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CONTROL MEASUREMENTS OF GEOMETRY AT LOCATION OF CRANE CARRIAGE WHEELS: TOLERANCE – METHOD OF MEASUREMENTS – INSTRUMENTARIUM

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1. INTRODUCTION

Regulation and systematic control of changes in geometry of location of wheels and construction elements of a crane bridge are a vital region of assignments in engineering geodesy where requirements of precision are very high. Unpredictable deformations of construction of a bridge and parameters of location and wheel span substantiate the necessity for conducting verifying measurements and conservatory and regulation works. Crane bridges, according to norms and regulations, have to be geodetically conserved in the following cases:
- within the limits of acceptance measurements before admitting for normal exploration;
- after performing vital changes in bridge construction and/or the set of wheels;
- where changes in exploitation conditioning exist;
- at least once a year and even more often in areas of mining exploitation.

In cases of measurements of deformations and dislocation of engineering units and constructions, the evaluation of precision is commonly performed by submitting a deflection of a standard, final result of measurements. In a basic norm of metrology DIN 1319 – part 3 it is postulated that the evaluation of precision of measurement was performed based on the criteria of uncertainty of measurement. Grounded on measurement tolerance stated in various directives, norms and standards , the authors (Klein K. – H. 2001), within limits of a comprehensive study, determined, analyzed and compared permitted values of uncertainty of measurements for geometric parameters. The authors ex cathedra state that the calculated precision of measurements are possible to obtain only with exceptionally high expenditure of work. This important statement not only applies to the evaluation of geometrical deflection of the under-crane rail but also to the basic elements of the construction of bridge and crane. In the case of parameters of location of wheels, values of uncertainty of measurements are often as small as tenth parts of a millimeter (Hennecke F. 1989). It means that special requirements are stated as far as used instruments and measuring devices are concerned. The aim of the elaboration is presenting integrated technology to determine the deflection of skidding of crane wheels with the use of innovative electronic lineal and presentation of the achieved results of experimental researches.

2. CAUSES AND RESULTS OF INCORRECT COOPERATION OF CONSTRUCTION OF A BRIDGE AND SUB-CRANE RAILS

Researches and experiments over many years have proved that the main reason for excessive attrition of the side surfaces of rail heads, rolling surfaces of wheels and their rim are lateral forces which appear perpendicularly to the direction of movement. They usually have a random character. The unilateral, unsymmetrical exploitation load of a bridge, incorrect location of wheels and varied running characteristics of driven wheels mean that forces created by lateral stress are carried onto the whole construction. In effect, on particular fragments of rail, unconstrained run of the bridge is disturbed and slanting and/or swinging drive may occur. The front of the crane is retraced from the rectilinear direction of the drive and the rims of the wheels press the side surfaces of the rail head. Irregular, characteristic acoustic effects often appear – metallic cracks, which indicate possible jamming and stopping of the construction of the bridge. Multiple peelings appear on the rolling surfaces of wheels, side surfaces of rail heads and rims. (Bryś H. 2000). Products of attrition of elements of heads of rails and wheels gather in sections of contractions of clearance. The intensity of side forces influence: a degree of deformity of the bridge (resultant of permanent and resilient deflection) and level buckling of the track.

As far as mechanics go, building of machines and permissible measurements tolerance, vital characteristics influencing the geometry state of crane bridge construction are:
- identity of diameters of driving wheels;
- incorrect location of running wheels on horizontal and vertical surfaces (torsion and/or deflection from the vertical surface);
- incorrect span of running wheels;
- bridge resistance for momentary and permanent deflections;
- efficiency of the wheels driving mechanism ;
- non-rectilinear and incorrect fitting of crane rails;
- slacking of prop screws and deflection of sub-crane beams.

During intensive exploitation the crane bridge is submitted to permanent geometrical deformations which can cause decreasing reliability of work of the whole construction. In effect tolerance of diagonal measurements, span and location of wheels and clearance of axis of rails of crane track are exceeded.

