
POWER
EQUIPMENT

Improving the Mechanism for Emergency Extraction of the Leveling Rod in the Coke Ejection System at Ural Steel

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Abstract—In the coke ejection system serving the ovens in coke batteries 1, 3, 4, and 6 in the coke shop at Ural Steel, a manual winch mounted beside the main drive is used to remove the leveling rod from the coke oven in the event of drive failure. Two workers cannot complete this task in less than an hour. Replacement of the manual winch by an electromechanical winch is proposed to automate and speed up the extraction of the rod in the coke ejection system and to improve the reliability of the emergency rod-extraction mechanism. Modernization of the emergency extraction mechanism reduces unplanned downtime and the cost of coke; increases the profitability and coke output; and eliminates manual labor. The capital investment may be quickly earned back.

Keywords: coke ejection system, coal batch, loading leveling device, leveling rod, emergency drive, winch, modernization

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The coke shop at Ural Steel, which mainly produces metallurgical coke (>25 mm), coke nuts (10–25 mm), and coke breeze (≤10 mm), is based on coke batteries 1, 3, 4, and 6 [1, 2]. Batteries 1, 3, and 4 each contain 61 coking chambers; the annual output of each one is 426000 t of coke (moisture content 6%). Battery 6 contains 65 coking chambers; its annual output is 690000 t of coke (moisture content 6%) [2]. On the machine side, coke batteries 1, 3, 4, and 6, positioned in parallel, are served by coke ejection systems ensuring the removal of coke from the coking chamber and the charging of fresh coal batch [3].

When new batch is being loaded, a special leveling system in the coke ejection system smooths (levels) the top of the coal charge in the coking chamber to permit free passage of the vapor and gas products to the output hatch. The degree of chamber filling and the heating conditions depend on the quality of this smoothing operation and the design of the leveling rod. If the density of the coal charge is increased, the proportion of poorly caking (SS) and gas (G) coal in the coking batch may be increased, and the productivity of the coke batteries may be improved.

The leveling system mounted in the upper area of the coke ejection system consists of a leveling rod, auxiliary metal structures, the control drive for the bar, a tension device, the drive of the emergency

extraction mechanism, supporting racks, and the door-opening drive for leveling.

The leveling rod is introduced in the coking chamber through the open leveling hatch of the door on the machine side, over practically the whole chamber length, and performs long and short reciprocating motions. As a result, the batch is evened out. The rod moves on supporting rollers mounted on racks, by means of a reversible rope drive consisting of an electric motor, a gear system, a drum with a cable, and a brake. The rod is fixed by the upper supporting rollers. The leveling system is controlled from the operator's cabin. (The electrical system permits manual or automatic operation of the rod.)

When the main drive mechanism of the main drive fails, the rod is removed from the furnace by a manual winch mounted beside the drive. Two workers cannot complete this task in less than an hour.

In the present work, the mechanism for emergency extraction of the leveling rod is modernized.

ANALYSIS

We consider the modernization of the mechanism for emergency extraction of the leveling rod for a specific example: coke ejection system KV 30.3 serving coke battery 6. Table 1 summarizes its characteristics.

Table 1. Characteristics of coke ejection system

Characteristic	Value
Service capacity, cycle/h	5–7
Duration of basic operating cycle	480
Number of setups per cycle	2
Speed, m/s:	
operational	1.64
in maintenance mode	0.01–0.05
extraction rod	0.5 ± 0.03
scraper tools in cleaning mechanisms for frames and doors	≤ 0.35
Working path, mm:	
extraction rod	20227
leveling rod	16150
in door removal	2000
in door cleaning	900
door removal mechanism	130
Dimensions of coke ejection system, mm:	
length	24380
width	12700
height	10930
Maximum force, kN:	
coke ejection	300
batch charging	30
door removal	120
installing doors in chamber	45
Diameter of supporting wheels, mm	800
Number of supporting wheels:	
total	8
drive wheels	4
Track, mm	10000
Base, mm	7600
Total rated power, kW	355
Power consumption, kW h/cycle	6–8
Number of electric drives	18
Mass, t	228

