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(54) METHOD OF ROLLING BALLS

(57) A method of rolling balls, especially from feet of scrap railway rails, characterized in that a blank (30) in the shape of a section of a railway rail foot is heated to the temperature appropriate for hot forming, after which the heated blank (30) is placed in grooves (2a) and (2b) of feeding rollers (1a) and (1b), then the feeding rollers (1a) and (1b) are set to rotate at the same speed (n1) and the blank (30) is moved towards a front guide (3) at a constant speed (V1), thereafter, grooved rolls of a first stand (5a) and (5b) are set to rotate at a constant speed (n2) in opposite directions, and grooved rolls of a second stand (11a) and (11b) are set to rotate at a constant speed (n3) in opposite directions, and grooved rolls of a third stand (17a) and (17b) are set to rotate at a constant speed (n4) in opposite directions, and grooved rolls of a fourth stand (13a) and (13b) are set to rotate at a constant speed (n5) in opposite directions, at the same time, guide rollers (27a) and (27b) are set to rotate at a constant speed (n6) in the same direction, and, at the same time, helical rolls (31a) and (32b) are set to rotate at equal speeds (n7) in the same direction, thereafter the blank (30) is guided into a guide hole (4) of a front guide (3) of the first stand and the blank (30) is moved towards the grooved rolls of the first stand (5a) and (5b), and the blank (30) is guided into trapezoid-shaped grooves (6a) and (6b) located on the surface of the grooved rolls of the first stand (5a) and (5b), which have a depth (h1) less than half the height of the blank (30).

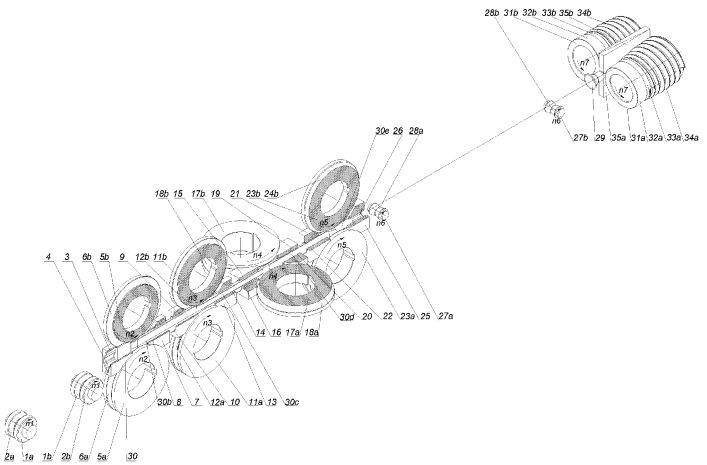

Fig. 2

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Description

[0001] The invention relates to a method of rolling balls, especially from feet of scrap railway rails.

[0002] A number of methods for manufacturing balls intended for grinding media for ball mills have been known and used so far. The most common ones include casting, die forging and rolling. The balls are cast from cast steel which is cast into permanent moulds made of metal, the so-called casting dies. Die forging of balls is typically carried out on friction presses, with the use of billets in the form of bars made of steel with increased carbon and manganese content. Immediately after the forging process, the flash is trimmed on eccentric presses. The highest efficiency in the production of balls is achieved using the skew rolling process. Information on the skew rolling of balls has been presented in a book by W. Dobrucki, "Zarys obróbki plastycznej metali" ("Outline of plastic forming of metals"), Wydawnictwo "Śląsk", Katowice, 1975. The process described in the book enables shaping of a single ball forging during one rotation of the rolls. During one minute, 160 balls with a diameter of about Ø 30 mm or 40 balls with a diameter of about Ø 120 mm are obtained. The balls are rolled in skew rolling mills equipped with two rolls with helically cut single grooves, typically 3.5 turns in length. The axes of the rolls are inclined obliquely to the axis of the billet - a bar, at an angle of 3° to 7°. During rolling, the rolls rotate in the same direction, while the billet rotates in the opposite direction. To obtain good rolling results, the diameter of the billet should be about 0.97 of the diameter of the finished balls, while the diameter of the rolls should be 5 to 6 times greater than the diameter of the rolled balls. Also known and used are methods of processing scrap railway rails, which allow for management of the railway scrap and obtaining a valuable consumable material from it. The most common methods include die forging of blanks from sections of heads of scrap railway rails and longitudinal rolling of bars from heads cut off from worn rails. The processes of longitudinal rolling of circular cross-section bars from the heads of scrap railway rails are described in detail in a book by Z. Pater, J. Tomczak, "Walcowanie śrubowe kul do młynów kulowych" ("Helical rolling of balls for ball mills"), Wydawnictwo Politechniki Lubelskiej, Lublin 2012. Depending on the diameter of the bars, the rolling process presented in the book is carried out between two or four pairs of rolls with parallel axes that rotate in opposite directions. The surfaces of the rolls have oval and circular groove cuts. In the first pass, a section of the head of the scrap railway rail is rolled in an oval cut, then the blank in the form of an oval-shaped bar is transferred to the second - circular cut, where the bars with a circular cross-section are rolled. In the case of forging rolling, the length of billets used for rolling is limited by the possibility of feeding them into the workspace of the rolls and by their weight. Most often, in such a process, the billet is fed manually and is held in the tongs throughout the shaping process. The aforementioned limitation does not occur in the case of metallurgical rolling, which allows for shaping bars with a length of up to several meters. The authors indicate that it is also possible to roll bars with circular cross-section in skew rolling mills. In the skew rolling process, the rolls are arranged symmetrically around the blank, and their axes are twisted at equal angles to the rolling axis. During the rolling process, the tools rotate at constant speeds in the same direction, grabbing the blank and pulling it into the workspace, where the bars are rolled as a result of flow formation of the blank. The use of the skew rolling process to produce a round bar from the rail head requires that its end is shaped into a cone, which is necessary in view of a smooth introduction of the material between the rolls. In order to initiate the rolling process, it is also necessary to use a pusher, which is used to feed the blank between the rolls, which then, while shaping the bar, will automatically pull it into the space between the rolls.

[0003] Polish patent PL 225772 discloses a method of skew rolling of bars with circular cross-section from the heads of scrap railway rails. The method consists in shaping bars between two rolls, which in the initial part have flanges, gradually flow forming the material during the rotation. The method disclosed in the patent requires the use of two rolls with a complicated shape, further it is necessary to guide the material in the workspace between two strips, which significantly reduces the stability of the process. Another limitation of the technology is the need to use different sets of rolls depending on the diameter of the bars to be shaped.

[0004] Polish patent application No. P.423386 discloses also a method of rolling bars from webs of scrap railway rails, which consists in two- step rolling of bars. In the first step, a preform with a nearly hexagonal cross-section is rolled longitudinally in a groove cut. Subsequently, in the second step, such a blank is rolled in a skew rolling mill between three tools into a bar of circular cross-section. This method allows for manufacturing of geometrically and dimensionally accurate bars with a circular cross-section from webs cut off from worn railway rails in a fairly wide range of diameters. The limitation of this technology may be a relatively low efficiency of such rolling.

[0005] A characteristic feature of the currently known and used methods of rolling ball forgings is the need to use blanks in the form of bars with high geometrical and dimensional accuracy. As a result, it makes it necessary to use metallurgical bars as billets. However, no processes of skew rolling of balls are available, which would be carried out in a small number of cuts immediately after the longitudinal rolling of scrap elements.

[0006] The objective of the invention is to provide rolling of ball forgings directly from feet cut off from worn railway rails.

