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Positioning of Wheelsets When Measuring Linear Parameters

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ABSTRACT

Positioning equipment refers to devices for moving objects, namely lifting devices, and are used in various branches of mechanical engineering, including railway engineering. Devices of this type are relevant for use in measuring technology for positioning rotating parts. The positioning device is usually used as part of equipment for measuring and monitoring the dimensions of wheelsets.

The purpose of the study was to consider various methods and devices for positioning wheelsets, to identify their advantages, constraints and disadvantages.

The objective of the research was to develop a new positioning device intended to improve dependability of operations, expand the range of application and functionality. The article provides recommendations for creating a more universal positioning device suitable for use with various types of wheelsets.

Keywords: railway transport, positioning, movement, transfer, wheelset, measuring system, linear parameters, measuring position.

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INTRODUCTION

Positioning devices are used in railway engineering in production of wheelsets, as well as at railways' maintenance and repair facilities in the process of repairing and assembling wheelsets. The positioning device is designed to move the wheelset from the rail track to the measuring system to the point (position) of measuring linear parameters after repair or assembling of the wheelset to check the dimensional accuracy, including after reprofiling its tread surface. The positioning device is usually used as part of technological equipment for repair of wheelsets [1; 2], and, in particular, as part of systems for measuring the linear parameters of the elements of wheelsets [3–6], by which their service life is assessed [7–9].

Using *a comparative analysis*, the study described in the article examines the advantages and limitations of known positioning methods and devices. The disadvantages of existing devices are associated with the low positioning accuracy of the wheelset, due to errors in its placement relative to the measuring system, as well as to measurement errors arising from vibration of the wheelset when it rotates in the measurement position.

The *objective* of the research was to develop a new positioning device intended to overcome the shortcomings of known devices and increase the dependability of their operation. The article provides recommendations for further development of a more universal positioning device for various types of wheelsets.

RESULTS

Historical Background of Known Devices for Positioning of Wheelsets

Wheel positioning devices have been used in measurement technology for over 40 years. One of the earliest devices of this kind was the device proposed by H. Wittkopp and H. Gruteser in 1981 from Wilhelm Hegenscheidt GmbH [10]. In this device, the units that provide locating of the wheelset are structurally separated, namely, it provided for locating device and the test bed table, which is used as a lift for the wheelset. However, this division led to the need for an additional operation to move the wheelset from the test bed table to the locating device, which complicated the measurement process, and thus, if considered from modern times, was a certain disadvantage of the device.

In 1988, in application No. 262425 PRL [then Polish People's Republic], another device for positioning was proposed [11]. This device [11], described in detail in [12], has a locating device and a test table with supports designed to accommodate a wheelset. The locating device [11] was thus combined with the test bed table, in contrast to the previous device [10]. This combination led to a simplified design but reduced the accuracy of measurements since the wheelset is subject to shocks and impacts during its placement on the table and is also subject to vibration during subsequent rotation. This leads to runouts (due to deviations from the nominal dimensions of the wheelset and test bed table), which reduces the accuracy of measurements.

Another disadvantage of the device [11] is the low positioning accuracy associated with large tolerances [possible tolerances are described in[1]] for deviation from the concentricity of the tread circle and for deviation of the height of the wheel ridges (up to 1 mm). Another disadvantage is insufficient stability of the wheelset, which occurs because the wheelset is placed on supports through contact with the wheel flanges.

Device with Increased Positioning Accuracy

In 2007, with participation of the author of the article, a device for positioning a wheelset with increased accuracy was developed [13]. The purpose of creating the device was to improve the positioning accuracy and stability of wheelsets of type RU1–950 and RU1SH-950 of cargo wagons on 1520 mm gauge mainline railways.

These wheelsets[2] were produced until 2006 with a nominal diameter of 950 mm. The structural diagram of the positioning device [13] is shown in Pic. 1.