3. GEOMETRICAL INTERPRETATION OF DEVIATIONS AT LOCATION OF CRANE WHEELS

To basic factors causing the highest influence on horizontal and vertical location of wheels belong:
- lack of performance the condition of rectangularity and a grade of resistance of bridge construction to deflections;
- a degree of deformation of track rails on horizontal surface;
- one sided exploitation load of a bridge along one of the tracks;
- type and kind of build-up on the wheels at the front.

Based on the results of control measurements of wheel location and according to the required standards (Polish Norm PN-89/M-45453 elaborate on International Norm ISO 8306-1985), geometrical deflations are marked. The most vital of them together with tolerance of measurements are shown in the following tables.

In the first (table 1) deflection are shown concerning wheel location according to the crane bridge. Their values are connected to the size of the bridge.

Table 1. Tolerance of measurements of wheel location and construction span of the bridge

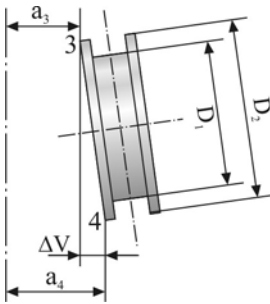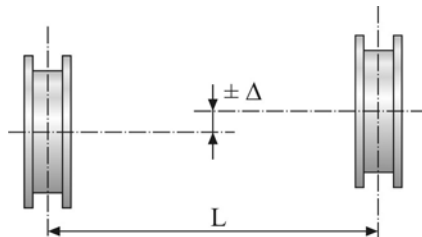| Location of wheels in front		Location of wheels in bridge span	
Horizontal distance of wheel axis B [m]	Deflection of location Δ [mm]	Theoretical span of crane bridge construction L [m]	Deflection of location Δ [mm]
B ≤ 10 m	$\Delta \leq 2$ mm	L ≤ 14 m	$\Delta \leq 5$ mm
B > 10 m	$\Delta \leq [2+0,1(B-10)]$ mm	14 m < L ≤ 29 m	$\Delta \leq 6$ mm
	$\Delta^{maks} \leq 15$ mm	L > 29 m	$\Delta \leq 8$ mm

In table 2 we presented deflection of wheel location on horizontal surface to the rail axis are shown.

Table 2. Tolerance of measurements of wheel location in horizontal plane according to rail axis

Horizontal- parallel deviation of wheel location according to the axis of a rail $\Delta \leq B/1000$		Horizontal deviation from singular parallelism of wheel sets in fronts $\Delta H \leq D/500$	
Horizontal distance of wheel axis B [m]	Location deviation Δ [mm]	Wheel diameter D [mm]	Location deviation ΔH [mm]
B = 3 m	$\Delta \leq 3$ mm	D = 1000 mm	$\Delta H \leq 2$ mm

In table 3 we presented deflection of wheel location in the vertical plane and deflections of axis of driving wheels in both the horizontal and vertical planes.

**Table 3. Tolerance of measurements of wheel location in the vertical plane
and deflections of axis of driving wheels in both the horizontal and vertical planes**

Deviation from side verticality of a wheel rim $\Delta V \le D/500$		Deviation of driving wheel (driver by a common shaft) relocation when the bridge of a crane is not distracted $\Delta \le L/1000$	
Wheel diameter D [mm]	**Location deviation ΔV [mm]**	**Span of crane bridge L [m]**	**Location deviation Δ [mm]**
D = 1000 m	**$\Delta V \le 2$ mm**	**L =15 m**	**$\Delta \le 15$ mm**