[0007] The essence of a method of rolling balls, especially from feet of scrap railway rails according to the in-

vention, is that a blank in the shape of a section of a railway rail foot is heated to the temperature appropriate for hot forming. After that, the heated blank is placed in grooves of feeding rollers. Then, the feeding rollers are set to rotate at the same speed and the blank is moved towards a front guide at a constant speed. Thereafter, grooved rolls of a first stand are set to rotate at a constant speed in opposite directions, and grooved rolls of a second stand are set to rotate at a constant speed in opposite directions, and grooved rolls of a third stand are set to rotate at a constant speed in opposite directions, and grooved rolls of a fourth stand are set to rotate at a constant speed in opposite directions. At the same time, guide rollers are set to rotate at a constant speed in the same direction, and, at the same time, helical rolls are set to rotate at equal speeds in the same direction. After that, the blank is guided into a guide hole of a front guide of the first stand, the blank is moved towards the grooved rolls of the first stand, and the blank is guided into the trapezoid-shaped grooves located on the surface of the grooved rolls of the first stand, which have a depth less than half the height of the blank and a width greater than the thickness of the blank, and the inclination angle of the side walls of the grooves of the grooved rolls of the first stand greater than the inclination angle of the blank walls. And the diameter of both grooved rolls of the first stand is the same, wherein the axes of both grooved rolls of the first stand are located in a horizontal plane, and the distance between the axes of both grooved rolls of the first stand is equal to the diameter of the grooved rolls of the first stand. The blank is then gripped with the groove surfaces of the grooved rolls of the first stand and the blank in the shape of the railway rail foot is flow formed into a rhombus-shaped blank. The height of a cut formed by the trapezoidal grooves of the grooved rolls of the first stand has a depth which is greater than the width of the cut formed by the trapezoidal grooves of the grooved rolls of the first stand, wherein the rhombus-shaped blank is held in a rolling axis behind a rolling gap of the grooved rolls of the first stand in a rhombus-shaped hole of a rear guide of the first stand. After that, the blank is moved towards the second rolling stand, which consists of two identical grooved rolls of the second stand, which have the same diameter and trapezoidal grooves on their surfaces, the depth of which is less than the depth of the trapezoidal grooves of the grooved rolls of the first stand, and the width of the trapezoidal grooves of the grooved rolls of the second stand is greater than the width of the trapezoidal grooves of the grooved rolls of the first stand. The axes of the grooved rolls of the second stand are horizontal and are spaced apart by the diameter of the grooved rolls of the second stand, then the end of the blank is guided into a hole of an entry guide of the second rolling stand, where its position is held, then the end of the blank is guided into the trapezoidal grooves, which are located on the cylindrical surfaces of the grooved rolls of the second stand, and the blank with a rhombus-shaped cross-section is flow formed into a blank with a nearly rhombic cross-section. The height of the cross-section of the blank is less than the height of the cross-section of the blank after rolling in the trapezoidal grooves of the grooved rolls of the first stand. Behind a rolling gap of the second stand, the rolled blank is guided in a rhombus-shaped hole of a rear guide of the second rolling stand, then the blank is guided into a guide hole of a front guide of the third stand and the blank is moved towards the grooved rolls of the third stand and the blank is guided into the oval-shaped grooves located on the surface of the grooved rolls of the third stand, which have a depth less than half the height of the blank and a width greater than the thickness of the blank. The diameter of both grooved rolls of the third stand is the same. The axes of both grooved rolls of the third stand are located in a vertical plane, and the distance between axes of both grooved rolls of the third stand is equal to the diameter of the grooved rolls of the third stand. The radius of the oval-shaped grooves is the same for both grooved rolls of the third stand. Then, the blank is gripped with groove surfaces of the grooved rolls of the third stand and a rhombus-shaped blank is flow formed into an oval-shaped blank, the vertical axis of an oval cut formed by the grooves of the grooved rolls of the third stand having a length that is greater than the height of the rhombic cross-section of the blank rolled in the trapezoidal grooves of the second stand. The oval-shaped blank is held in the rolling axis behind a rolling gap of the grooved rolls of the third stand in an oval-shaped hole of ta rear guide of the third stand. After that, the blank is moved towards the fourth rolling stand, which consists of two identical grooved rolls of the fourth stand, which have the same diameter and the surfaces of which have concave grooves with a radius equal to half the diameter of the rolled ball. The axes of the grooved rolls of the fourth stand are located horizontally and spaced apart by the diameter of the grooved rolls of the fourth stand. Thereafter, the end of the blank is guided into a hole of an entry guide of the fourth rolling stand. Then, the end of the blank is guided into circular-shaped grooves, which are located on the cylindrical surfaces of the grooved rolls of the fourth stand, and the blank with an oval-shaped cross-section is flow formed into a bar with nearly circular cross-section, with the diameter of the bar being greater than the diameter of the rolled ball. After that, the rolled bar is moved in grooves of the guide rollers in the direction of skew rolls and the bar is guided into a hole of a guiding sleeve, in which the correct position of the bar is maintained. Then, using the guide rollers, the bar is guided into a workspace of a skew rolling mill, consisting of two helical rolls and two guides. Both helical rolls have the same working diameter, and their axes are twisted in opposite directions relative to the rolling axis by the same value of the twist angle of the rolls. The guides are located parallel to the rolling axis, and the distance between the working surfaces of the guides is greater than the diameter of the rolled bar. After that, the end of the bar is gripped with conical surfaces located in an entry zone of

two helical rolls, which rotate with equal speeds in the same direction, the bar is set to rotate at a constant speed in the direction opposite to the direction of rotation of the helical rolls, and the cross-section of the bar is flow formed using conical surfaces and the cross-section of the bar is calibrated to a diameter smaller than the diameter of the rolled ball using two cylindrical surfaces located behind the conical surfaces of the helical rolls. Subsequently, helical protrusions located on the surfaces of the helical rolls are sunk into the cylindrical surface of the earlier calibrated bar. The helical protrusions of the helical rolls have concave side surfaces, the radius of which is equal to half the diameter of the rolled ball. Then, annular grooves with spherical side surfaces are gradually formed on the bar, the blank being held in the workspace during rolling by two guides, located opposite each other, between the helical rolls. Then, as a result of the action of the helical protrusions with concave side surfaces located on the helical rolls, the depth of the annular grooves increases until the ball is formed and completely separated from the bar. As a result, the ball with a diameter smaller than the diameter of the bar is obtained.

[0008] The advantageous effect of the invention is that it allows for plastic shaping of balls directly from a blank in the shape of a section of foot cut off from worn railway rails. As a result, it is possible to roll ball forgings with a minimum number of longitudinal stands. The invention is characterized by a high efficiency of ball production as compared with that achieved in the die forging and casting processes. Further, the use of bar calibration immediately before rolling of the balls shortens the rolling time and reduces the sensitivity of the process to the geometric accuracy of the blanks.

[0009] The invention is presented in an embodiment in the drawings, wherein Fig. 1 shows an isometric view of the rolling process in the initial stage, Fig. 2 shows an isometric view of the process during rolling of a bar in longitudinal stands, Fig. 3 shows an isometric view of the process after rolling of a bar, Fig. 4 shows an isometric view of the process during rolling of balls, Fig. 5 shows a side view of tools and rolled balls, fig. 6 shows the A-A section through the axis of the first stand, Fig. 7 shows the B-B section through the axis of the second stand, Fig. 8 shows the C-C section through the axis of the third stand, Fig. 9 shows the D-D section through the axis of the fourth stand, and Fig. 10 shows the E-E section through the rolling axis in the skew stand.

