during the storage of products, can affect the overall condition of the rack system in the warehouse by their frequency of repetition. During daily use, the emergence of changes in relation to the overall compactness of racks can occur. This can result in the emergence of workplace accidents and damage to stored material (Figure 1). For the operator of the warehouse, this fact represents considerable financial expenses, and their value can be liquidating for the business.

Fig. 1. Demonstration of the warehouse liquidating condition (6 tips)

For the above reasons, it is necessary to pay sufficient attention to this issue. The solution comes in the form of inspection of such racking systems, in terms of meeting the basic requirements for their operation (inspection of planar surfaces). In warehouses, it is necessary to perform geodetic measurements in order to determine the spatial position of racks and tracks along which forklift stackers move. In hobby markets, the attention must be paid to the safety of people moving around high racks, as well as to products placed on these racks, or optionally to forklift stackers moving around those racks. Since the area of interest is usually located in relatively confined conditions, it is necessary to apply such methods and procedures of measurement, which could lead to the most accurate interpretation of results. There was already the case in Slovakia in 2015 when a fatal accident of a little boy happened in an unnamed hobby market, where the collapse of the deposited material on racks was the reason.

At the beginning of geodetic activities, the levelling of tracks of forklift stacker was realised. In the next step, the network of fixed points on the floor or the warehouse construction was established. Subsequently, the geodetic network and detailed survey points placed on three levels of racks were measured by the total station. Struts of racks should be placed vertically and in parallel lines, what in fact was not fulfilled. Deviations of the actual position of racks from the proper position were determined by regression analysis. The calculation of deviations, production of longitudinal profiles and horizontal and vertical cross sections between racks in the warehouse was the main result of the processing. Elimination of the out-of-flatness of the floor as well as the non-verticality of racks'struts affects the financial demands of the building modifications. The overall economic efficiency of building modifications can be solved by the Data Envelopment Analysis (DEA) method, by which we can design the best solution for choosing the type of building modifications (Drabiková, 2016).

2. Regression analysis

In data processing, there is often a task to determine whether two or more random variables are stochastically independent, i.e. it has to be determined whether there is a dependency between two or more variables expressed by functional relationships in 2D or 3D (Labant et al., 2019):

$$y = f(x), \qquad z = g(x, y). \tag{1}$$

The analysed data are obtained from monitoring the phenomenon by measuring values of the dependent variable Y when changing the values of argument (independent variable) X. The task is to find such an estimation of functional dependency between variables X, Y, that the course of the function expresses the measured course of the phenomenon in the best possible way. Regression analysis deals with the description of course of this dependency and determination of the type of functional relationship. Correlation analysis deals with the determination of power, or confidence (tightness), of the relationship between correlated variables.

The examined variables represent only empirical data x_i, y_i instead of the exact values X, Y. An empirical polygon of points P_i (Figure 2) is formed from these pairs of data. The adjusting – regression curve $y = f(x)$ is continuous and approximates points of the empirical polygon (passes through them as close as possible). Distances of points from the adjusting curve $y = f(x)$ are *residuals* (regression errors) e_i. The estimation of functional dependency between variables x_i, y_i that is characterised by the adjusting curve is the result of regression analysis. The analysed pairs of data may have *real interdependence*, but only the best *estimate of functional dependence* is obtained by mathematical tools. Outlying values of the empirical polygon from the real interdependence are *fluctuations* ε_i, which include everything that affects the values y_i and is not explained by the values x_i.