On the horizontal base 1 of the device [13], vertical guides 2 are fixed, which are made in the form of pipes. Inside the guides 2 there are movable racks 6, on which supports 3 are installed to accommodate the wheelset 4 when removed from the rails 5. The racks 6 are located

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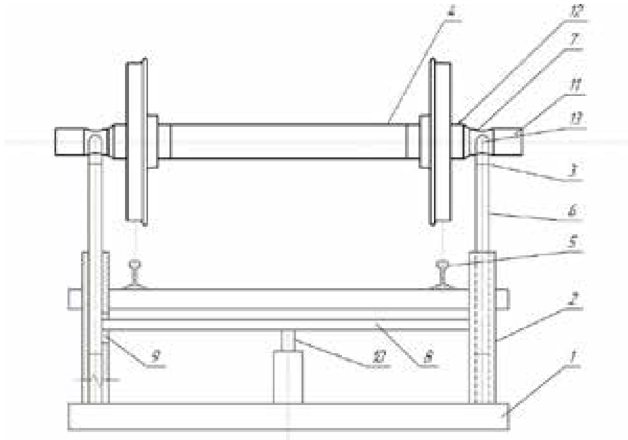
[1] Instruction TsV-944 for inspection, certification, repair and assembling of wagon wheelsets. Approved by the Ministry of Railways of Russia dated June 20, 2003, No. TsV-944. Valid since 2006–01–01. [Electronic resource]: https://docs.cntd.ru/document/1200102226.

[2] GOST [Russian state standard] 4835–2013. Wheelsets of railway cars. Technical conditions. Introd. 2014–01–07 by order of the Federal Agency for Technical Regulation and Metrology dated November 8, 2013, No. 1421-st. Moscow, Standartinform, 2014, 66 p.



Pic. 1. Device for positioning a wheelset [13]: 1 – base, 2 – guides, 3 – supports, 4 – wheelset, 5 – rails, 6 – racks, 7 – fillet transitions, 8 – crossbar, 9 – slots in the guides, 10 – movement mechanism, 11 – neck of the axle, 12 – pre-hub part of the axle, 13 – area of contact between the support and the fillet transition.

at a distance between them equal to the distance between the fillet transitions 7 and are connected by a crossbar 8. The guides 2 have slots 9, in which crossbar 8 moves. Crossbar 8 rests on the vertical movement mechanism 10 installed on the base 1. The supports 3 are made in the form of V-shaped cradle for interaction with the surface of the fillet transitions 7, located between the cylindrical part of the neck 11 and the pre-hub part 12.

The contact surfaces of the supports 3 are made as mating and responding the generatrix of the fillet transitions 7, that is, the cross-section of the contact surfaces of the supports 3 around contact 13 of the support and the fillet transition coincides with the cross-section of the surface of the fillet transitions 7.

The set task to increase the positioning accuracy and the stability of the wheelset was solved in the device [13] through making the supports in the form of V-shaped cradles. The main feature of the device [13] is that the contact surface of the supports is made as mating the generatrix of the fillet transition surface (the reduction of the diameter of the axle neck in the fillet area[1] reaches 0,45 mm), and the distance between the racks is chosen equal to the distance between the fillet transitions. This design of the device [13] made it possible (by moving the supports under the indicated fillet transitions) to reduce the positioning error introduced by the mechanical components of the device [11] when the supports interact with the wheel flanges. This reduction is ensured by the fact that the tolerances on the dimensions of the fillet transitions (0,2 mm [8]) are five times smaller than the tolerances on the dimensions of the diameter of the wheels of the wheelset, measured along their ridges (about 1 mm). Thus, the positioning accuracy of the wheelset axis in [13] was increased to ±0,2 mm.

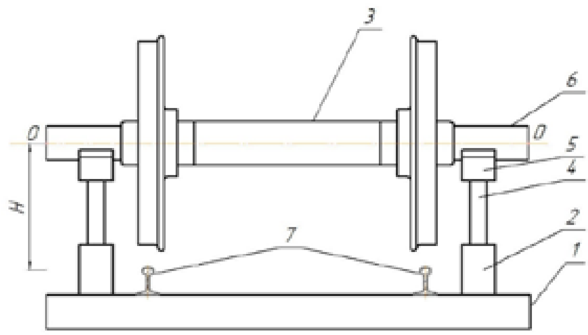
The stability of the wheelset in the device [13] is increased due to a significant reduction in the height of the wheelset in relation to the supports, since the diameter of the fillet transitions (about 130 mm) with which the wheelset rests on the supports is much smaller than the diameter of the wheels (950 mm).