The main equipment of the coke ejection system is located in the working areas of the metal structure: the lower area accommodates the compressor station, the air lines, and the cabin of the control system; the mechanism responsible for rod motion is in a special area on the lower flange of the support beams; the middle area is the site of the ejection device and leveling device, the door removal unit with mechanisms for cleaning the doors and frames of the coke ovens, and the drive of the leveling system (Fig. 1), the storage bunker of the leveling system, and the degreasing unit; and the upper area accommodates the leveling rod, the device for

opening and closing the leveling door, the batch dispersal mechanism, and the machinist's cabin [4].

The leveling rod or the coke ejection system is equipped with flanges to seal the upper part of the coal charge in the coke oven and fill the space between the hatches with batch. They are mounted in the following order: the first is on the tip of the leveling rod; the second and third are at distances of 2.2 and 3.3 m.

The leveling rod is introduced in the coke oven after the extreme bunkers of the coal car are completely empty and the center bunker is paused, at the

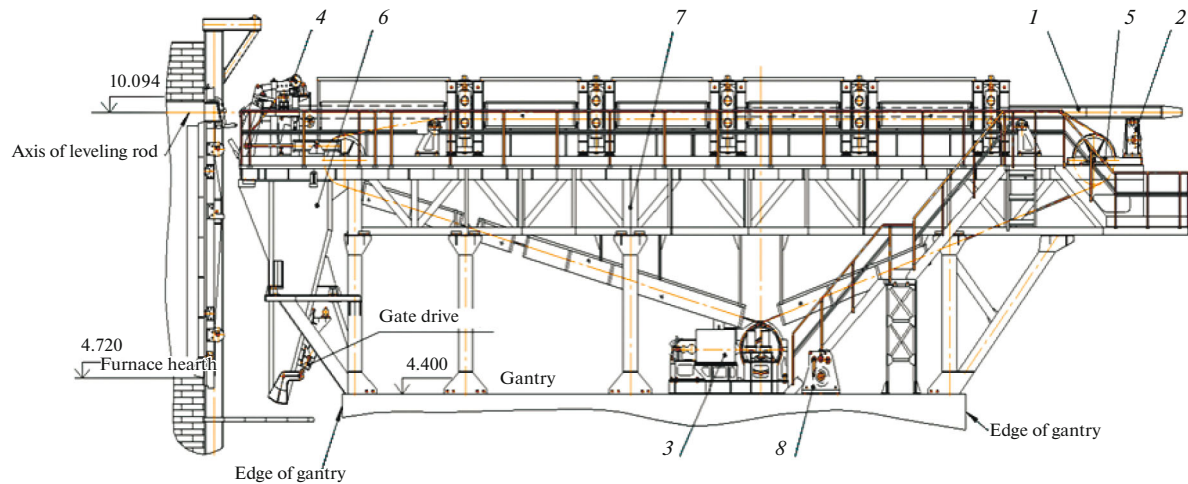


Fig. 1. Leveling system: (1) leveling rod; (2) columns with supporting rollers; (3) drive; (4) mechanism for opening and closing the leveling hatch; (5) tension unit; (6) bunker; (7) metal structure; (8) emergency drive.

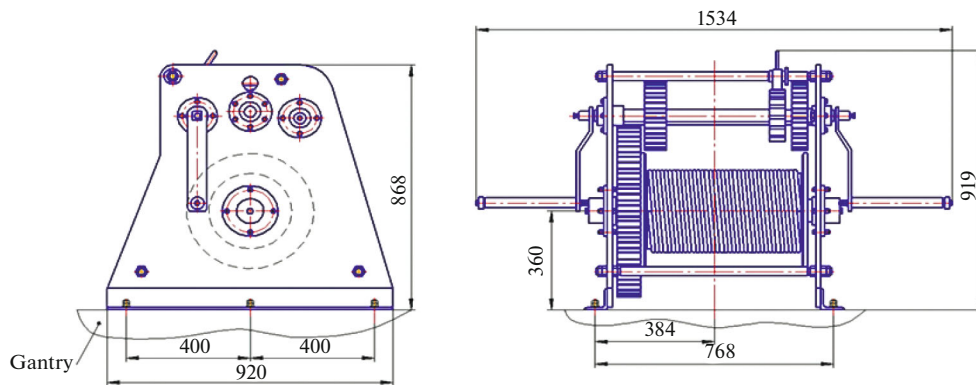


Fig. 2. TL-5A winch.