[0010] A method of rolling balls, especially from foot sections of scrap railway rails, consists in that a blank 17 in the shape of a section of a railway rail head was heated to the temperature appropriate for hot working, which was 1200°C. Then, the heated blank 17 was placed in the grooves 2a and 2b of the feeding rollers 1a and 1b. After that, the feeding rollers 1a and 1b were set to rotate at the same speed n1 of 60 rpm, and the blank 17 was moved towards the front guide 3 at a constant speed V1 of 100 mm/s. Subsequently, the grooved rolls of the first stand 5a and 5b were set to rotate at a constant speed n2 of 12 rpm in opposite directions. At the same time, the grooved rolls of the second stand 11a and 11b were set to rotate at a constant speed n3 of 15 rpm in opposite directions, and the grooved rolls of the third stand 17a and 17b were set to rotate at a constant speed n4 of 16 rpm in opposite directions, and the grooved rolls of the fourth stand 13a and 13b were set to rotate at a constant speed n5 of 20 rpm in opposite directions. At the same time, the guide rollers 15a and 15b were set to rotate at a constant speed n6 of 35 rpm in the same direction and at the same time the helical rollers 31a and 31b were set to rotate at the same speeds n7 of 45 rpm in the same direction. Then, the blank 30 was guided into a guide hole 4 of the front guide of the first stand 3, and the blank 17 was moved towards the grooved rolls of the first stand 5a and 5b, and the blank 30 was guided into the trapezoid-shaped grooves 6a and 6b located on the surface of the grooved rolls of the first stand 5a and 5b. The grooves 6a and 6b of the grooved rolls of the first stand 5a and 5b had a depth h1 of 50 mm, which was less than half the height of the blank 30, and a width b1 of 42 mm which was greater than the thickness of the blank 30, and the angle of inclination $\gamma 1$ of the side walls of grooves 6a and 6b of grooved rolls of the first stand 5a and 5b equal to 32°, which was greater than the angle of inclination of the blank 30 walls. The diameter D1 of both grooved rolls of the first stand 5a and 5b was the same and was 500 mm. The axes of both grooved rolls of the first stand 5a and 5b were located in a horizontal plane, and the distance between axes of both grooved rolls of the first stand 5a and 5b was equal to the diameter D1 of 500 mm of the grooved rolls of the first stand 5a and 5b. Then the blank 30 was gripped with the groove surfaces 6a and 6b of the grooved rolls of the first stand 5a and 5b and the blank 30 in the shape of a railway rail foot was flow formed into a rhombus-shaped blank 30b, the height of the cut formed by the trapezoidal grooves 6a and 6b of the grooved rolls of the first stand 5a and 5b had a depth h1 equal to 50 mm, which was greater than the width b1 equal to 42 mm of the cut formed by the trapezoidal grooves 6a and 6b of the grooved rolls of the first stand 5a and 5b. The rhombus-shaped blank 30b was held in the rolling axis behind the rolling gap of the grooved rolls of the first stand 5a and 5b in the rhombus-shaped hole 8 of the rear guide of the first stand 7. Then the blank 30b was moved towards the second rolling stand, which consisted of two identical grooved rolls of the second stand 11a and 11b, which had the same diameter D2 of 500 mm, and surfaces with trapezoidal grooves 12a and 12b with a depth h2 of 32 mm which was less than the depth h1 of the trapezoidal grooves 6a and 6b of the grooved rolls of the first stand 5a and 5b, and a width b2 of 52 mm of the trapezoidal grooves 12a and 12b of the grooved rolls of the second stand 11a and 11b which was greater than the width b1 of the trapezoidal grooves 6a and 6b of the grooved rolls of the first stand 5a and 5b. On the other hand, the axes of the grooved rolls of the second stand 11a and 11b were lo-

cated horizontally and spaced apart by the diameter D2 of the grooved rolls of the second stand 11a and 11b, equal to 500 mm. Thereafter, the end of the blank 30b was guided into a hole 10 of the entry guide 9 of the second rolling stand, where its position was maintained. Then, the end of the blank 30b was guided into the trapezoid-shaped grooves 12a and 12b, which were located on the cylindrical surfaces of the grooved rolls of the second stand 11a and 11b, and the blank 30b with a rhombus-shaped cross-section was flow formed into a blank 30c with nearly rhombic cross-section, wherein the height 2h2 of 64 mm of the cross-section of the blank 30c was less than the height 2h1 of 100 mm of the cross-section of the blank 30b after rolling in the trapezoidal grooves 6a and 6b of the grooved rolls of the first stand 5a and 5b. Behind the rolling gap of the second stand, the rolled blank 30c was guided in a rhombus-shaped hole 14 of the rear guide 13 of the second rolling stand, then the blank 30c was guided into a guide hole 16 of the front guide of the third stand 15 and the blank 30c was moved towards the grooved rolls of the third stand 17a and 17b. After that, the blank 30c was guided into the oval-shaped grooves 18a and 18b, located on the surface of the grooved rolls of the third stand 17a and 17b, which had a depth h3 equal to 16 mm, which was less than the half the height of the blank 30c, and a width b3 equal to 74 mm, which was greater than the thickness of the blank 30c. The diameter D3 of 500 mm of both grooved rolls of the third stand 17a and 17b was the same. The axes of both grooved rolls of the third stand 17a and 17b were located in a vertical plane, and the distance between axes of both grooved rolls of the third stand 17a and 17b was equal to the diameter D3 of the grooved rolls of the third stand 17a and 17b and was 500 mm. The radius R3 of the oval-shaped grooves 18a and 18b, equal to 75 mm, was the same for both grooved rolls of the third stand 17a and 17b. Then, the blank 30c was gripped with the groove surfaces 18a and 18b of the grooved rolls of the third stand 17a and 17b and the rhombus-shaped blank 30c was flow formed into an oval-shaped blank 30d, wherein the vertical axis of the oval cut formed by the grooves 18a and 18b of the grooved rolls of the third stand 17a and 17b had a length b3 equal to 68 mm, which was greater than the height 2h2, equal to 70 mm, of the rhombic cross-section of the blank 30c rolled in the trapezoidal grooves of the second stand 12a and 12b. The oval-shaped blank 30d was held in the rolling axis behind the rolling gap of the grooved rolls of the third stand 17a and 17b in an oval-shaped hole 20 of the rear guide of the third stand 19. After that, the blank 30d was moved towards the fourth rolling stand, which consisted of two identical grooved rolls of the fourth stand 23a and 23b, which had the same diameter D4, equal to 500 mm, and the surfaces of which had concave grooves 24a and 24b with a radius R4 of 21.5 mm, equal to half the diameter dk of the rolled ball 36. The axes of the grooved rolls of the fourth stand 23a and 23b were located horizontally and spaced apart by a diameter D4 of the grooved rolls of the fourth stand 23a and 23b, equal to 500 mm. Thereafter, the end of the blank 30d was guided into a hole 22 of the entry guide 21 of the fourth rolling stand. Then, the end of the blank 30d was guided into the circular-shaped grooves 24a and 24b, which were located on the cylindrical surfaces of the grooved rolls of the fourth stand 23a and 23b, and the blank 30d with an oval-shaped cross-section was flow formed into a bar 30e with nearly circular cross-section, wherein the diameter dp of the bar 30e was 43.5 mm and was greater than the diameter dk of the rolled ball 36 equal to 42 mm. After that, the rolled bar 30e was moved in the grooves 28a and 28b of the guide rollers 27a and 27b towards the skew rolls 31a and 31b, and the bar 30e was guided into a hole of the feeding sleeve 29, in which the correct position of the bar 30e was maintained. Then, using the guide rollers 27a and 27b, the bar 30e was guided into the workspace of the skew rolling mill, consisting of two helical rolls 31a and 31b and two guides 35a and 35b. Both helical rolls 31a and 31b had the same working diameter D of 340 mm, and their axes were twisted in opposite directions relative to the rolling axis by the same twist angle of the rolls γ, which was 3.5°. The guides 35a and 35b were parallel to the rolling axis, and the distance between the working surfaces of the guides 35a and 35b was greater than the diameter dp of the rolled bar 30e, and during the rolling was equal to 45 mm. Then, the end of the bar 30e was gripped with conical surfaces 32a and 32b located in the entry zone of two helical cylinders 31a and 31b, which rotated at the same speeds n7 in the same direction, and the bar 30e was set to rotate at a constant speed n8 of 180 rpm in the direction opposite to the direction of rotation of the helical rolls 31a and 31b, and the bar 30e was moved at a speed V2 of 50 mm/s, and using the conical surfaces 32a and 32b the cross-section of the bar 30e was flow formed, by shaping a transitional conical surface with an opening angle α of 4°, and then the cross-section of the bar 30e was calibrated using two cylindrical surfaces 33a and 33b located behind the conical surfaces of the helical rolls 31a and 31b to a diameter of 41 mm, which was smaller than the diameter of the rolled ball dk, which was 42 mm. Subsequently, helical protrusions located on the surfaces of the helical rolls 31a and 31b were sunk into the cylindrical surface of the earlier calibrated bar 30e. The concave side surfaces 34a and 34b of the helical protrusions of the helical rolls 31a and 31b had concave side surfaces 34a and 34b, the radius Rk of which was 21 mm and was equal to half the diameter dk of the rolled ball 36. Then, annular grooves with spherical side surfaces were gradually formed on the blank 30e. During the rolling, the blank was held in the workspace by two guides 35a and 35b, located opposite each other, between the helical rolls 31a and 31b. Then, as a result of the action of the helical protrusions with concave side surfaces 34a and 34b of the helical rolls 31a and 31b, the depth of the annular grooves was increased until the ball 36 was formed and completely separated from the bar 30e. As a result of the action of the helical pro-

jections with concave side surfaces 34a and 34b, a ball 36 with a diameter dk equal to 42 mm, smaller than the diameter dp of the bar 30e, equal to 41.5 mm, was formed.