An additional factor increasing the stability of the wheelset in the device [13] is due to an increase in the distance between the supports to attain the distance between the fillet transitions (1874 mm), which exceeds the distance between the wheel flanges by 402 mm (1472 mm).

The location of the racks 6 at a distance between them equal to the distance between the fillet transitions and directly under the supports in the device [13] eliminates the possibility of bending deformation of the support mounts that occurs when the wheelset is supported by the wheel flanges on the protruding supports of the test bed table (which is observed in the device [11]) and allows further improving positioning accuracy.

The special design of the contact surface of the supports in the form of a reciprocal generatrix of the fillet transition surface makes it possible to reduce the specific pressure on the supports from the side of the wheelset, which helps prevent local wear of the contact surface of the supports, resulting in increased positioning accuracy during long-term operation of the device [13].

Making the supports in the form of V-shaped cradles makes it possible to install the wheelset



Pic. 2. Schematic image of the device for moving wheelsets: 1 – base, 2 – mechanism for vertical movement of the wheelset, 3 – wheelset, 4 – moving part of the vertical movement mechanism, 5 – supports with flat pads, 6 – axle neck, 7 – rail track, O-O is the geometric axis of the wheelset, H is the height of the location of the geometric axis of the wheelset located at the measurement position [14].

symmetrically with respect to the axial vertical plane, as well as with respect to the transverse vertical plane of the positioning device, which simplifies the process of installing the wheelset in the measurement position. The choice of the method of placing the wheelset by contacting the fillet transitions with supports made in the form of V-shaped cradles, the contact surface of which corresponds to the generatrix of the fillet transitions surface, makes it possible to fix the wheelset in both the transverse and longitudinal directions. This ensures reliable fixation of the measured object relative to the selected coordinate system.

However, this device [13] also has constraints and disadvantages, namely, there is no possibility of using the device for wheelsets of different types – for wheelsets with different distances between the fillet transitions of the axle journals and with journals of different diameters.

Device for Positioning Wheelsets with Axle Journals of Different Diameters

The next stage in author's development of positioning devices was associated with a new device for moving (positioning) wheelsets, in 2022 [14]. The development of this device is aimed at ensuring the preservation of the surface of the axle journals, increasing the dependability of the device and expanding the scope of application for wheelsets of various types, namely, for wheelsets with different distances between fillet transitions and with axle journals of different diameters.

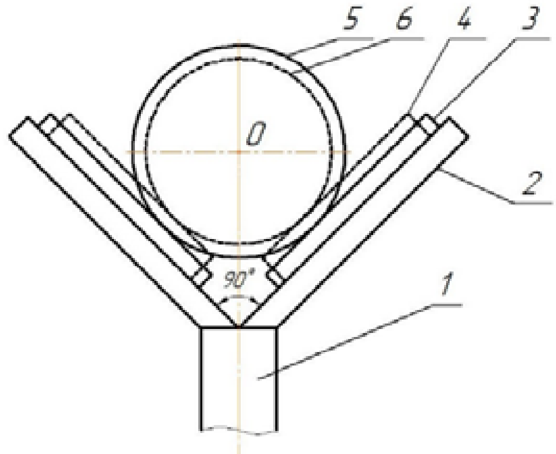
Pic. 2 shows a schematic image of the device [14], Pic. 3 shows a section along the transverse (radial) vertical plane of the mechanism for vertical movement of the wheelset, and Pic. 4 shows a fragment of a device for moving (positioning) [14] as part of an automated system for non-contact measurement of the geometric parameters of wheelsets[3], developed based on the principles of creating a device for measuring the linear dimensions of wheelsets [15].

On the base 1 of the device [14] (see Pic. 2), a vertical movement mechanism 2 is fixed, on the moving parts 4 of which supports 5 are attached to accommodate the journals 6 of the axle of the wheelset 3. The mechanism 2 includes hydraulic cylinders (not shown in Pic. 2).