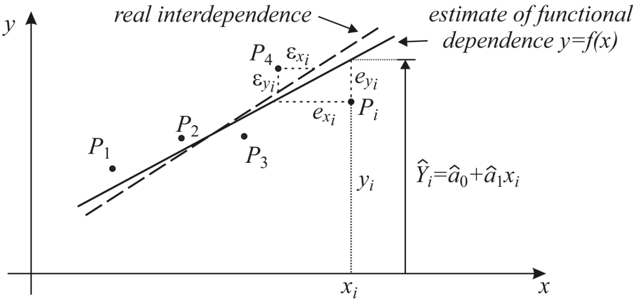

Fig. 2. The real interdependence and its estimation between variables x_i and y_i

The LSM (Least Squares Method) is used to estimate the parameters of the regression function. There are three possible solutions but the correct one is if corrections v_{yi} for values of the function y_i as well as corrections v_{xi} for the function argument x_i are considered (Labant et al., 2019):

$$y_i + v_{yi} = f_3(x_i) + \frac{\partial f_3(x_i + v_{xi})}{\partial (x_i + v_{xi})} v_{xi}\,, \quad \text{while} \quad \mathbf{v}_\mathbf{x}^T \mathbf{P}_\mathbf{x} \mathbf{v}_\mathbf{x} + \mathbf{v}_\mathbf{y}^T \mathbf{P}_\mathbf{y} \mathbf{v}_\mathbf{y} = \min. \tag{2}$$

This alternative of the solution is the most correct and it is solved by the orthogonal regression TLS (Total Least Squares), which works with planar data using the minimization of the sum of quadrates of perpendicular distances d_i of points of the empirical polygon P_i from the regression curve. Only the linear regression can be used for the problem situation.

2.1. Linear regression

The empirical polygon in the form of dot diagram of values x_i, y_i has the trend of linear dependency and can be described by the first-degree polynomial, i.e. a line or a line segment (Figure 2). The linear model equation is defined as:

$$y_i = a_0 + a_1 x_i\,, \tag{3}$$

where y_i is the dependent variable, x_i is the independent variable, a_0 is the intercept and a_1 is the regression coefficient that expresses the slope of the regression line. The calculation of parameters a_0, a_1 using LSM is based on the corresponding form of the objective function $Y = a_0 + a_1 x$ as estimates (Labant et al., 2019):

$$\begin{pmatrix} \hat{a}_0 \\ \hat{a}_1 \end{pmatrix} = \underset{(2,1)}{\hat{\mathbf{A}}} = (\mathbf{X}^T\mathbf{X})^{-1}(\mathbf{X}^T\mathbf{y}); \quad \text{while} \quad \underset{(n,2)}{\mathbf{X}} = \begin{pmatrix} 1 & x_1 \\ 1 & x_2 \\ \vdots & \vdots \\ 1 & x_n \end{pmatrix}, \quad \underset{(n,1)}{\mathbf{y}} = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix}. \tag{4}$$

Subsequently, the adjusted values $\hat{Y}_i$ can be calculated:

$$\hat{Y}_i = \hat{a}_0 + \hat{a}_1 x_i \,. \tag{5}$$

3. Localisation of the subject

Geodetic measurements of spatial position were performed in a warehouse with racks (Figure 3 – left), which were about 9.2 m high with stored manufacturing components. The electronically guided forklift stackers (Figure 3 – in the middle) or platforms (Figure 3 – right) moved between racks, waddling when moving. Geodetic activities consisted of measurements of the planarity of forklift stacker's track and spatial position of racks. Before the actual measurements, it was necessary to become acquainted with the area of interest and choose the appropriate procedures and methods of measurement, measuring instruments and equipment, as well as all necessary accessories. Especially important was the choice of suitable date of measurement, since the warehouse was in a continual operation and the movement of the forklift stacker would make the measurement impossible. Therefore, geodetic measurements were carried out at the time of inventory check. With the help of hydraulic platform, targets were placed precisely where it was necessary also in the upper parts of racks.