List of reference signs

[0011]

1a, 1b	- feeding rollers
2a, 2b	- grooves on feeding rollers
3	- front guide of the first stand
4	- guide hole of the front guide
5a, 5b	- grooved rolls of the first stand
6a, 6b	- trapezoid-shaped grooves
7	- rear guide of the first stand
8	- rhombus-shaped hole
9	- entry guide of the second stand
10	- hole of the entry guide of the second stand
11a, 11b	- grooved rolls of the second stand
12a, 12b	- trapezoid-shaped grooves of the grooved rolls of the second stand
13	- rear guide of the second stand
14	- hole of the rear guide of the second stand
15	- entry guide of the third stand
16	- hole of the entry guide of the third stand
17a, 17b	- grooved rolls of the third stand
18a, 18b	- oval-shaped grooves of the grooved rolls of the third stand
19	- discharge guide of the third stand
20	- hole of the discharge guide of the third stand
21	- entry guide of the fourth stand
22	- oval hole of the entry guide of the fourth stand
23a, 23b	- grooved rolls of the fourth stand
24a, 24b	- grooves of the grooved rolls of the fourth stand
25	- rear guide of the fourth stand
26	- square-shaped hole of the rear guide of the fourth stand
27a, 27b	- guide rollers
28a, 28b	- grooves of the guide rollers
29	- feeding sleeve
30	- blank in the shape of a railway rail foot
30b	- bar after rolling in the first stand
30c	- bar after rolling in the second stand
30d	- blank after rolling in the third stand
30e	- bar after rolling in the fourth stand
31a, 31b	- helical rolls
32a, 32b	- conical surfaces of helical rolls
33a, 33b	- cylindrical surfaces of helical rolls
34a, 34b	- concave surfaces of helical protrusions
35a, 35b	- guides
36	- rolled balls
D	- diameter of helical rolls
D1	- diameter of grooved rolls of the first stand
D2	- diameter of grooved rolls of the second stand
D3	- diameter of grooved rolls of the third stand
D4	- diameter of grooved rolls of the fourth stand
dk	- diameter of rolled ball
dp	- diameter of rolled bar
h1	- depth of trapezoidal grooves of the grooved rolls of the first stand
h2	- depth of trapezoidal grooves of the grooved rolls of the second stand
h3	- blank width

b1 - width of trapezoidal grooves of the grooved rolls of the first stand

b2 - width of trapezoidal grooves of the grooved rolls of the first stand

b3 - blank width

Rk - radius of concave side surfaces of the helical protrusions

R3 - radius of concave grooves of the grooved rolls of the third stand

R4 - radius of concave grooves of the grooved rolls of the forth stand

n1 - speed of guide rollers

n2 - speed of grooved rolls of the first stand

n3 - speed of grooved rolls of the second stand

n4 - speed of grooved rolls of the third stand

n5 - speed of grooved rolls of the fourth stand

n6 - speed of guide rollers

n7 - speed of helical rolls

n8 - rotational speed of the bar

V1 - speed of blank movement

V2 - speed of bar movement

α - opening angle of conical surface

γ - twist angle of the axes of helical rolls

$\gamma 1$ - angle of inclination of side walls of the grooves of grooved rolls of the first stand

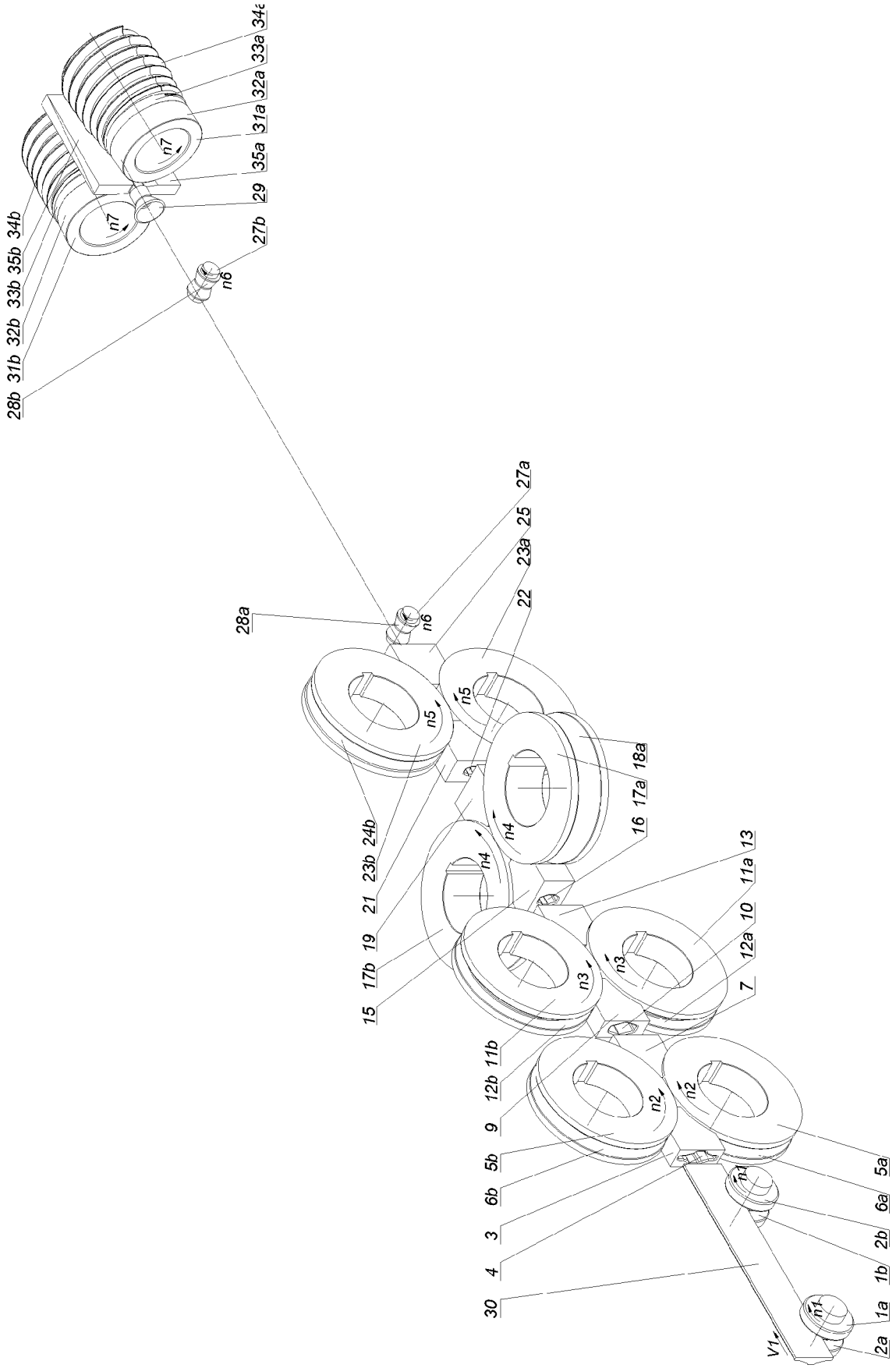
$\gamma 2$ - angle of inclination of side walls of the grooves of grooved rolls of the second stand

