(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 501 485 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
05.02.2025 Bulletin 2025/06

(21) Application number: **23887611.4**

(22) Date of filing: **04.09.2023**

(51) International Patent Classification (IPC):
B21H 1/06 *(2006.01)* ***B21K 1/76*** *(2006.01)*
B21J 5/00 *(2006.01)*

(86) International application number:
PCT/CN2023/116748

(87) International publication number:
WO 2024/098917 (16.05.2024 Gazette 2024/20)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **09.11.2022 CN 202211398745**

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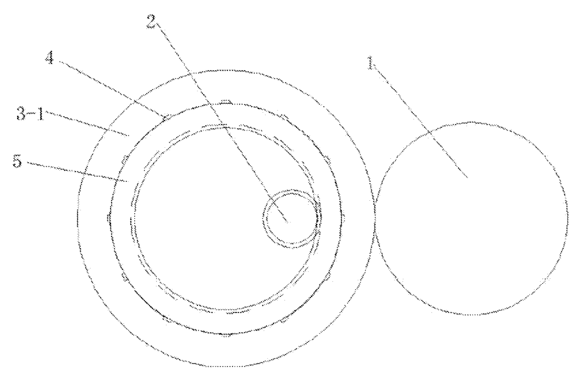
(54) INTEGRAL FORMING METHOD FOR AXIAL SPECIAL-SHAPED RING FORGING

(57) The present invention relates to the technical field of rolling processes, and discloses an integral forming method for an axial special-shaped ring forging. The integral forming method comprises the following specific steps: S1, heating for forging; S2, forging in multiple directions; S3, punching an upsetting cake; S4, heating for pre-rolling; S5 pre-rolling; and S6, axially rolling a special-shaped ring: putting a ring blank (5) obtained by heating into intermediate rigid molds (I 3-1, II3-2), wherein the intermediate rigid molds (I 3-1, II3-2) are special-shaped molds provided with axial grooves (4), the intermediate rigid molds (I 3-1, II3-2) are in cooperation with core rollers (2, 6) and a straight-wall main roller (1), and final rolling is performed to obtain the axial special-shaped ring forging. By introducing the intermediate rigid molds, the near-net forming production and manufacturing of the axial special-shaped ring forging are achieved, and a machining allowance is reduced, so that the allowance of a product is optimized, thereby increasing the utilization rate of the raw materials, and reducing raw material costs and machining costs.

FIG. 8



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Description

TECHNICAL FIELD

[0001] The present invention belongs to the technical field of rolling processes, and in particular to an integral forming method for an axial special-shaped ring forging.

BACKGROUND

[0002] With the rapid development of aerospace industry, modern national defense industry and transportation industry in China and at abroad, the demand for ring forgings for aerospace vehicles and aero-engines is increasing. As the ring rolling technology becomes more and more mature, the design of ring parts is becoming more and more refined, and the near-net forming design and manufacturing application of special-shaped ring forgings also become more and more extensive. The cross section of the special-shaped ring forging is closer to the shape outline of the parts, which can greatly reduce the machining allowance, thus reducing the damage of machining to the forging streamline of the ring, saving a lot of precious metal materials, and improving the material utilization rate.

[0003] However, at present, there is no manufacturer capable of achieving the integral forming of special-shaped ring forgings with axial stringers in outer diameter in China and at abroad. At present, the main production process of such products is as follows: firstly, the flange with end frame in the inner hole is machined after using straight-wall ring rolling, and then the outer diameter is machined by milling to achieve axial abnormity of the outer diameter. However, in such a production process, the material utilization rate is extremely low, the flow line of forgings is destroyed, the working procedure is complicated, and the comprehensive cost is high.

[0004] In addition, the existing patent CN102085549B discloses a forming method for machining an outer peripheral surface of a high cylinder forging by using a follow-up mold sleeve. However, in this patent, a circumferential groove of the inner ring surface of the follow-up mold sleeve is in a circumferential direction, so only the special-shaped rolling in a circumferential direction can be achieved. Because ring rolling is characterized by the continuous deformation of metal in the circumferential direction, the existing special-shaped ring forgings are all shaped in the circumferential direction, and the special-shaped rings are evenly distributed along the circumference, that is, the shapes of each axial section position must be the same. With the development of ring rolling equipment, even if this method is not adopted, the production of such ring-shaped special-shaped ring forgings can be achieved. However, there is no report about the integral forming of the axial special-shaped ring forgings in China and at abroad.