The supports 5 are V-shaped and have flat replaceable pads installed on them. The thickness of the pads is selected for each type of wheelset separately depending on the diameter of the axle journals 6 to ensure the level of the position of the geometric axis of the wheelsets 3 with journals of different diameters at the same height *H* in the measurement position. Height *H* is measured from the level of the rail heads to the level of the geometric axis of the wheelset at the measurement position.

A distinctive feature of carrying out measurements in the device [14] is that the wheelset 3 is raised to the measurement position to a given height *H* using mechanical contact of the flat pads of the supports 5 with the cylindrical axle journals 6 of the wheelset 3. Next, the wheelset is fixed in the measurement position in the system[3] for measuring the linear parameters of wheelsets [15], then rotation of the wheelset 3 is switched on and its linear parameters are measured. After the measurements are taken, all operations are performed in the reverse order and the wheelset is lowered onto the rail track 7. Pic. 3

[3] «Geopar» Automated systems for non-contact measurement of geometric parameters of wheelsets. Technical specifications. TS 3138–076–52473498–2008 (NZhSA.401.722.000 TS). Introd. 2008–08–08, 22 p.



Pic. 3. Location of the journals of the wheelset axles in the measurement position on the support pads of the device for moving the wheelsets (section along the transverse vertical plane of the vertical movement mechanism in Pic. 2): 1 – moving part of the movement mechanism, 2 – support, 3 and 4 – pads of different thickness, 5 and 6 – journals of different diameters, O – geometric axis of the wheelset [14].

shows the location of the axle journal on the support pads of the vertical movement mechanism of the device for moving wheelsets [14].

The moving part 1 of the vertical movement mechanism (see Pic. 3) contains supports 2 with pads 3, 4 of different thicknesses, which ensure the location of journals 5, 6 of different diameters in the wheelset measurement position. The angle between two parts of the supports is 90 degrees.

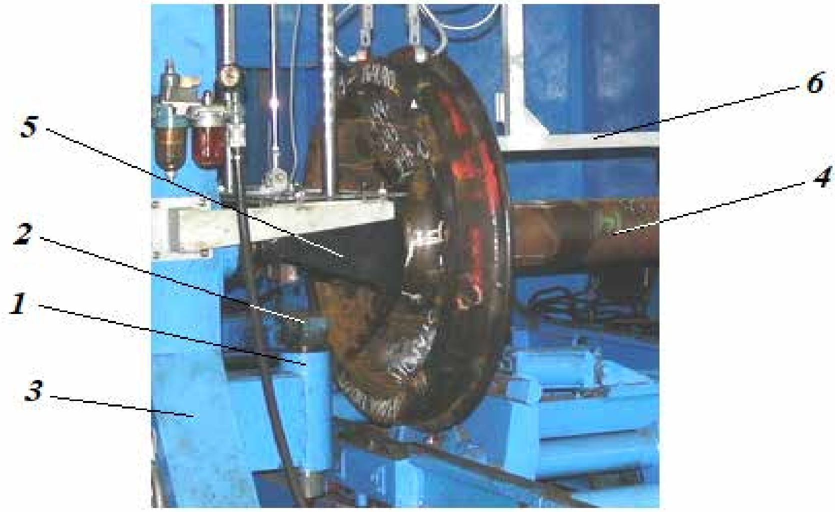
Pic. 4 shows a fragment of a device for moving wheelsets [14], which is part of the system[3] for measuring geometric parameters.

A device for moving wheelsets [14], including a vertical movement mechanism 1 (hydraulic cylinder) and a support 2 with pads, is part of the system for measuring geometric parameters, including a stand 3, a block 5 for measuring the diameters of the axle neck and a block 6 for measuring the diameters of the wheelset axle 4.

When determining geometric parameters, each measurement was repeated five times ($n = 5$). The arithmetic mean value was taken as the measured value D_{meas}:

$$D_{meas} = \frac{D_1 + D_2 + \ldots + D_n}{n}.$$

The absolute error for each measurement result was determined as the difference between the arithmetic mean value of the parameter



Pic. 4. Fragment of a device for moving wheelsets as part of the system3 for measuring geometric parameters: 1 – mechanism for vertical movement of a wheelset to the measurement position (hydraulic cylinder), 2 – support with pads, 3 – installation stand for measuring geometric parameters, 4 – wheelset in measurement positions, 5 – block for measuring the diameters of the axle journal, 6 – block for measuring the diameters of the wheelset axle [14].

measurement result and the actual size D_{act} of the calibration device:

$\pm \Delta = D_{meas} - D_{act}$.