Claims

1. A method of rolling balls, especially from feet of scrap railway rails, **characterized in that** a blank (30) in the shape of a section of a railway rail foot is heated to the temperature appropriate for hot forming, after which the heated blank (30) is placed in grooves (2a) and (2b) of feeding rollers (1a) and (1b), then the feeding rollers (1a) and (1b) are set to rotate at the same speed (n1) and the blank (30) is moved towards a front guide (3) at a constant speed (V1), thereafter, grooved rolls of a first stand (5a) and (5b) are set to rotate at a constant speed (n2) in opposite directions, and grooved rolls of a second stand (11a) and (11b) are set to rotate at a constant speed (n3) in opposite directions, and grooved rolls of a third stand (17a) and (17b) are set to rotate at a constant speed (n4) in opposite directions, and grooved rolls of a fourth stand (13a) and (13b) are set to rotate at a constant speed (n5) in opposite directions, at the same time, guide rollers (27a) and (27b) are set to rotate at a constant speed (n6) in the same direction, and, at the same time, helical rolls (31a) and (32b) are set to rotate at equal speeds (n7) in the same direction, thereafter the blank (30) is guided into a guide hole (4) of the front guide (3) of the first stand and the blank (30) is moved towards the grooved rolls of the first stand (5a) and (5b), and the blank (30) is guided into trapezoid-shaped grooves (6a) and (6b) located on the surface of the grooved rolls of the first stand (5a) and (5b), which have a depth (h1) less than half the height of the blank (30) and a width (b1) greater than the thickness of the blank (30), and the inclination angle ($\gamma 1$) of the side walls of the grooves (6a) and (6b) of the grooved rolls of the first stand (5a) and (5b) greater than the inclination angle of the blank (30) walls, while the diameter (D1) of both grooved rolls of the first stand (5a) and (5b) is the same, wherein axes of both grooved rolls of the first stand (5a) and (5b) are located in a horizontal plane, and the distance between the axes of both grooved rolls of the first stand (5a) and (5b) is equal to the diameter (D1) of the grooved rolls of the first stand (5a) and (5b), then the blank (30) is then gripped with the groove surfaces (6a) and (6b) of the grooved rolls of the first stand (5a) and (5b), and the blank (30) in the shape of a railway rail foot is flow formed into a rhombus-shaped blank (30b), wherein the height of a cut formed by the trapezoidal grooves (6a) and (6b) of the grooved rolls of the first stand (5a) and (5b) has a depth (h1) which is greater than the width (b1) of the cut formed by the trapezoidal grooves (6a) and (6b) of the grooved rolls of the first stand (5a) and (5b), wherein the rhombus-shaped blank (30b) is held in a rolling axis behind a rolling gap of the grooved rolls of the first stand (5a) and (5b) in a rhombus-shaped hole (8) of a rear guide (7) of the first stand, after which the blank (30b) is moved towards the second rolling stand, which consists of two identical grooved rolls of the second stand (11a) and (11b), which have the same diameter (D2) and trapezoidal grooves (12a) and (12b) on their surfaces, the depth (h2) of which is less than the depth (h1) of the trapezoidal grooves (6a) and (6b) of the grooved rolls of the first stand (5a) and (5b), and the width (b2) of the trapezoidal grooves (12a) and (12b) of the grooved rolls of the second stand (11a) and (11b) is greater than the width (b1)

of the trapezoidal grooves (6a) and (6b) of the grooved rolls of the first stand (5a) and (5b), and axes of the grooved rolls of the second stand (11a) and (11b) are horizontal and are spaced apart by the diameter (D2) of the grooved rolls of the second stand (11a) and (11b), thereafter the end of the blank (30b) is guided into a hole (10) of an entry guide (9) of the second rolling stand, where its position is held, then the end of the blank (30b) is guided into the trapezoidal grooves (12a) and (12b), which are located on the cylindrical surfaces of the grooved rolls of the second stand (11a) and (11b), and the blank (30b) with a rhombus-shaped cross-section is flow formed into a blank (30c) with a nearly rhombic cross-section, wherein the height (2h2) of the cross-section of the blank (30c) is less than the height (2h1) of the cross-section of the blank (30b) after rolling in the trapezoidal grooves (6a) and (6b) of the grooved rolls of the first stand (5a) and (5b), wherein behind a rolling gap of the second stand, the rolled blank (30c) is guided in a rhombus-shaped hole (14) of a rear guide (13) of the second rolling stand, then the blank (30c) is guided into a guide hole (16) of a front guide of the third stand (15) and the blank (30c) is moved towards the grooved rolls of the third stand (17a) and (17b), and the blank (30c) is guided into oval-shaped grooves (18a) and (18b) located on the surface of the grooved rolls of the third stand (17a) and (17b), which have a depth (h3) less than half the height of the blank (30c) and a width (b3) greater than the thickness of the blank (30c), while the diameter (D3) of both grooved rolls of the third stand (17a) and (17b) is the same, wherein the axes of both grooved rolls of the third stand (17a) and (17b) are located in a vertical plane, and the distance between axes of both grooved rolls of the third stand (17a) and (17b) is equal to the diameter (D3) of the grooved rolls of the third stand (17a) and (17b), whereas the radius (R3) of the oval-shaped grooves (18a) and (18b) is the same for both grooved rolls of the third stand (17a) and (17b), then the blank (30c) is gripped with groove surfaces (18a) and (18b) of the grooved rolls of the third stand (17a) and (17b) and the rhombus-shaped blank (30c) is flow formed into an oval-shaped blank (30d), wherein the vertical axis of an oval cut formed by the grooves (18a) and (18b) of the grooved rolls (17a) and (17b) of the third stand having a length (b3) that is greater than the height (2h2) of the rhombic cross-section of the blank (30c) rolled in the trapezoidal grooves of the second stand (12a) and (12b), wherein the oval-shaped blank (30d) is held in the rolling axis behind a rolling gap of the grooved rolls of the third stand (17a) and (17b) in an oval-shaped hole (20) of a rear guide (19) of the third stand, after which the blank (30d) is moved towards the fourth rolling stand, which consists of two identical grooved rolls of the fourth stand (23a) and (23b), which have the same diameter (D4) and the surfaces of which have concave grooves (24a) and (24b) with a radius (R4) equal to half the diameter (dk) of a rolled ball (36), and the axes of the grooved rolls of the fourth stand (23a) and (23b) are located horizontally and spaced apart by the diameter (D4) of the grooved rolls of the fourth stand (23a) and (23b), and after that the end of the blank (30d) is guided into a hole (22) of an entry guide (21) of the fourth rolling stand, then, the end of the blank (30d) is guided into circular-shaped grooves (24a) and (24b), which are located on the cylindrical surfaces of the grooved rolls of the fourth stand (23a) and (23b), and the blank (30d) with an oval-shaped cross-section is flow formed into a bar (30e) with nearly circular cross-section, with the diameter (dp) of the bar (30e) being greater than the diameter (dk) of the rolled ball (36), and after that the rolled bar (30e) is moved in grooves (28a) and (28b) of the guide rollers (27a) and (27b) in the direction of skew rolls (31a) and (31b) and the bar (30e) is guided into ta hole of a guiding sleeve (29), in which the correct position of the bar (30e) is maintained, then, using the guide rollers (27a) and (27b), the bar (30e) is guided into a workspace of a skew rolling mill, consisting of two helical rolls (31a) and (31b) and two guides (35a) and (35b), wherein the both helical rolls (35a) and (35b) have the same working diameter (D), and their axes are twisted in opposite directions relative to the rolling axis by the same value of the twist angle of the rolls (γ), while the guides (35a) and (35b) are located parallel to the rolling axis, and the distance between the working surfaces of the guides (35a) and (35b) is greater than the diameter (dp) of the rolled bar (30e), then the end of the bar (30e) is gripped with conical surfaces (32a) and (32b) located in an entry zone of the two helical rolls (31a) and (31b), which rotate with equal speeds (n7) in the same direction and the bar (30e) is set to rotate at a constant speed (n8) in the direction opposite to the direction of rotation of the helical rolls (31a) and (31b), and the cross-section of the bar (30e) is flow formed using conical surfaces (32a) and (32b) and the cross-section of the bar (30e) is calibrated to a diameter less than the diameter (dk) of the rolled ball (36) using two cylindrical surfaces (33a) and (33b) located behind the conical surfaces (32a) and (32b) of the helical rolls (31a) and (31b), and subsequently, helical protrusions located on the surfaces of the helical rolls (31a) and (31b) are sunk into the cylindrical surface of the earlier calibrated bar (30e), wherein the helical protrusions of the helical rolls (31a) and (31b) have concave side surfaces (34a) and (34b), the radius (Rk) of which is equal to half the diameter (dk) of the rolled ball (36), and then, annular grooves with spherical side surfaces are gradually formed on the bar (30e), with the blank (30e) being held in the workspace during rolling by two guides (35a) and (35b), located opposite each other, between the hel-