Fig. 3. The warehouse with racks together with forklift stacker and platform

4. Measuring instruments

To measure the verticality of racks, i.e. the spatial position of their poles, a total station Leica TPS 1202 was used (Figure 4 – left). This total station enables to determine the position of a point using a surveying prism with the accuracy of measured length $m_s = 2\ \text{mm} + 2\ \text{ppm} \cdot s$, where s is slope distance and with the accuracy measured horizontal ω and vertical z angle $m_{\omega,z} = 0.0006^g = 2''$ (Leica TPS1200+). Equipment used during measurements: heavy wooden tripod that absorbs vibrations together with the tool for protection against slipping (Figure 4 – in the middle above), surveying prisms, retro-reflective target and diagonal (zenith) eyepiece (Figure 4 – in the middle below) that ensures a comfortable observation when measuring high-placed points. It also includes a counterweight, which is simply attached to the object-lens. It is possible to use the technology of terrestrial laser scanning (TLS) to determine the spatial position of racks (using point clouds). The position accuracy of single measurement is 6 mm with using TLS (Pukanská et al., 2014).

Fig. 4. Measuring instruments and equipment

A digital levelling instrument Leica DNA03 (Figure 4 – right) was used for precise measurement of the track planarity. Together with the instrument, also the appropriate equipment such as heavy wooden tripod that absorbs vibrations and invar bar code staff had to be used. The bar code is printed on an invar strip with the expansion coefficient < 1 ppm/°C. The staff is equipped with two spirit level vials and two handles, which guarantee the stability of the staff when used. Its length is 3 m and weight 4.9 kg. The accuracy of high-precision levelling using invar bar code staffs is ±0.3 mm/km with the resolution of height (accuracy of reading) ±0.01 mm for the distance range from the invar levelling rod of 1.8–60 m (Leica DNA).

5. Geodetic measurements in the warehouse

Levelling using Leica DNA03: Height of the floor was determined for each strut of racks, in order to determine collision situations in cross-section profiles together with the visualisation of a forklift stacker. A survey station of the instrument was selected in the middle of the track, and the invar bar code staff was placed directly on the floor without a levelling rod turning plate. The levelling was performed for two tracks (No. 1 and 2 – red points no. 501–556) (Figure 5) and for two lines in each track (No. 1 and 2 – lines of forklift stacker's movement). 56 heights of points in 4 lines were obtained by the levelling.

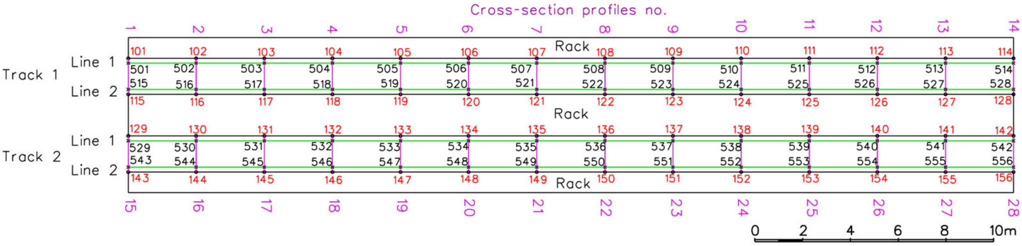

Fig. 5. Illustration of tracks, lines and cross-section profiles

Spatial measurement using Leica TPS 1202: For two tracks of forklift stackers, two survey stations (no. 5001, 5002) were placed so that a good visibility to detailed survey points of racks was reached from both of them. Survey stations on a smooth concrete floor were identified by paper targets, which were attached by adhesive tape (Figure 6 – left). Four orientation points (Figure 6 – in the middle) (no. 5003–5006) in a local coordinate system were chosen so that they are visible from both survey stations (Gašinec *et al.* 2012a). The origin of the local coordinate system was inserted in the 1st survey stations (point 5001) and the *x*-axis in the longest orientation (point 5005). Detailed survey points were measured using reflector tape adhered to a block-shaped magnet (Figure 6 right) (Rákay et al., 2012).