command of the coal car operator [2]. Leveling proceeds automatically until coal batch appears in the observation window. Then the operator of the coke ejection system signals the coal car operator to close the gate on the center bunker. Thereafter leveling is manually controlled; 3–5 passes of length 8.5–9.0 m are made. The leveling rod is introduced along the axis of the gas exhaust column on the coke side.

For the leveling rod of each coke ejection system, the risks of maximum rod introduction in the coking chamber by short and long strokes have been established. The position of the leveling rod with respect to the furnace roof is regulated, and the rod design and rollers ensure that the rod sags by no more than 250 mm when extended over the entire furnace length. After leveling ends, the rod is removed from the furnace to the transport position, automatically or at the command of the coal car operator. The operator of the coke ejection system closes the lid of the leveling hatch, seals the hatch and the top of the door using

special grease, and moves the coke ejection system to the next coke oven [2].

Once a month, a five-person team performs an 8-h repair session on the coke ejection system, with inspection and repair of the wheels, the gear systems, and other mechanisms. Every three years, a ten-person team undertakes major repairs of the coke ejection system (lasting two days), with rehabilitation of the metal structures and the mechanisms.

In the event of mechanical breakdown of the drive for emergency retrieval of the leveling rod, it may be removed from the coke oven using a TL-5 manual winch of drum type (Fig. 2), with the following characteristics:

Tractional force on rope, kN	50
Rope diameter, mm	21
Minimum rope capacity of drum, m	75
Maximum force on a single lever, kg	12

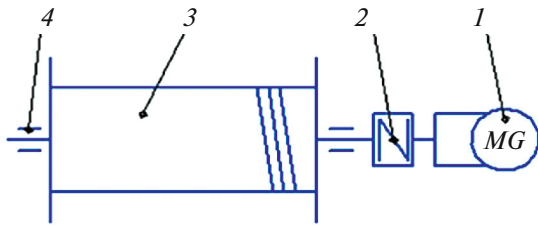


Fig. 3. Kinematic diagram of modernized mechanism for emergency retrieval of the leveling rod: (1) motor–gearbox unit (MG); (2) elastic bush–pin coupling; (3) drum; (4) bearing.

In modernization of the mechanism for emergency retrieval of the leveling rod in the coke ejection system at the Ural Steel coke plant, the TL-5A manual winch of drum type is replaced by a winch with an electric drive. In Fig. 3, we show a kinematic diagram of the modernized mechanism for emergency retrieval of the leveling rod.

A winch of motor–gearbox type is mounted on a welded frame. Its benefits include modular design, low noise, and ease of maintenance. Bearings of the winch drum are mounted on columns welded to the frame. The shaft of the motor–gearbox unit is connected to the shaft of the winch’s drum by an elastic bush–pin coupling enclosed in a protective casing that is bolted to the frame (Fig. 4).

In fracture of the main drive of the leveling system, the rod remains in the furnace. To remove the rod, the rope attached to the winch’s drum is connected to the tip of the rod and then the motor–gearbox unit is turned on. The rope is wound on a drum and the rod is removed from the furnace.

The initial data for the calculation are as follows: $V = 1.5$ m/s is the velocity of the leveling rod; and $l = 30$ m is the maximum rope length.