In particular, to measure the diameters of the axle journals of the RU1–957 and RU1SH-957 wheelsets in the range of 129…131 mm, a KS130 calibration rod, 130 mm long, measured by the metrology service with an error of ± 0,0013 mm, was used. The calibration rod was installed on a technological bracket in the block for measuring the diameters of the axle neck. Then the length of the rod was measured, which corresponded to the diameter of the wheelset axle journal. The absolute error in measuring the diameter of the axle neck did not exceed ± 0,0040 mm.

Benefits of the New Positioning Device

The use of flat pads (see Pic. 3) in a new device for measuring wheelsets with axle journals of different diameters [14] allows the wheelset to be installed symmetrically relative to the axial vertical plane, which facilitates the subsequent positioning of the wheelset in the system[3]. Making the pads flat allows them to be quite wide (up to 120 mm) in the direction of the wheelset axis. This made it possible to measure wheelsets with different distances between fillet transitions and, thus, further expanded the scope of the device [14].

The use of replaceable flat pads, the thickness of which is selected depending on the diameter of the axle journals, made it possible to position wheelsets with journals of different diameters.

Making the pads from brass, which has a lower hardness than the hardness of the journals of steel wheelsets, made it possible to eliminate damage to the surface of the axle journals.

The contact of flat pads with the cylindrical surfaces of the journals ensures the greatest positioning accuracy of the wheelset, since the tolerance with regard to the diameter of the axle journal (0,004 mm) is significantly less than the tolerances (1,0 mm) regarding the dimensions of other parts of the wheelset (wheel flanges, wheel treads), the surfaces of which are used as contact surfaces in devices [10; 11].

However, the positioning accuracy of the wheelset with a value of the order of ± 0,004 mm, in this case still turns out to be unattainable, since the positioning error is determined by the manufacturing tolerances of the elements of the vertical movement mechanism, which in actual execution are of the order of 0,1 mm, so this is precisely the value and determines the actual positioning accuracy (±0,1 mm) of the wheelset in the device [14]. This positioning accuracy (±0,1 mm) is twice as high as the positioning accuracy in the device [13], in which it is ±0,2 mm.

Experience in operating a moving device [14] for positioning wheelsets as part of an automated system[3] for non-contact measurement of geometric parameters located in the final control area of the railway wagon-wheel workshops of Gorkovskaya railway has shown that the device [14] has significant advantages in comparison with known devices for positioning [10; 11]. The high technical features of the device were confirmed [14] in terms of increasing the accuracy of positioning the wheelset at the measurement position (up to ±0,1 mm) and in terms of ensuring the positioning of wheelsets with axle journals of different diameters. The diameters of the journals of the wheelset axles are, for example, for wagons, TEP-70 diesel locomotives and wagons with increased axle loads of 130[1], 160[2] and 180 mm[4], respectively.

The objective of further developments should be to create a more universal device for positioning any type of wheelsets, including those for high-speed trains [16]. It is also necessary to develop a special mechanism for lifting wheelsets with journals of different diameters to the measurement position, which would ensure their positioning at the similar level of the geometric axis of the wheelset without the use of replaceable pads.

CONCLUSIONS

The development of a new positioning device [14] for positioning wheelsets technically resulted in expanded scope of application of the device and its functionality, increase in operational dependability and ensured safety of the cylindrical surfaces of the journals of the wheelsets axle. The device provides high positioning accuracy of wheelsets (up to ±0,1 mm) with different distances between fillet transitions and with axle journals of different diameters. To further expand the scope of application, it is necessary to develop a more universal positioning device suitable for use for all types of rolling stock wheelsets.

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[4] GOST [Russian state standard] 22780–93. Axles for wagons on 1520 (1524) mm gauge railways. Types, parameters and sizes. Introd. 1995–01–01. Resolution of the Committee of the Russian Federation on standardisation, metrology and certification dated 02.06.1994, No. 160, 20 p.