Fig. 6. Denotation of survey stations, orientations and detailed survey points

Before the actual measurement, the calculation of mean coordinate errors of measured points based on the known parameters of the used instrument was made (Ižvoltová and Chromčák, 2015; Labant et al., 2019; Pukanská et al., 2014). Since all the detailed survey points of one track were measured from only one survey station (Sokol et al., 2014), the standard coordinate error of surveying network was not considered:

$$m_{xy}^2 = \left(m_s^2 \cdot \sin^2 z + s^2 \cdot \sin^2 z \frac{m_\omega^2}{\rho_g^2} + s^2 \cdot \cos^2 z \frac{m_z^2}{\rho_g^2} \right) = \left(m_s^2 \cdot \sin^2 z + \frac{s^2 \cdot m_{\omega,z}^2}{\rho_g^2} \right) \quad [\mathrm{m}]. \quad (6)$$

TS Leica TPS1202 provides the measurement of an angle with the accuracy $m_{\omega,z}$=0.0006^g and the measurement of a length with the accuracy $m_s = 2\,\mathrm{mm} + 2\,\mathrm{ppm} \cdot s$ (the conversion coefficient is $\rho_g = 63{,}66198^g$). The maximum calculated standard coordinate error for the measured length 45.0 m with the accuracy $m_s = 0.00209$ m and the measured zenith angle 103^g is $m_{xy} = 0.00213\ \mathrm{m} = 2.13\ \mathrm{mm}$.

Detailed survey points were placed in 14 cross-section profiles in two tracks (Figure 5) at the bottom, middle and upper part of racks at individual struts (Figure 7 – left). The points at the upper level where the forklift stacker had the greatest side swing were very important. The lower level points were used to verify the verticality of the rack struts. The middle level points were measured to determine the course of the rack struts. Each detailed survey point was measured at two positions of the telescope. For nearby detailed survey points located at the upper level of racks, the diagonal eyepiece with a counterweight had to be used (Figure 7 – right). Together, 168 spatially known points were obtained by the detailed survey in both tracks in 14 profiles and at three levels. Points were placed at heights of about 0.04 m (1st struts at 0.5 m), 5.5 m and 8.8 m above the floor. After the completion of the spatial measurement, export of measured data to the memory card was made, followed by further processing.

Fig. 7. The layout of detailed survey points and the diagonal eyepiece

6. Processing of measurements

After the completion of geodetic activities in the central warehouse, the processing of measured data using the appropriate software could be performed.

Processing of levelling measurements (height analysis): using the measured data, it was necessary to calculate heights of points at individual tracks of forklift stacker, that will be used for the calculation of deviations and subsequent graphical interpretation using longitudinal vertical profiles (Figure 8). With all heights of points known, we continued by the calculation of the centre of gravity of individual tracks, representing the average height of all points in a single track:

$$\bar{h} = \frac{1}{n} \cdot \sum_{i=501}^{528} h_i = 50.0008 \text{ m}. \tag{7}$$

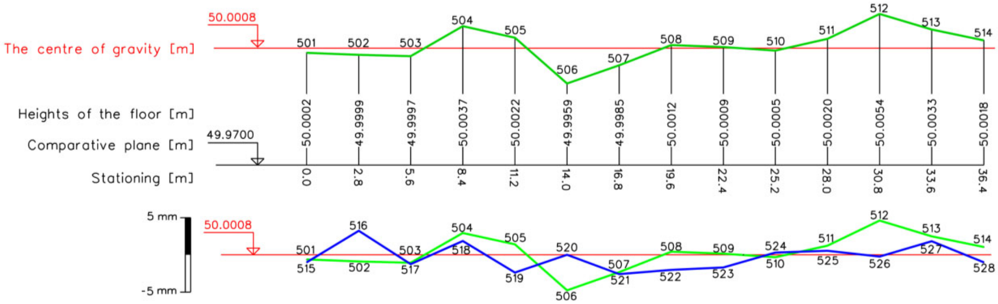

Fig. 8. The longitudinal vertical profile of the 1st line of the 1st track and the height comparison of the 1st and 2nd line of the 1st track

Subsequently, the plane (red line) was fitted to the centre of gravity. Deviations from this plane, which have a plus sign downwards and minus sign upwards, were calculated. Deviations in heights ranged from −4.6 to 4.9 mm (Figure 8 – points 512 and 506) with the average absolute deviation:

$$d_h = \frac{1}{n} \cdot \sum_{i=1}^{n} \left| h_i - \bar{h} \right| \text{ mm}. \tag{8}$$

Based on these deviations, it can be considered if the reconstruction of individual tracks will be needed.