ical rolls (31a) and (31b), then, as a result of the action of the helical protrusions with concave side surfaces (34a) and (34b) located on the helical rolls (31a) and (31b), the depth of the annular grooves increases until the ball (36) is formed and completely separated from the bar (30e), and as a result, the ball (36) with a diameter (dk) smaller than the diameter (dp) of the bar (30e) is obtained.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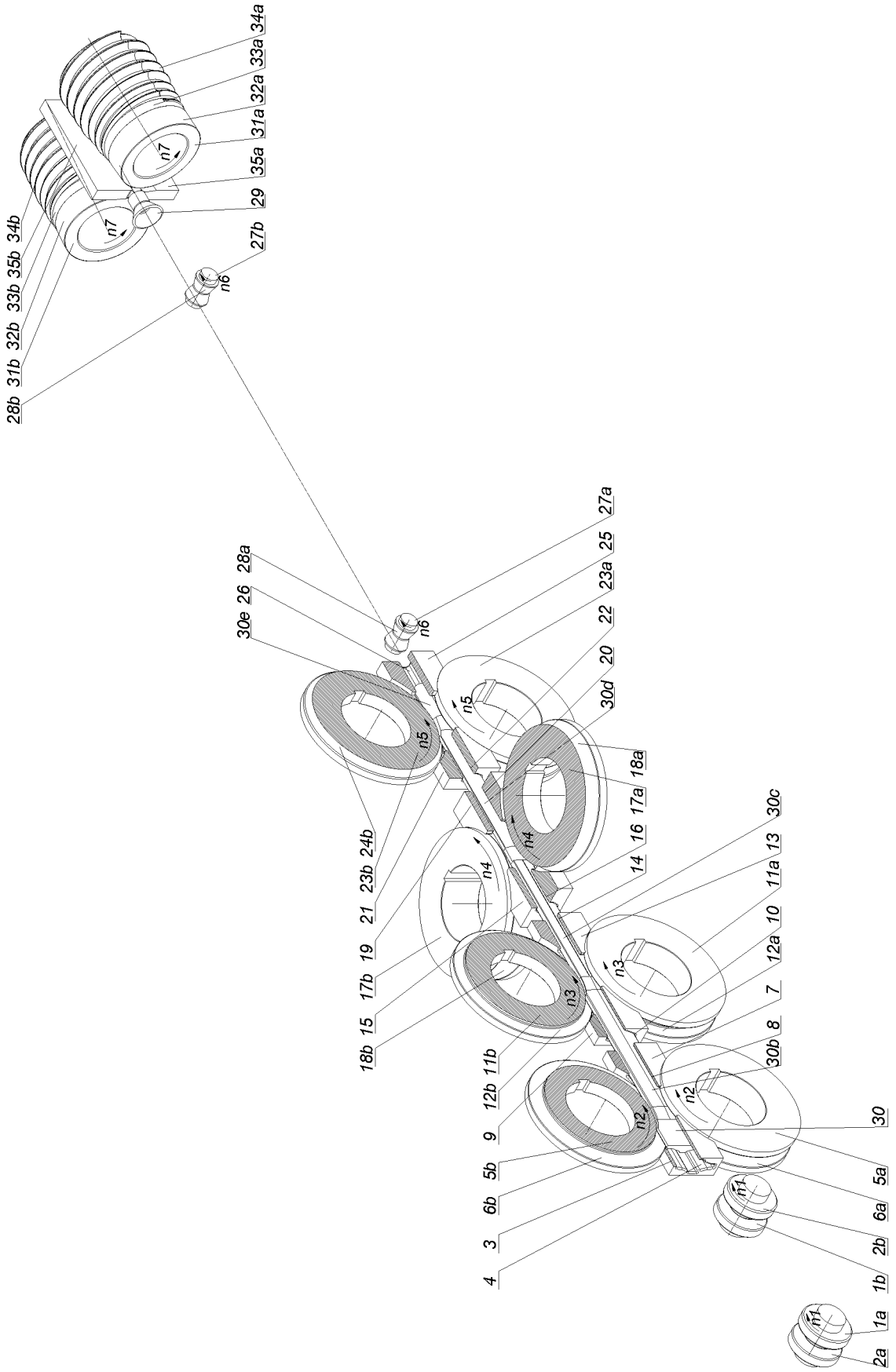
V1
28b
31b
32b
33b
35b
34b
34a
33a
32a
31a
35a
29
27b
28a
27a
25
23a
22
24b
23b
21
19
17b
15
18a
17a
16
13
11a
10
12a
7
11b
12b
9
5b
6b
3
4
30
5a
6a
2b
1b
1a
2a

Fig. 1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7
8
9
10
11a
11b
12a
12b
13
14
15
16
17a
17b
18a
18b
19
20
21
22
23a
23b
24b
25
26
27a
27b
28a
28b
29
30
30b
30c
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30e
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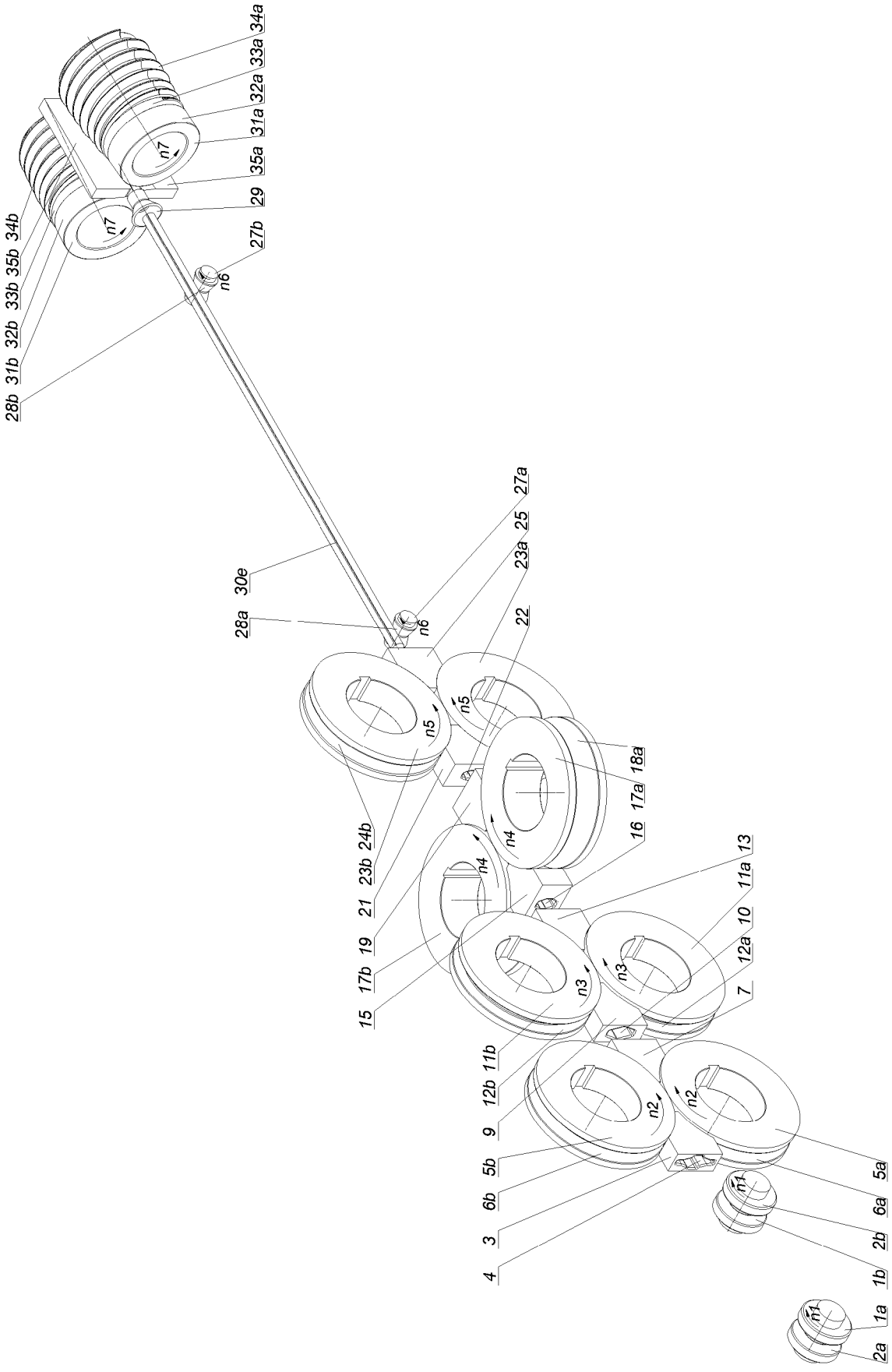
33b
34a
34b
35a
35b