The working force in the rope is

$$S = (mg)/\eta = (2677 \times 9.81)/0.98 = 26797.3 \text{ N,}$$

where $m = 2677$ kg is the mass of the rod; $g = 9.81$ m/s² is the acceleration due to gravity; and $\eta = 0.98$ is the efficiency of the bypass module.

The permissible rupture force of the rope is [5]

$$F_0 \geq Z_r S = 3.15 \times 26797.3 = 84411.5 \text{ N,}$$

where $Z_r = 3.15$ is the minimum use factor (margin of strength) of the rope, determined according to the classification of the mechanism in the ISO 4301/1 standard (in operational mode M1 in the present case).

In accordance with State Standard GOST 2688–80, we select rope (diameter 13 mm) of the 1770 N/mm² (180 kgf/mm²) quality group; the total rupture force of all the strands in the rope is 107 500 N and the rupture force of the entire rope is at least 89 000 N [6].

The diameter of the winch’s smooth drum, welded from St3 steel (State Standard GOST 380–2005 [7]) is $D_d = 250$ mm, according to the calculations; its length $L_d = 552$ mm. The drum’s wall thickness is $\delta = 20$ mm; its flange diameter is $D_{fl} = 330$ mm.

The efficiency of the modernized drive in the mechanism for emergency retrieval of the leveling rod is

$$\eta_{dr} = \eta_{mg} \eta_{co} \eta_{rb} = 0.88 \times 0.98 \times 0.99 = 0.85.$$

Here $\eta_{mg} = 0.88$ is the efficiency of the motor–gearbox unit; $\eta_{co} = 0.98$ is the efficiency of the coupling; and $\eta_{rb} = 0.99$ is the efficiency of the pair of roller bearings.

The power required for rod extraction is

$$N = (SV_{ro})/(1000\eta_{dr}) = (26797 \times 1.0)/(1000 \times 0.85) = 31.5 \text{ kW,}$$

where S is the maximum working force in the winch rope, N; V_{ro} is the speed at which the rope is wound on the drum, m/s; and $\eta_{dr} = 0.85$ is the efficiency of the modernized drive in the mechanism for emergency retrieval of the leveling rod. We assume that $V_{ro} = 1.0$ m/s.

The drum speed n_d is

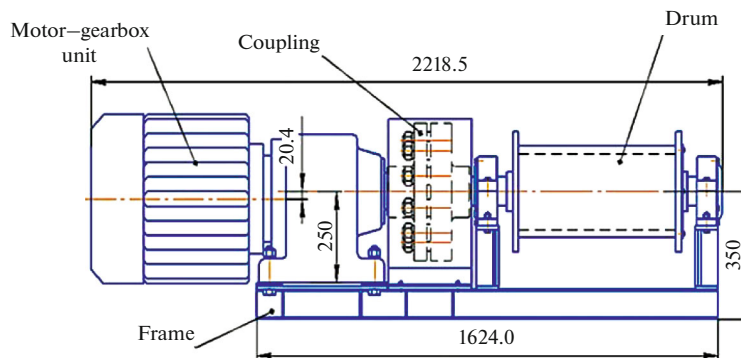


Fig. 4. Electrically driven winch.

$$n_d = \frac{1000 \times 60 V_{ro}}{\pi [D_d + d_{ro}]} = \frac{1000 \times 60 \times 1.0}{3.14 \times [250 + 13]} = 72.7 \text{ rpm},$$

where $d_{ro} = 13$ mm is the rope diameter.

On the basis of the calculation, we select an RC107 cylindrical coaxial motor–gearbox unit with relatively high efficiency, low cost, a long working life, and the following characteristics: power 37 kW; efficiency of the AIS-225-S4 electric motor 92.7%; rated torque of output shaft 4820 N m; speed of output shaft 73 rpm; and gear ratio 20.07.

The drum's shaft is supported by two double-row spherical rolling bearings with asymmetric rollers (bearing 3614 according to State Standard GOST 5721–2022, the equivalent of the imported 22314 bearing) of the appropriate load capacity and durability.