Processing of polar spatial measurements (spatial analysis): Coordinates of points were determined using a geodetic computer software according to (Dandoš et al., 2013; Gašinec et al., 2012b) on the principle of the polar method (Labant et al., 2019; Šíma et al., 2011). The straight line of poles placement, which should approximate the real position of poles and to which positional deviations will be determined, was obtained by regression analysis. Measured points of the bottom level only were used for calculation, because the bottom level showed the lowest deviations from the regression line. Linear regression did not provide the expected results because the layout was placed in a general position in the local coordinate system (Sokol et al., 2015). Therefore, the whole layout was rotated so that individual lines were parallel to the Y axis, which was done using the congruent transformation with scale factor $m = 1$. This ensured that the calculation at the bottom level eliminated longitudinal deviations e_{Yi} and only transversal remained, i.e. e_{Xi}, which represent the deviation of the pole towards the movement path of the forklift stacker. A control calculation was done using orthogonal regression by singular value decomposition SVD according to (Gašinec et al., 2012a; 2014). For the middle and upper level, transversal and longitudinal deviations were calculated as differences of measured (red, blue and purple labelling) and adjusted coordinates of points of the regression line (green lines) (Figure 9). Each of the levels differs in colour, as well as a different number of points. Transversal deviations ranged from -19.1 to 14.4 mm (points of the upper level 356 and 347) with the average absolute deviation 3.3 mm. Longitudinal deviations ranged from -7.6 to 17.5 mm (points 314 and 347) with the average absolute deviation 4.4 mm. The graphical representation of longitudinal profiles and positional deviations is completed in two scales. The positive values of transversal deviations were mapped in the direction of numbering of points to the left side and negative values to the right side. The positive longitudinal deviations were mapped in the direction of numbering of points and negative deviations backwards.

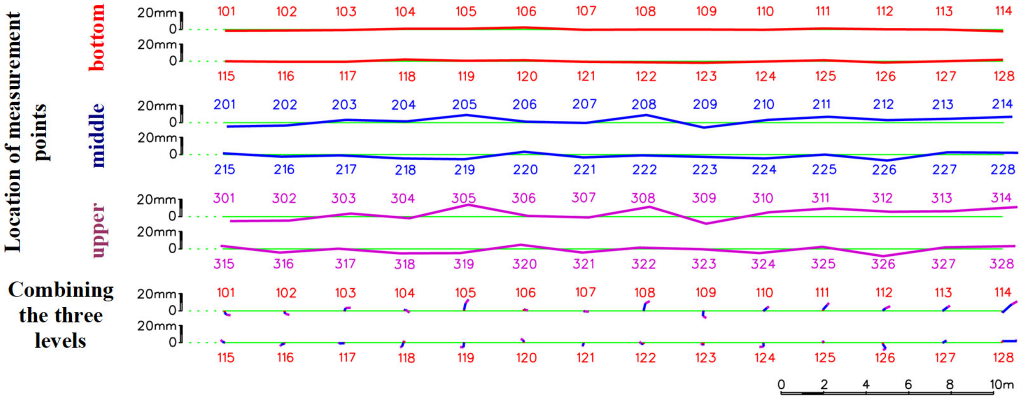

Fig. 9. Three positional profiles of the 1. track with the total positional deviations