4. METHOD OF DEFINING GEOMETRICAL PARAMETERS AT LOCATION OF CRANE WHEELS

For geodetic definition of geometric location of wheels various methods are used in practice: laser technique or optical method based on precisely traced parallel to theoretical axis of rails of a track of base rectangular – I, II, III and IV. In base points S.I and S.II (fig. 1) vertical measuring planes are defined by means of a rotation level with laser vertical plane or by TOTAL STATION (Ćmielewski K. 1995).
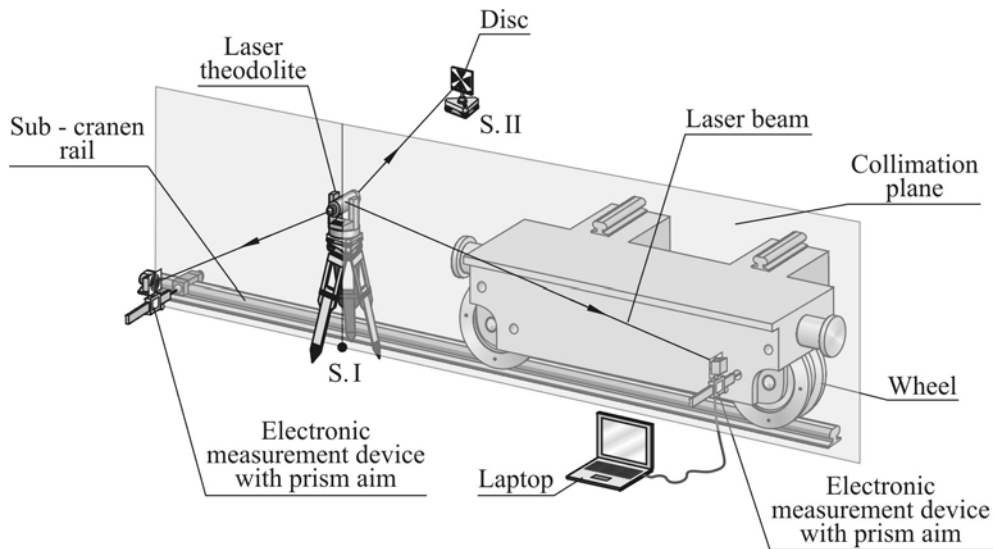

**Fig. 1. Scheme presentation of a measurement of geometry of wheel location with use
of a laser reference plane and electronic lineal.**

The condition of parallelism of both vertical planes is checked by a precise invar rule when all vital corrections are taken into consideration in at least two cross-sectional

planes – beginning and end. With use of a measurement device, we define horizontal distances is between a laser plane of benchmark and all control points 1, 2, 3 and 4 on the side surfaces of wheel rims (fig. 2).
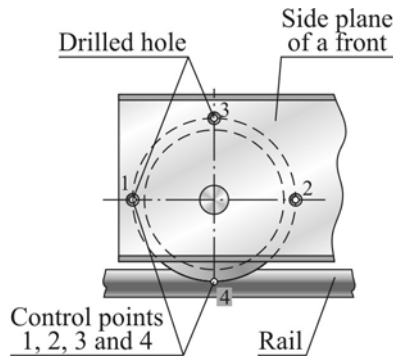

Fig. 2. Control points on the side surfaces of wheel rims.

Obtainment of the precise measurements of wheel location (fig. 3) (10th parts of a millimeter) without use of specialist equipment is in practice very troublesome as a measuring device should fulfill suitable conditions while it is located next to the points on the wheels. The axis of the device should be situated horizontally and vertically to the measurement benchmark plane.
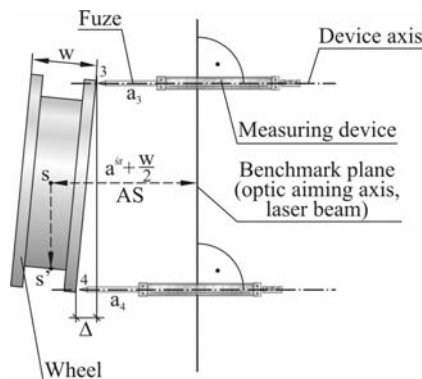

Fig. 3. Placing the device at the measurement points of the wheel.

Performed observations allow defining of the point (fig. 3) which lies in the geometric middle of the said circle and to define deflection of parameters for the wheels location. The aim of defining point s' orthogonal view onto the surface of the head of the rail, we can calculate and deposit the section AS from the formula (1).

$$AS = \frac{a^1 + a^2 + a^3 + a^4}{4} + \frac{w}{2}$$

(1)

Points s of particular wheels, according to authors, allow performance of wider analyses concerning connections of the wheels and crane bridge and deflection occurring in it.