REFERENCES

1. Senko, V. I., Chernin, R. I., Udodov, A. S. New technological equipment for repairing wheelsets of wagons [*Novaya tekhnologicheskaya osnastka dlya remonta kolesnykh par vagonov*]. *Current issues of mechanical engineering,* 2014, Vol. 3, pp. 285–287. EDN: ZCHPZF.

2. Skryabin, V. A. Testing of technological equipment for manufacture of wheelsets of railway transport [*Ispytaniya tekhnologicheskogo oborudovaniya dlya izgotovleniya kolesnykh par zheleznodorozhnogo transporta*]. *Repair. Recovery. Modernization*, 2018, Iss. 8, pp. 4–10. EDN: XWBTJR.

3. Krasilnikov, V. S., Erilin, E. S., Fogel, A. L. Pat. No. 2301968 Russian Federation, IPC G 01 B 11/08, G 01 B 11/24. Method for monitoring part diameters. Applicant and patent holder: State Unitary Enterprise Nizhny Novgorod Branch – a subsidiary of VNIIZhT of the Ministry of Railways of the Russian Federation. No. 2005132431/28; application 20.10.2005; publ. 27.06.2007. Bull. No. 18, 5 p. EDN: YPEUHD.

4. Krasilnikov, V. S., Erilin, E. S., Fogel, A. L. Pat. No. 2312304 Russian Federation, IPC G 01 B 7/12. Device for measuring the diameter of solid-rolled wheels and tires on a rolling circle. Applicant and patent holder: State Unitary Enterprise Nizhny Novgorod branch – a subsidiary of VNIIZhT of the Ministry of Railways of the Russian Federation. No. 2006126223/28; application 19.07.2006; publ. 10.12.2007. Bull. No. 34, 5 p. EDN: JMLRXB.

5. Krasilnikov, V. S., Erilin, E. S., Fogel, A. L. Pat. No. 65209 Russian Federation, IPC G 01 B 7/12. Device for monitoring the geometric parameters of rolling stock wheel tires. Applicant and patent holder: State Unitary Enterprise Nizhny Novgorod Branch – a subsidiary of VNIIZhT of the Ministry of Railways of the Russian Federation. No. 2007102761/22; application 24.01.2007; publ. 27.07.2007, 6 p. EDN: BAWQDM.

6. Krasilnikov, V. S., Erilin, E. S., Fogel, A. L. Pat. No. 62233 Russian Federation, IPC G 01 B 7/12. Device for measuring the diameter of solid-rolled wheels on a rolling circle. Applicant and patent holder State Unitary Enterprise Nizhny Novgorod branch – a subsidiary of VNIIZhT of the Ministry of Railways of the Russian Federation. No. 2006138924/22; application 03.11.2006; publ. 27.03.2007, 5 p. EDN: GQXNVX.

7. Koltsov, Yu. A., Skrebkov, A. V. Estimation of the service life of wheelsets of electric locomotives based on information on measurements of controlled parameters [*Otsenka resursa kolesnykh par elektrovozov po informatsii o zamerakh kontroliruemykh parametrov*]. *Transport Urala*, 2019, Iss. 4 (63), pp. 49–52. EDN: VIPGVN.

8. Ignatiev, O. L., Ignatieva, O. V. Innovative approach to reducing wear of wheelsets of non-traction rolling stock to increase operational efficiency [*Innovatsionniy podkhod k snizheniyu iznosa kolesnykh par netyagovogo podvizhnogo sostava dlya povysheniya ekspluatatsionoi effektivnosti*]. *Proceedings of Rostov State Transport University*, 2020, Iss. 1 (50), pp. 30–32. EDN: ECVFKZ.

9. Vorobyov, A. A., Shadrina, N. Yu., Shadrin, A. N. Experimental assessment of the accuracy of restoring rims of wheelsets of traction rolling stock on wheel-milling machines [*Eksperimentalnaya otseka tochnosti vosstanovleniya bandazhei kolesnykh par tyagovogo podvizhnogo sostava nakoleso-frezernykh stankakh*]. *New materials and technologies in mechanical engineering*, 2022, Iss. 35, pp. 17–22. EDN: WJRZQS.