Based on the measurement results, the spatial relationships between the floor, forklift stacker and racks were determined. Cross-section profiles (Figure 10) simulating the movement of the forklift stacker between racks in the warehouse were created. 14 cross-section profiles were created for both tracks, giving the total of 28 profiles. In each cross-section profile, distances of forklift stacker d_i from struts of the rack at individual levels are illustrated, shown in red colour. In Figure 10 at the top right, the vertical axis of tilted stacker is shown in green colour and the vertical line passing through the centre of the stacker at floor level is shown in black colour. The non-parallelism of these two axes at the top of the stacker is expressed by the value of deviation o_i and purple arrow that shows the direction in which the stacker is tilted. In Figure 10, cross-section profiles with the maximum tilt of stacker (left – Cross-section profiles no. 6) and minimum tilt (in the middle – Cross-section profiles no. 3) are displayed. In Figure 10 at the bottom right, the bottom part of profiles is shown, where the number of points at poles, the number of points on the stacker track, as well as their corresponding heights are located.

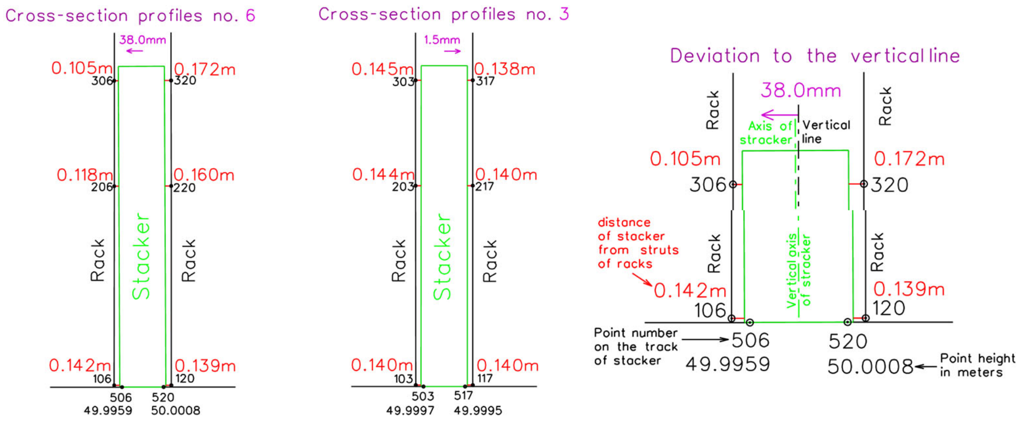

Fig. 10. Two cross-section profiles with transversal deviations and two illustrative details

The stacker should move at a distance 0.140 m from the poles of racks on both sides. The analysis of profiles demonstrated that the average distance of stacker from struts of racks is $\bar{d} = 0.142$ m. Extreme values of distances d_i are $d_{\min} = 0.105$ m and $d_{\max} = 0.182$ m. The dispersion σ_d of values d_i is determined according to the equation for adjustment of direct measurements (Labant et al., 2019):

$$\sigma_d = \pm\sqrt{\frac{\mathbf{v}\,\mathbf{v}^T}{n-1}}, \tag{9}$$

where the vector of corrections is obtained from the relation $v_i = \bar{d} - d_i$ and the mean error of the average distance is defined as:

$$\sigma_{\bar{d}} = \pm\sqrt{\frac{\mathbf{v}\,\mathbf{v}^T}{n(n-1)}}. \tag{10}$$

By the adjustment, the following values were determined: $\sigma_d = 18$ mm and $\sigma_{\bar{d}} = 2.4$ mm.

If the elimination of out-of-flatness of the floor is performed, i.e. deviations of stacker o_i tilt is nullified, then also distances d_i' to poles of racks will change. Extreme values d_i' will approximate to $\bar{d}$ with values $d_{\min} = 0.127$ m and $d_{\max} = 0.158$ m. It was determined by the adjustment of d_i' that the $\sigma_{d'}$ drops to 6 mm and $\sigma_{\bar{d}'}$ to 1 mm. It follows that the elimination of out-of-flatness of the floor (its adjusting) will increase the safety of the operation in the warehouse.