Fig. 2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23a
23b
24b
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27a
27b
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33b
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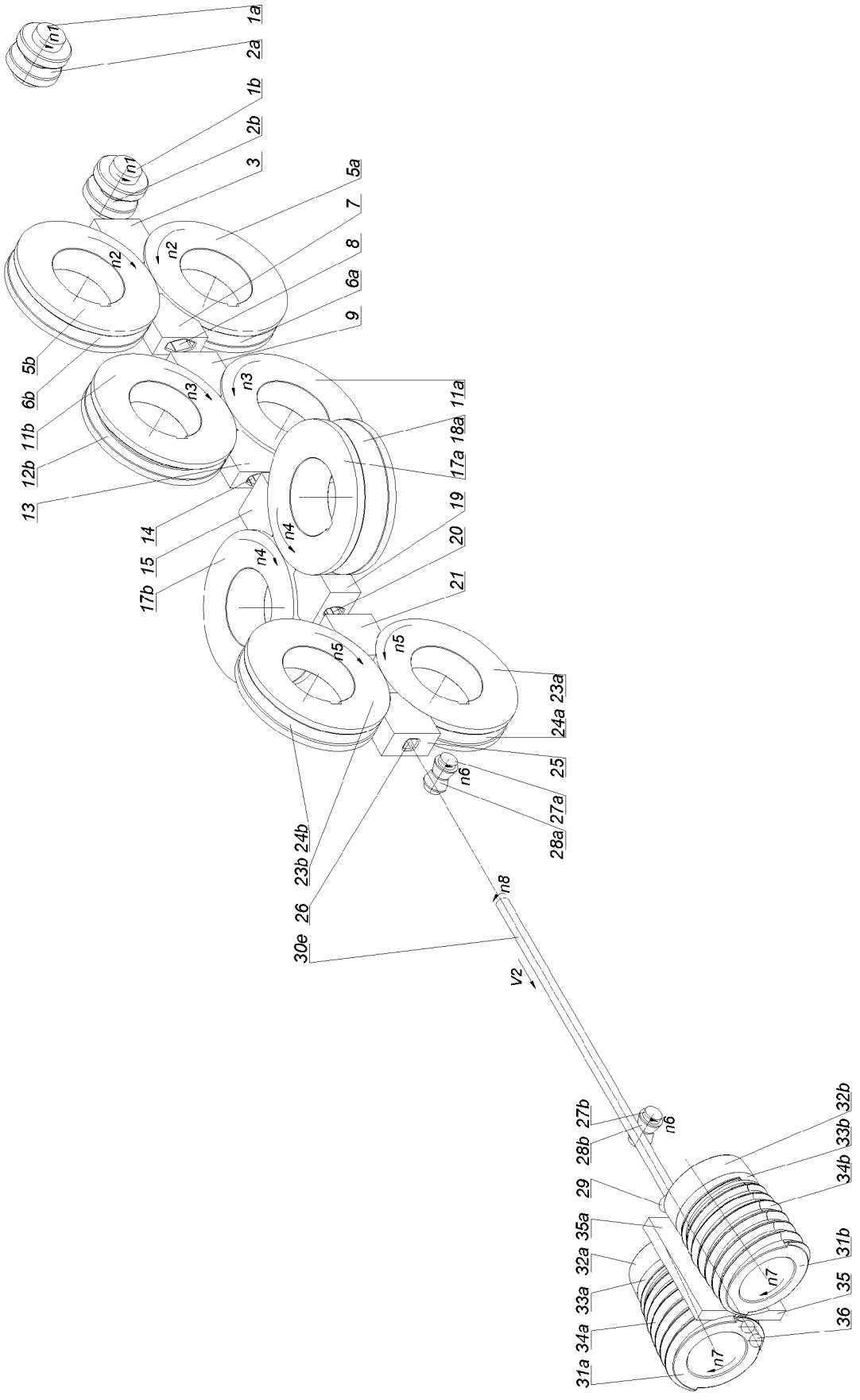
34b
35a
35b

Fig. 3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18a
17a
19
20
21
14
15
17b
n4
n4
n5
n5
23a
24a
25
n6
27a
28a
23b
24b
26
30e
n8
V2
n6
27b
28b
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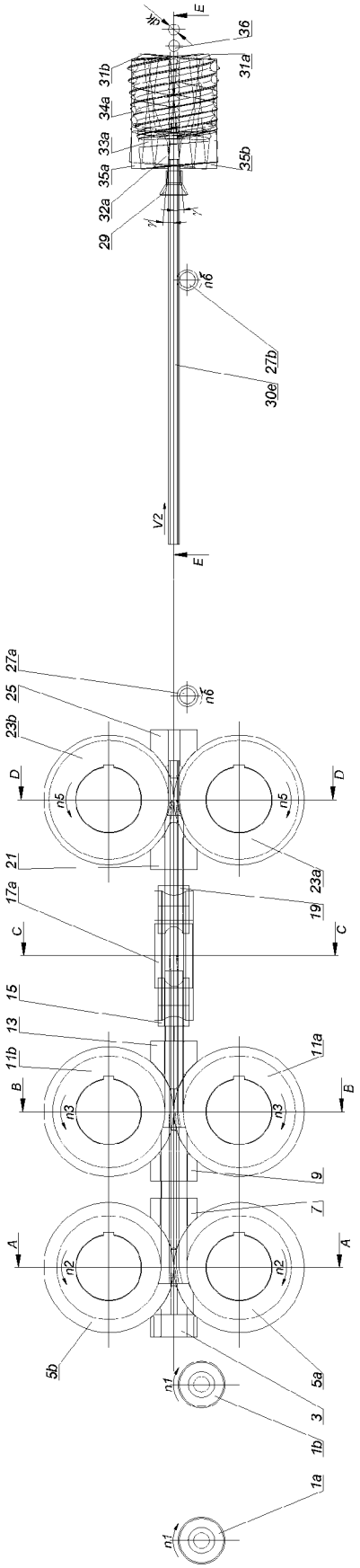
31a
n7
n7
32b
33b
34b
31b
35
36

Fig. 4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35b
32a
29
n6
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V2
E
27a
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D
n5
21
23a
19
17a
C
15
13
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n3
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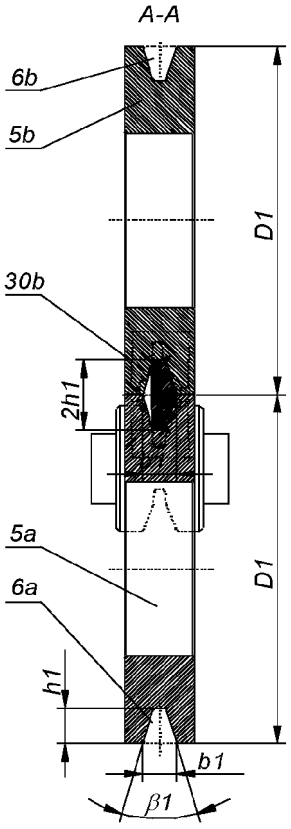
7
A
n2
5b
5a
n1
3
1b
1a

Fig. 5


A-A
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5b
D1
30b
2h1
5a
D1
6a
h1
b1
β1