10. Patent SU847945A3, USSR, IPC G 01 B 5/08; G 01 B 5/20. [Russian title: A method for measuring the rolling profiles of wheelsets during reprofiling and a device for its implementation]. Applicant: Wilhelm Hegenscheidt GmbH (Germany). Inventors: Helmut Wittkopp, Helmut Gruteser. Application 2407201 dated 06.10.1976; publ. 15.07.1981, Bull. No. 26 (1981), 6 p. [Electronic resource]: https://patentimages.storage.googleapis.com/04/34/ff/3e75af9a0b4c1c/SU847945A3. Last accessed 22.11.2023.

11. Application for invention No. 262425 PRL, IPC G 01 B; B 61 K. Method and device for measuring the geometric condition of a wheelset and wear of its working profiles. Applicant: Kolejowe Zakłady Maszyn i Sprzętu Drogowego «RACIBÓRZ», Racibórz. Inventors: Madecki, Oerzy; Przewoźnik, Andrzej; Rudzki, Michał; Sierżant, Roman; Tokarski, Janusz; Wiechuła, Paweł. Publ. 1988, Bull. Patent Office of the People's Republic of Poland No. 318/384/1988, No. 384, P. 82. [Zgłoszenie wynalazku Nr 262425 PRL. Sposob i urzadzenie do pomiaru stanu geometrycznego zestawow kołowych i zuzyclie profilow roboczych tych zestawow, MKP G 01B; B 61K. Biuletyn urzedu patentowego Nr 318 /384/ 1988]. [Electronic resource]: https://uprp.gov.pl/sites/default/files/bup/1988/18/bup18_1988.pdf. Last accessed 22.11.2023.

12. Sychenkov, V. V., Frolovsky, V. V. Pat. 2229995 Russian Federation, IPC B 61 K 9/12, G 01 M 17/10. A method for basing a wheelset, a basing device and a device for positioning a wheelset, as well as a complex for measuring the standardized linear dimensions of wheelsets. Applicant and patent holder: Sychenkov, Vladimir V. No. 2001133186/11; application 06.12.2001; publ. 10.06.2004, Bulletin. No. 16, 14 p. EDN: TEDPHP.

13. Krasilnikov, V. S., Erilin, E. S., Zemlyakov, S. G. [*et al*]. Pat. 62103 Russian Federation, IPC B 66 F 11/00. Device for positioning a wheelset. Applicant and patent holder: State Unitary Enterprise Nizhny Novgorod branch – a subsidiary of VNIIZhT of the Ministry of Railways of the Russian Federation. No. 2006138920/22; application 03.11.2006; publ. 27.03.2007. Bull. No. 9, 5 p. [Electronic resource]: https://www1.fips.ru/Archive/PAT/2007FULL/2007.03.27/INDEX_RU.HTM. Last accessed 22.11.2023.

14. Krasilnikov, V. S. Pat. 212118 Russian Federation, IPC B 66 F 11/00; SPK B 66 F 11/00. Device for moving wheelsets. Applicant and patent holder: Samara State Transport University. No. 2022110773; application 20.04.2022; publ. 06.07.2022. Bull. No. 19. – 5 p. EDN: ONRBCO.

15. Krasilnikov, V. S., Beagon, V. S., Erilin, E. S. [*et al*]. Pat. 2319925 Russian Federation, IPC G 01 B 5/08, G 01 B 5/20. Device for measuring the linear dimensions of wheelsets. Applicant and patent holder: State Unitary Enterprise Nizhny Novgorod branch – a subsidiary of VNIIZhT of the Ministry of Railways of the Russian Federation. No. 2006114906/28; application 02.05.2006; publ. 20.03.2008. Bull. No. 8. – 6 p. EDN: ARYASB.

16. Mikhailov, I. G., Knyazev, D. A., Sukhov, A. V. [*et al*]. The concept of wheelsets for a promising high-speed train [*Kontseptsiya kolesnykh par dlya perspektivnogo vysokoskorostnogo poezda*]. *Bulletin of Institute for Problems of Natural Monopolies: Railway Engineering,* 2018, Iss. 2 (42), pp. 49–61. EDN: XMGCAH. ●

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