SUMMARY

[0005] For the problems in the prior art, the present invention provides an integral forming method for an axial special-shaped ring forging. A near-net forming production and manufacturing of the axial special-shaped ring forging are achieved by introducing intermediate rigid molds with axial grooves.

[0006] The technical objective of the present invention is achieved through the following technical solutions:

S1: heating for forging: heating a blank to 440-480°C, and taking the blank out of a furnace after heat preservation for 18-20 h;

S2: forging in multiple directions: forging the blank in multiple directions by using a press to improve structure properties of the blank, thus obtaining a cylindrical blank;

S3: punching an upsetting cake: upsetting and deforming the cylindrical blank in an axial direction, and punching the cylindrical blank with a cylindrical punch after reaching a predetermined height to obtain a ring blank with a hole;

S4: heating for pre-rolling: heating the ring blank with a hole obtained in Step S3 to 440-480°C, taking the ring blank out of the furnace after heat preservation for 9-12 h;

S5: pre-rolling: pre-rolling the ring blank with a hole, and pre-rolling the blank to a ring blank with a rectangular axial section;

S6: axially rolling a special-shaped ring: heating the ring blank to 440-480°C, taking the ring blank out of the furnace after heat preservation for 9-12 h, and then placing the ring blank obtained by heating into intermediate rigid molds, wherein the intermediate rigid molds are special-shaped molds provided with axial grooves, the intermediate rigid molds are in cooperation with core rollers and a straight-wall main roller, and final rolling is performed to obtain an axial special-shaped ring forging, wherein a specific cooperative rolling method of the intermediate rigid molds, the core rollers and the straight-wall main roller is as follows:

controlling the straight-wall main roller to rotate in a forward direction; driving, by the straight-wall main roller, the intermediate rigid mold to rotate in a reverse direction; driving, by the intermediate rigid mold, the ring blank to rotate accordingly in the reverse direction, controlling the core roller to make a feed motion towards a direction of the straight-wall main roller in a radial direction, and making a hold roller in contact with an outer diameter of the intermediate rigid mold, wherein when an outer diameter of the ring blank is completely attached to an inner diameter of the intermediate rigid mold, the ring blank and the intermediate rigid mold move synchronously, and have consistent angular velocity and linear velocity; and continuously controlling the straight-wall main roller to rotate in the forward direction, and controlling the core roller to make the feed motion towards a direction of the straight-wall main roller in the radial direction.

[0007] Preferably, the core roller is a straight-wall core roller, or a special-shaped core roller.

[0008] Preferably, one or both ends of the special-shaped core roller are provided with flange steps for rolling special-shaped ring rolling of the inner hole of the ring blank, and an inner end frame flange is formed in an inner wall surface of the ring blank.

[0009] Preferably, a procedure for performing special-shaped ring rolling of the inner hole using the special-shaped core roller is between Step S5 of pre-rolling and Step S6 of heating for axially rolling a special-shaped ring, and comprises specific steps as follows:

heating the ring blank obtained by pre-rolling in Step S5 to 440-480°C, taking the ring blank out the furnace after heat preservation for 9-12 h, and then performing special-shaped ring rolling of the inner hole of the heated ring blank by using the special-shaped core roller and the straight-wall main roller to obtain a ring blank with a special-shaped inner hole.

[0010] Preferably, Step S2 includes specific steps as follows: performing upsetting and drawing-out and upsetting in a Z-axis direction, drawing-out and upsetting in a Y-axis direction, and drawing-out and upsetting in an X-axis direction on the blank in turn by using a press, then drawing-out in the Z-axis direction, controlling the deformation amount of each pass to be 45%-55%, and controlling a forging pressing speed of the press to be 10-50 mm/s.

[0011] Preferably, Step S3 specifically includes the following steps:

S3-1: performing upsetting and rounding on the cylindrical blank in the Z-axis direction, and controlling the deformation amount to be 45-55%; and
S3-2: punching the upset blank to a ring blank with a preset size.