7. Testing the measured positional change of poles

In surveying, the test of hypothesis about the equality of mean values (Ižvoltová et al., 2014) is used to test the measured displacement of observed points (for example on poles of racks). Measurement of the spatial position $Z_i(Y_i, X_i, H_i)$ of the target P_i on the object is performed. The question is whether the changes $\Delta z = \Delta Z - \varepsilon_{\Delta Z}$ result from a real movement of the poles or they are the product of unavoidable surveying errors with the unchanged position of the target (poles). The real error of the measured change will be defined as:

$$\varepsilon_{\Delta Z} = \Delta Z - \Delta z\,, \tag{11}$$

where ΔZ represents the real change $\Delta Z = Z_1 - Z_0$, Δz the measured change $\Delta z = z_1 - z_0$ and $\varepsilon_{\Delta Z}$ is the function of errors of the initial measurements. The null hypothesis for the real change will be defined as:

$$H_0\colon\ \Delta Z = 0, \qquad \Delta z = -\varepsilon_{\Delta Z}\,. \tag{12}$$

If the hypothesis is valid, the measured result Δz is only its real error.

Due to unavoidable errors ε in measurements, the error $\varepsilon_{\Delta Z}$ and the value of Δz will always have a real value (even if $\Delta Z = 0$). However, the value of $\varepsilon_{\Delta Z}$ cannot practically exceed certain thresholds. Measured values Δz have a normal distribution $N(\Delta Z, \sigma^2_{\Delta Z})$, as well as their errors. The confidence interval for measured changes can be defined as:

$$P\left(|\varepsilon_{\Delta z}| > t_\alpha \sigma_{\Delta z}\right) = P_{H0}\left(|\Delta z| > t_\alpha \sigma_{\Delta z}\right) = \alpha, \tag{13}$$

where $\sigma_{\Delta z}$ is a posteriori variance factor of unit weight.

In the test of the null hypothesis, three variants may occur:

1. If $|\Delta z| < \sigma_{\Delta z} - H_0$ is accepted and the displacement of point is not proven by measurement – $\Delta Z = 0$;
2. If $\sigma_{\Delta z} < |\Delta z| < 2\sigma_{\Delta z}$ – there is the displacement of point with the risk of incorrect decision 32 – 5% $\Delta Z \neq 0$;
3. if $|\Delta z| > 2\sigma_{\Delta z}$ – the value of Δz is statistically significant, H_0 is rejected and $\Delta Z \neq 0$. The risk of incorrect decision is 5%.

A posteriori variance factor of unit weight was determined for the statistical evaluation whether the measured changes of position of points (calculated deviations) are real changes. From the measurements, its value $\sigma_{\Delta z} = \pm 4.62$ mm was determined as standard deviation of observed points, and variations were assessed based on this value. Its doubled value is $2\sigma_{\Delta z} = \pm 9.24$ mm. Both values are displayed in cross-section deviations ($2\sigma_{\Delta z}$ – brown and $\sigma_{\Delta z}$ – light blue lines in Figure 11 and Figure 12). Values $\pm 2\sigma_{\Delta z}$

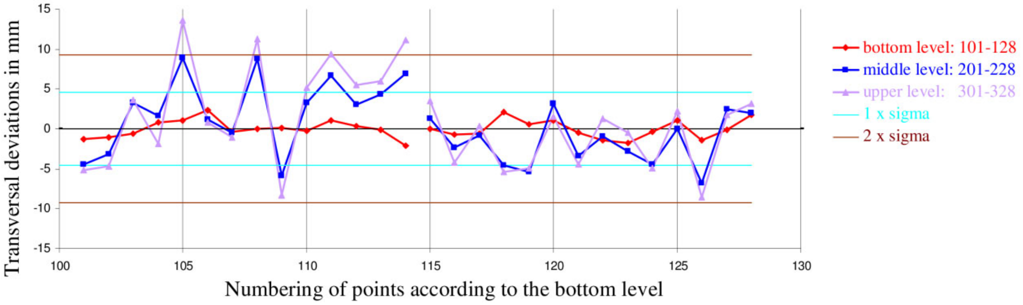

Fig. 11. Results of testing of transversal deviations e_{Xi} of rack poles of the 1st track

highlight points that have statistically significant changes in its position. The number of these points is 10, and they are located mostly on the upper level except for two points from the middle level (Figure 12 – points 247 and 256).