5. ELECTRONIC MEASURING DEVICE

Aiming at securing high precision and reliability of readings and meeting geometrical condition of perpendicularity of the measuring device to vertical benchmark plane, the authors designed (fig. 4) and constructed a prototype of a device with an electronic display of precision up to /0,01/ mm and with the possibility of sending data to a portable computer (fig. 5 and 6). The device is built with a spherical joint with a fuze which is set at a wheel measuring point and electrical lineal which also has a scale and prism that allows setting the axis of a wheel in a parallel position according to the horizontal laser plane. The device is used to measure not only rectilinearity of wheels but also, thanks to its changeable fuze, also to defining the location of wheels and other construction elements of a crane. To set the device correctly means to achieve a central covering of a laser beam (or a vertical laser strip) with the mode of the disc of concentric wheels and a net placed on a pentagonal prism by its turn around the horizontal axis and leveling the electronic lineal with a longitudinal leveling tube.
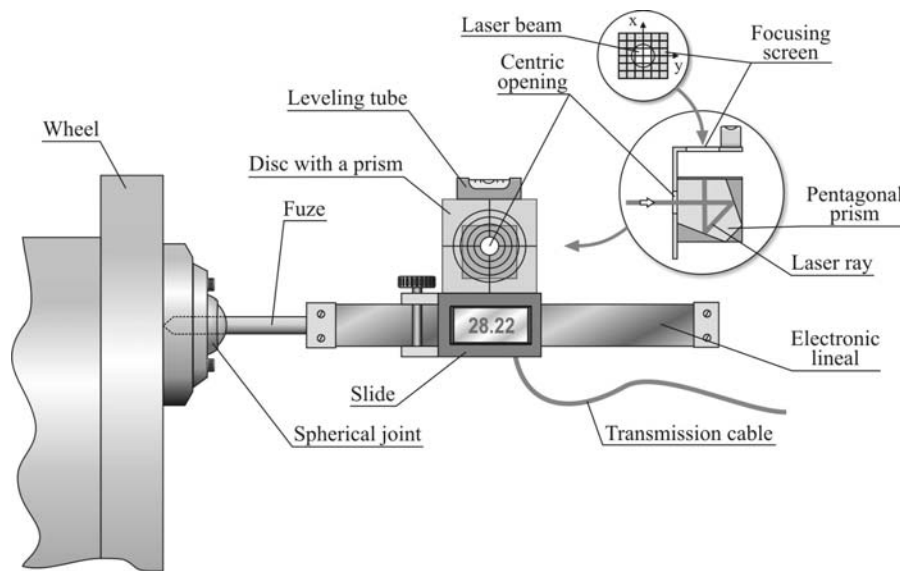

Fig. 4. View of an electronic measuring device.
A prototype of the device shown in pictures (fig. 5, 6) has also been made.

Fig. 5. View of a prototype of the device while in use, concerning a controlled point on the rim of a wheel.
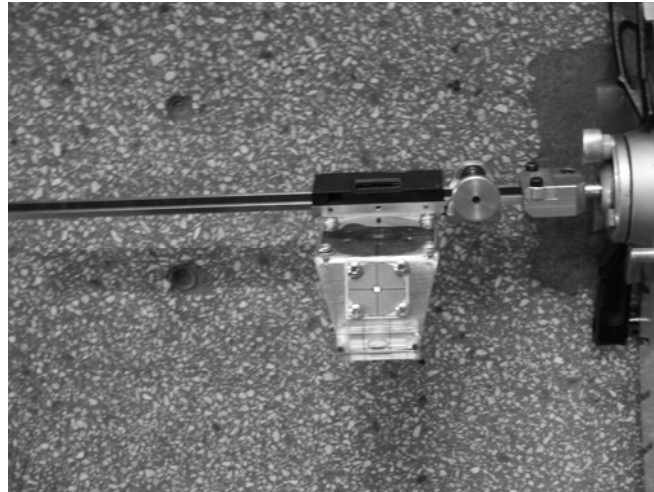
Fig. 6. View of a laser beam on a prism disc.