[0012] Preferably, in S5, the deformation amount of the pre-rolling is controlled to be 45%-60%, the rotating speed of the straight-wall main roller is 1.5-1.7 rad/s, the increase of speed for ring rolling is controlled to be 8-12 mm/s, and the blank is pre-rolled to a ring blank with a rectangular section.

[0013] Preferably, the deformation amount of special-shaped ring rolling of the inner hole is controlled to be 25%-40%, the rotating speed of the straight-wall main roller is 1.2-1.5 rad/s, and the increase of speed for ring rolling is controlled to be 5-8 mm/s.

[0014] Preferably, in S6, the intermediate rigid mold is an annular mold, at least one axially arranged axial groove is distributed on an inner wall surface of the ring mold in a circumferential direction, and the axial groove is in fit with an axial stringer of a target ring forging.

[0015] Preferably, in S6, specific ring rolling steps are as follows:

S6-1: preheating the intermediate rigid mold to 350-400°C, and placing the intermediate rigid mold on a working plane of a ring rolling machine;
S6-2: placing the heated ring blank into the intermediate rigid mold, wherein the outer diameter of the ring blank is less than an inner diameter of the intermediate rigid mold at a moment;
S6-3: enabling the core roller to penetrate through an inner hole of the ring blank, taking the intermediate rigid mold and the ring blank as a whole, and performing rolling by the ring rolling machine;
S6-4: controlling the straight-wall main roller to rotate in a forward direction; driving, by the straight-wall main roller, the intermediate rigid mold to rotate in a reverse direction; driving, by the intermediate rigid mold, the ring blank to rotate accordingly in the reverse direction, controlling the core roller to make the feed motion towards a direction of the straight-wall main roller in the radial direction, and making a hold roller in contact with the outer diameter of the intermediate rigid mold, wherein an outer diameter of the ring blank is attached to an inner hole of the intermediate rigid mold after deformation amount of the ring blank reaches 5-8%, a rotating speed of the straight-wall main roller is 1.2-1.5 rad/s, the increase of speed for ring rolling is 2-5 mm/s, and a feed speed of the core roller is 0.5-0.8 mm/s; and
S6-5: when the outer diameter of the ring blank is completely attached to the inner diameter of the intermediate rigid mold, moving the ring blank and the intermediate rigid synchronously, and making the ring blank and the intermediate rigid have consistent angular velocity and linear velocity; continuously controlling the straight-wall main roller to rotate in the forward direction, enabling the core roller to make the feed motion towards the direction of the straight-wall main roller in the radial direction, wherein the rotating speed of the straight-wall main roller is 0.8-1.2 rad/s, the increase of speed for ring rolling is 0.5-1 mm/s, and the feed speed of the core roller is 0.3-0.6 mm/s.

[0016] The beneficial effects are as follows: an integral forming method for an axial special-shaped ring forming disclosed by the present invention has the following advantages:

(1) By introducing the intermediate rigid mold, the near-net forming production and manufacturing of the axial special-shaped ring forging are achieved, a machining allowance is reduced, the utilization rate of the raw materials is improved, and the retained forging streamline reduces the raw material cost and machining cost.
(2) The axial special-shaped ring forgings manufactured by the method provided by the present invention can achieve uneven distribution of abnormal sections in the circumferential direction, and the shapes of various axial section positions may be inconsistent, and are suitable for forming various types of axial special-shaped ring forgings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 is a first schematic structural diagram of a target ring forging according to Embodiment 1;
FIG. 2 is a second schematic structural diagram of a target ring forging according to Embodiment 1;
FIG. 3 is a three-dimensional diagram of a target ring forging according to Embodiment 1;
FIG. 4 is a first schematic diagram of special-shaped ring rolling of an inner hole in Step 6 according to Embodiment 1;
FIG. 5 is a second schematic diagram of special-shaped ring rolling of an inner hole in Step 6 according to Embodiment 1;
FIG. 6 is a first schematic diagram of a ring blank with a special-shaped inner hole in Step 6 according to Embodiment 1;
FIG. 7 is a second schematic diagram of a ring blank with a special-shaped inner hole in Step 6 according to Embodiment 1;
FIG. 8 is a first schematic diagram of rolling of a ring blank in Step 7-4 according to Embodiment 1;
FIG. 9 is a second schematic diagram of rolling of a ring blank in Step 7-4 according to Embodiment 1;
FIG. 10 is a first schematic diagram of rolling of a ring blank in Step 7-5 according to Embodiment 1;
FIG. 11 is a second schematic diagram of rolling of a ring blank in Step 7-5 according to Embodiment 1;
FIG. 12 is a first schematic structural diagram of a target ring forging according to Embodiment 2;
FIG. 13 is a second schematic structural diagram of a target ring forging according to Embodiment 2;
FIG. 14 is a three-dimensional diagram of a target ring forging according to Embodiment 2;
FIG. 15 is a first schematic diagram of rolling of a ring blank in Step 6 according to Embodiment 2;
FIG. 16 is a second schematic diagram of rolling of a ring blank in Step 6 according to Embodiment 2;
FIG. 17 is a first schematic diagram of rolling of a ring blank in Step 6-5 according to Embodiment 2;
FIG. 18 is a second schematic diagram of rolling of a ring blank in Step 6-5 according to Embodiment 2.