The shaft of the winch drum and the output shaft of the motor–gearbox unit are connected by means of a MUVP 8000-70-1 coupling (State Standard GOST 21424–93) on the basis of the required shaft diameter and the calculated torque

$$T_{ca} = k T_{ra} = 1.25 \times 4820 = 6025 \text{ N m},$$

where $k = 1.25$ is the operational factor; $T_{ra} = 4820$ N m is the rated torque (or the maximum long-term torque).

The MUVP coupling compensates for 0.2–0.4 mm radial displacement of the shafts; up to 5 mm axial displacement; and up to 1.5° angular displacement [8]. The performance of the MUVP coupling is determined by the strength of the rubber bushes, estimated in terms of the pressure at bush–pin contact

$$p = \frac{2T_{ca} \times 1000}{z l_b d_p D_m} = \frac{2 \times 6025 \times 1000}{10 \times 71 \times 38 \times 280} \\ = 1.6 \text{ MPa} \leq [p] = 3 \text{ MPa}.$$

Here $T_{ca} = 6025$ N m is the calculated torque of the coupling; $z = 10$ is the number of bushes; $d_p = 38$ mm is the pin diameter at the rubber bush; $l_b = 71$ mm is the length of the rubber bush; $D_m = 280$ mm is the diameter of the circumference on which the pin centers are located; and $[p] = 3$ MPa is the permissible pin–bush pressure.

The check calculation for pin flexure in the MUVP coupling is as follows

$$\sigma_{fl} = \frac{T_{ca} l_b \times 1000}{0.1 z d_p^3 D_m} = \frac{6025 \times 71 \times 1000}{0.1 \times 10 \times 38^3 \times 280} \\ = 27.8 \text{ MPa} \leq [\sigma] = 80 \text{ MPa},$$

where σ_{fl} is the effective flexural stress in the pins, MPa; $[\sigma_{fl}]$ is the permissible flexural stress in the pins, MPa.

After checking the crumpling and shear strength, the half-coupling and drum shaft are connected by means of a $20 \times 12 \times 125$ key State Standard GOST 23360–78) made of steel 45 (State Standard GOST 1050–2013).

Leveling off the coal batch improves the efficiency of coke production when the design of the leveling system and leveling rod takes account of the influence of multiple cyclic temperature differences, leading to failure of the weld seams and warping of the rod components, with associated repair costs. Therefore, the benefits of leveling depend on improvement of the existing leveling rod design so as to reduce the raking of the batch back into the bunker [4].

The following designs of leveling rod are known.

1. A rod in which raking of the batch from the chamber in leveling is introduced and the efficiency of batch use is increased by installing a reversible drive screw within the immobile housing. The screw consists of individual sections connected by universal hinges [9].

2. A rod in which, to speed up the smoothing of the batch, a spade-like attachment is hinged at the front and supported in an elevated position during forward motion by means of a pin within a guide tube. The pin is set in motion by a carriage. A slide moves within the guides of the carriage; it is hinged to the carriage on one side and rigidly attached to the pin on the other [10].

3. A rod in which an electric vibrator and sealing plates are used to enclose the coal charge in the coke ovens. It also includes an air blower in a sealed casing [11].

4. A rod in which, besides a rigidly attached vibrator, two or more vibrators are freely attached so as to ensure their vertical motion [12].

5. A rod in which a housing encloses stops, a bar, and rotary components that are attached to shafts in the housing and connected to a drive. To increase the efficiency of this unit, the rotary components are connected to the drive by a lever system and a carriage mounted in the bar [13].

6. A rod consisting of parallel strips connected together at the front by partitions and at the rear by flat sheets. In this design, the life of the furnace lining is prolonged by removing excess batch from the gap between the leveling rod and the lining. To that end, each strip is equipped with blades at its outer surface and tapered guides mounted in its upper and lower parts on both sides of the blades, and holes are made in each strip on both sides of the blades [14].