For the device which was built, measuring tests were made on a base length of 4 mm in laboratory conditions (fig. 7).
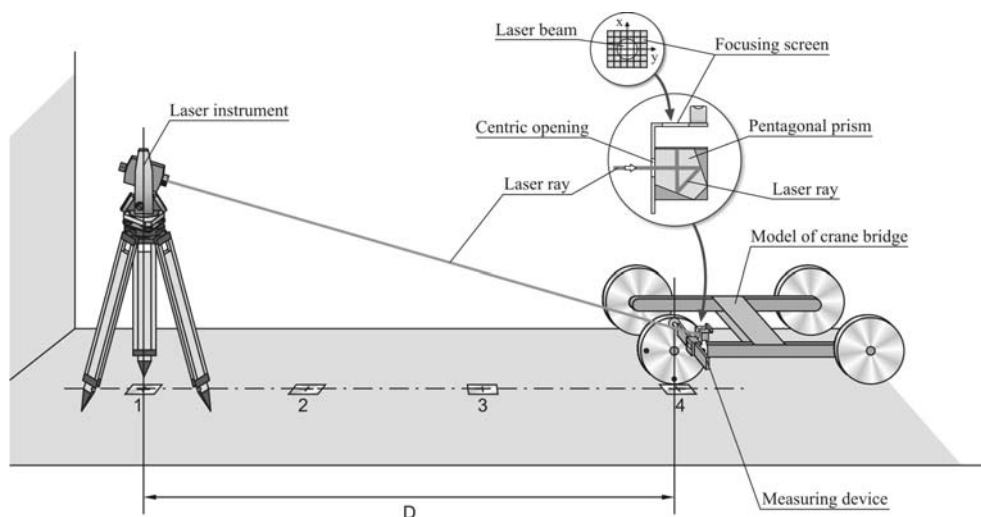

Fig. 7. View of location of an instrument and measuring device during test works.

On one of the ends we placed a laser transmitter and on the other end a prototype of the device which was placed on the rim of a wheel. The initial experimental researches depend on multiply laser beam direction into laser ray with prism and observation of the location which occurred after the laser beam went through a prism on a net (aiding disc) and next proceeding readings from electronic lineal. Researches were run for different (colligated on the disc) diameters of laser beam.

Table 4. Results of multiple readings of location of laser beams

Diameter of beam [mm]	0.5	1.0	2.0
Average result from 31 observations [mm]	37.44	37.52	37.51
Average error [mm]	0.055	0.073	0.083

6. SUMMARY AND FINAL CONCLUSION

Measurements of wheel location were performed with the precision of tenth parts of a millimeter in difficult observational conditions (measurement on heights, changeable lighting readings, oscillopsia, etc.) Such exactment comes from low values (singular millimeters) Geometric deviations concerning measurements is possible with the use of appropriate methods of observation and measuring devices which can be often seen in prototype versions. The authors, having taken into consideration many values of the use of laser techniques in geodesy, have evaluated a measuring device, which after full verification researches should complete precision conditions of wheel measurements. The made and presented prototype was tested in laboratory conditions which allowed formulation of the following conclusions:

- high repeatability of measurements of the built device (average error did not exceeded +/- 0,09 mm);
- introducing small construction changes, there is the possibility of modification of the device, where the aim is using it for measurement of rectilinearity of rails and slides;
- the device can cooperate with a singular beam or laser plane;
- observations by means of the device can be used in the disadvantageous conditions of bad lighting of production halls.

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SUMMARY

The article presents, discusses and analyses on the problem of gantry crane carriageable wheelset geometry and their potentialy destructive action on the subgantry rail tracks. The paper presents novel equipment with optical and electronic aiming and readout systems which may be used for initial certification and subsequent periodical tests of wheelsets of the crane bearing frame.