Fig. 6

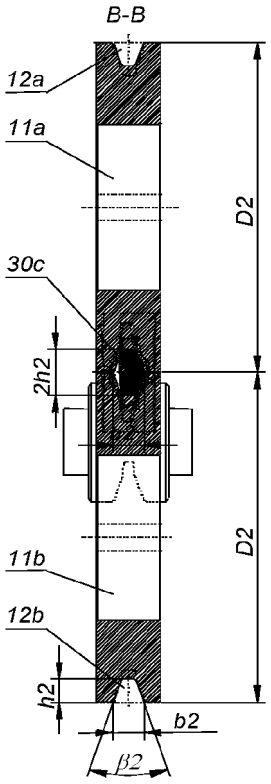
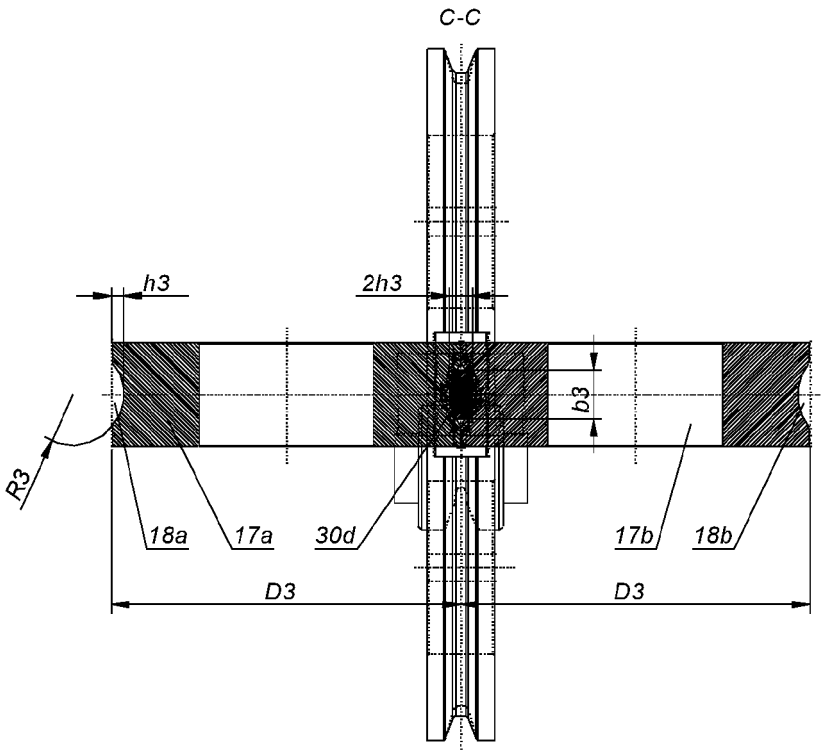

B-B
12a
11a
D2
30c
2h2
D2
11b
12b
h2
b2
β2

Fig. 7


C-C
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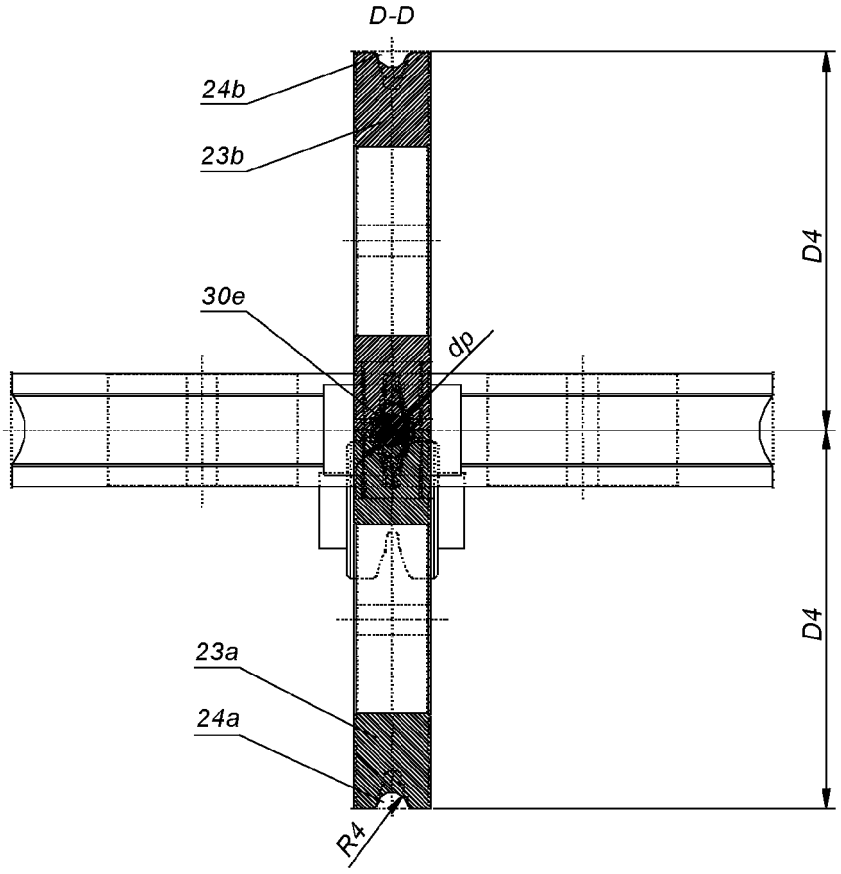
2h3
b3
R3
18a
17a
30d
17b
18b
D3
D3

Fig. 8


D-D
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23b
30e
dp
D4
D4
23a
24a
R4

Fig. 9

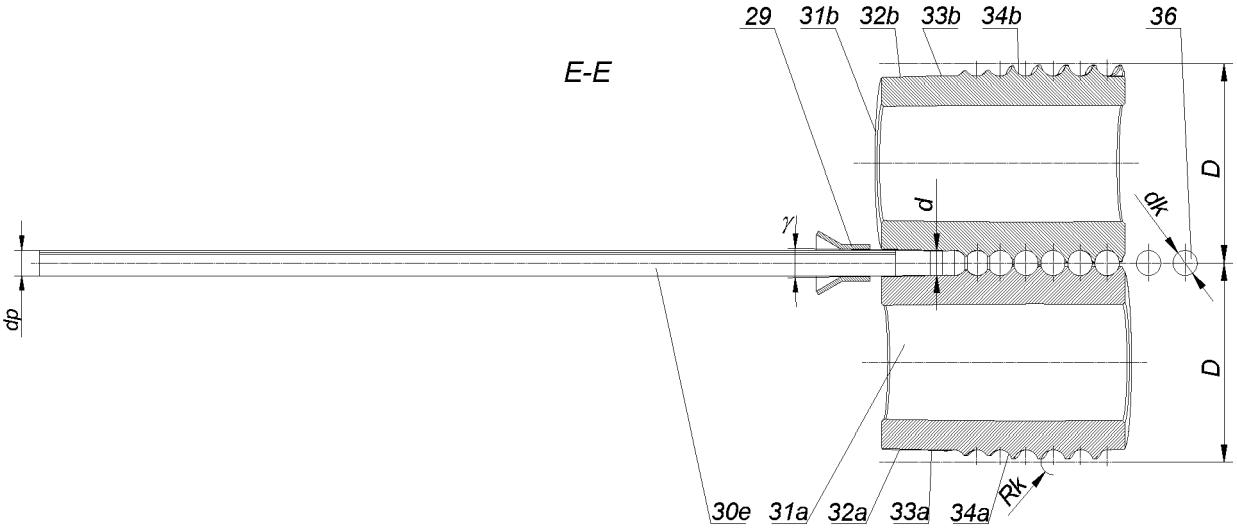

Fig. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 23 19 3049

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	PL 239 815 B1 (LUBELSKA POLT [PL]) 10 January 2022 (2022-01-10) * the whole document *	1	INV. B21K1/02 B21B1/085 B21B1/16
Y	PL 219 678 B1 (LUBELSKA POLT [PL]) 30 June 2015 (2015-06-30) * the whole document *	1	B21H1/14
A	PL 241 107 B1 (LUBELSKA POLT [PL]) 1 August 2022 (2022-08-01) * the whole document *	1	
A	US 1 910 271 A (WILLIAMS WILLIAM H) 23 May 1933 (1933-05-23) * figures 6-12 *	1	

TECHNICAL FIELDS SEARCHED (IPC)

B21K
B21B
B21H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	1 February 2024	Ritter, Florian

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EPO FORM 1503 03.82 (P04C01)

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01-02-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
PL 239815 B1	10-01-2022	NONE	
PL 219678 B1	30-06-2015	NONE	
PL 241107 B1	01-08-2022	NONE	
US 1910271 A	23-05-1933	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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- PL 225772 **[0003]**
- PL 423386 **[0004]**