7. A rod consisting of two lateral vertical parallel strips connected by vertical partitions and horizontal bars. To increase the productivity, the rod is equipped with central and lateral seals alternating over its length. The seals take the form of dihedral inclined upward and bounded below by a convex cylindrical surface, which is inclined to the faces at an angle greater than the natural slope of the coal batch and attached at its ends to the lower edges of the vertical partitions. The cylindrical surface of the seals is perpendicular to the lateral strips of the rod. The upper face edge of the lateral seals is rigidly connected to the upper edge of the rod's lateral strip [15].

8. A rod including lateral sheets connecting partitions, and a drive. To improve batch sealing and increasing the durability and reliability of the structure, the height of the connecting partitions is 30–40% of the rod height; and the rod is equipped with hinged plates of variable height and stops that are able to interact with the plates. The height of the plates in the central part of the rod is 95–100% of the height of the rod, while the height of the plates at the ends of the rod is 75–80% of the height of the rod [16].

9. A rod in which a vibrational mechanism consisting of three matching permanent magnets is used in order to improve coke quality, increase coke oven productivity, and reduce the metal content of the rod. Two of the magnets are made of rectangular strip and attached to the two front supports above the leveling rod; the third consists of zigzag tape with uniformly changing height and is attached at the output end of the rod. The two front supports include sprung guide rollers [17].

However, these leveling rod designs are complex [9–13, 17], insufficiently durable [12–14, 17], and ineffective [12, 15–17]. They do not sufficiently increase the uniformity and density of the coal charge, and the reliability of standard rod designs is low on account of failure of the transverse partitions in cyclic mechanical and thermal conditions [18]. In older designs, including the coke ejection system at Ural Steel, the rod is a simple welded structure of constant strength or cross section made from relatively inexpensive and unreliable grades of steel [19].

More promising designs were considered in [20, 21]. They permit more effective control of batch loading and leveling and reduce atmospheric emissions of dust and gas during batch loading and coking, with decrease in the environmental impact in the workplace.

A leveling rod in which curved leveling partitions are attached to parallel strips connected by transverse rods was discussed in [20]. To increase the reliability, the rods have projections at the ends and are mounted in the holes of parallel strips with a gap. The strips are equipped with stops that are attached at their internal surfaces and interact with the projections of the rods. Each partition is attached to strips at its opposite ends. To increase the one-time charge of batch in the coking chamber, the leveling partitions are mounted in pairs at some inclination to the parallel strips. Each pair forms some angle, open to the upper edge of the strips [20]. The reliability of the rod is increased by decreasing the critical stress produced by alternating mechanical loads and thermal impacts to safe values, with elastic deformation of the rod.

A rod with parallel strips connected by crosspieces in the form of bars fixed in holes within the parallel strips' side walls at an inclination to the direction of rod motion was considered in [21]. The barriers are hinged to the bars. Stops are located on the side walls

of the parallel strips. This design allows each barrier to act on the batch both from below, resulting in compaction; and horizontally at the wall and along the chamber, to level out the batch. It is better than the other designs in terms of the requirements on the batch compaction and increases the productivity of the coke ovens thanks to increase in the evenness and density of the upper batch layer in the oven, with decrease in raking of the batch back into the bunker.

Therefore, the next step in modernizing the coke ejection system at Ural Steel is to replace the existing leveling rod with a more efficient design.

CONCLUSIONS

1. We have considered the design and operating conditions of the mechanism for emergency extraction of the leveling rod in the coke ejection system at Ural Steel.

2. We have developed fundamental principles for modernization of the mechanism for emergency rod retrieval of the leveling rod: in particular, replacement of the TL-5A manual drum winch by a winch with an electric motor based on the RC107 cylindrical coaxial motor–gearbox unit.