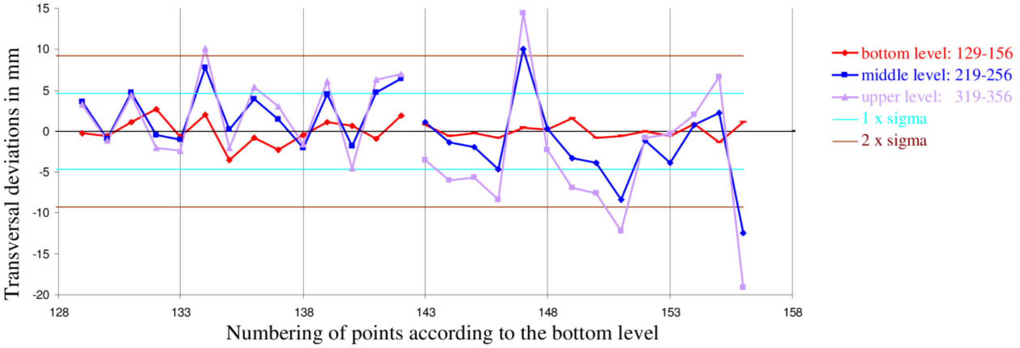

Fig. 12. Results of testing of transversal deviations e_{Xi} of rack poles of the 2nd track

8. Discussion

Based on the measured and processed data, it can be determined that the movement of forklift stacker along tracks between racks is currently safe. In the future, it would be advisable to make a reconstruction of the floor and rectification of racks into the vertical position. However, this would be appropriate only after the control measurement that should show worsening results due to the periodic loading of racks by storage products. The dispersion σ_d of distances of stacker from rack poles d_i will decrease from 18 mm to 6 mm, thus increasing its operational safety. The adjusting levelling plane of the floor is designed so that it passes through the centre of gravity of the track. Then, it is necessary to fill in lowered parts and grind away elevated parts. If the adjusting plane passes through the highest point of the track, grinding will not be necessary. Height of the adjusting plane h_{ZR} of the floor should be at the level of the highest point $+3$ mm, i.e. to prevent the floor raising by thin layers.

Determined transversal deviations of the position of points have undergone the testing based on a posteriori variance factor of unit weight $\sigma_{\Delta z}$. If the transversal deviation is $\geq 2\sigma_{\Delta z}$ (± 9.24 mm), it highlights statistically significant changes in the position of the relevant points. The number of these points is 10, and they are located mostly on the upper level except for two points from the middle level (Figure 11 and Figure 12 – biased values beyond brown lines). Elimination of these deviations is much more difficult since it is the correction of the position of poles at three levels.

9. Conclusions

Every company, or organisation, that implements its activities in conditions of the selected country should provide fully functional operation of its storage spaces. All racks in the warehouse (empty, partially or completely full) need to be stable. The stability of racks, their load capacity, verticality, and horizontality need to be checked annually, during putting in operation, as well as after any movement and adjustment of racks. The realized measurements did not show significant deformations of racks. Ten points out of the total number of measured points indicated deviations with a statistically significant change. Additional repeated measurement in order to monitor deformations resulting from periodic but irregular loading of racks by stored material is recommended. The content of this paper demonstrated the real need for periodic measurement of floor planarity and geometric parameters in order to maintain the sustainability in the system of handling in logistics processes.

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