3. The additional capital expenditures for modernization amount to 553 000 rub and will be earned back in 1.02 months. The annual coke output will be increased by 0.13%, the cost of the coke will be reduced by 6.1 rub, and profitability will be increased by 0.04%.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

REFERENCES

- Gribanov, E.A., Ganin, D.R., and Fuks, A.Yu., Increasing the efficiency of the blast furnace production of Ural Steel by reducing the content of the +80 mm fraction in metallurgical coke, *Chern. Met.*, 2023, no. 11, pp. 4–7. <https://doi.org/10.17580/chm.2023.11.01>
- TI-13657842-KKh-02-2022: Coke Production. Technological Instructions*, Novotroitsk, Orenburg oblast: AO Ural'skaya Stal', 2022.
- Vegman, E.F., Zherebin, B.N., Pokhvisnev, A.N., et al., *Metallurgiya chuguna. Uchebnik dlya vuzov* (Metallurgy of Cast Iron: A Textbook for Universities), Moscow: Akademkniga, 2004, 3rd ed.

4. Kaufman, A.L., Smelyanskii, A.Z., Kharlampovich, G.D., and Braun, N.V., *Master koksovogo proizvodstva* (Master of Coke Production), Moscow: Metallurgiya, 1994.
5. Kotel'nikov, V.S. and Shishkov, N.A., *Kommentarii k Pravilam ustroistva i bezopasnoi ekspluatatsii gruzopod'emnykh kranov* (Commentary to the Rules for the Construction and Safe Operation of Hoisting Cranes), Moscow: MTsFER, 2007.
6. *GOST (State Standard) 2688-80: Two Lay Rope LK-R Construction 6-19(1+6+6/6)+1 o.c. Dimensions*, Moscow: Izdatel'stvo Standartov, 2002.
7. *GOST (State Standard) 380-2005: Common Quality Carbon Steel. Grades*, Moscow: Standartinform, 2009.
8. Gulia, N.V., Klovov, V.G., and Yurkov, S.A., *Detali mashin. Uchebnik* (Machine Elements: A Textbook), Gulia, N.V., Ed., St. Petersburg: Lan', 2013.
9. Shevkalenko, F.A., Planing rod, SU Inventor's Certificate 101895, 1955.
10. Gornyi, V.G., Loginov, A.A., and Novikov, M.I., Planing rod, SU Inventor's Certificate 108375, 1957.
11. Gornyi, V.G., Loginov, A.A., and Novikov, M.I., Planing rod of coke pusher, SU Inventor's Certificate 121772, 1959.
12. Kretov, B.K., Planing rod, SU Inventor's Certificate 129632, 1960.
13. Gromov, N.F., Ushakov, A.A., Samsonov, M.V., et al., Planing rod, SU Inventor's Certificate 345183, 1972.
14. Minasov, A.Ya., Zinchenko, V.I., and Dzyuba, V.Ya., Planing rod, SU Inventor's Certificate 1214711, 1986.
15. Udovenko, A.P., Shchegolev, S.V., and Shapovalov, V.F., Planing rod for leveling and compaction of coal charge in coke oven, SU Inventor's Certificate 1370128, 1988.
16. Chamov, A.V. and Dyachenko, V.M., SU Inventor's Certificate 1788004, 1993.
17. Kuzyaev, I.M., Nachovnyi, I.I., and Ploshenko I Dr, I.G., Device for leveling and compaction of charge in coke oven, SU Inventor's Certificate 1433967, 1988.
18. Il'chenko, D.V. and Veretel'nik, S.P., Ways of modernization of planing boom designs, *Naukovi Pratsi Donets'kogo Natsional'nogo Tekhnichnogo Universitetu. Seriya Khimiya i Khimichna Tekhnologiya*, 2013, no. 1, pp. 173–178.
19. Leibovich, R.E., Yakovleva, E.I., and Filatov, A.B., *Tekhnologiya koksokhimicheskogo proizvodstva* (Technology of Coke and Chemical Production), Moscow: Metallurgiya, 1982.
20. Parfenyuk, A.S., Khromov, N.A., Bulatov, A.A., et al., Planing rod, SU Inventor's Certificate 1237697, 1986.
21. Parfenyuk, A.S., Moskalets, F.I., Veretel'nik, S.P., et al., Planing rod, SU Inventor's Certificate 1682378, 1991.

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