[0018] In the drawings: 1-straight-wall main roller; 2-special-shaped core roller; 2-1-flange step; 3-1-intermediate rigid mold I; 3-2-intermediate rigid mold II; 4-axial groove; 5-ring blank; 6-straight-wall core roller.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0019] To make the objectives, technical solutions and advantages of the present invention more clearly and apparently, the present invention is further described in detail below in conjunction with the accompanying drawings and embodiments. It should be understood that the specific embodiments described here are only used to explain the present invention than limiting.

Embodiment 1

[0020] As shown in FIG. 1 to FIG. 3, an axial special-shaped ring forging with an outer axial stringer and upper and lower inner end frame flanges is provided, with specific forming steps as follows:

Step 1. Heating for forging: 660 kg aluminum alloy bars ($\Phi500\times1200$) ≤400°C are placed into a furnace, and then taken out the furnace after the temperature is increased to 460°C and kept at 460°C for 18 h.
Step 2. Forging in multiple directions: the blank is forged in multiple directions by using a press to improve the structure property of the blank, thus obtaining a cylindrical blank. The specific steps are as follows:
in a Z-axis direction of the blank (the aluminum alloy bar), the blank is upset to $620\times620\times610$ (the deformation amount in the Z-axis direction is 49.2%), drawn out to $420\times420\times1350$ (the deformation amount in the Z-axis direction is 54.8%), and upset to $620\times620\times610$ (the deformation amount in the Z-axis direction is 54.8%). Afterwards, in a Y-axis

direction of the blank, the blank is drawn out to 420×1350×420 (the deformation amount in the Y-axis direction is 54.1%), and upset to 620×610×620 (the deformation amount in the Y-axis direction is 54.8%). Then, in an X-axis direction of the blank, the blank is drawn out to 1350×420×420 (the deformation amount in the X-axis direction is 54.1%), and upset to 610×620×620 (the deformation amount in the X-axis direction is 54.8%). Finally, in the Z-axis direction, the blank is drawn out to 420×420×1350 (the deformation amount in the Z-axis direction is 54.1%). In this embodiment, the forging pressing speed of the press is controlled to be 30 mm/s. In the present invention, the size in all embodiments is mm in unit.

Step 3. Punching an upsetting cake: the upsetting and rounding are performed in the Z-axis direction of the cylindrical blank until the size reaches Φ640×730 (the deformation amount in the Z-axis direction is 45.9%). Afterwards, the cylindrical blank is punched using a cylindrical punch (in which the size of the inner hole is Φ250) to obtain a ring blank with a hole, which has the size of Φ665 (outer diameter) ×Φ250 (inner diameter) ×730.

Step 4. Heating for pre-rolling: the ring blank with a hole is heated to 460°C and then is taken out of the furnace after the temperature is kept at 460°C for 11 h.

Step 5. Pre-rolling: the ring blank with a hole is pre-rolled on a horizontal ring rolling machine to a ring blank 5 with a rectangular axial section until the size is Φ1010 (outer diameter) ×Φ800 (inner diameter) ×730 (the deformation amount of wall thickness is 49.3%). The rotating speed of the straight-wall main roller 1 is controlled to be 1.5 rad/s, and the increase of the speed for ring rolling is 10 mm/s.

S6. Special-shaped ring rolling of an inner hole: after the ring blank 5 is heated to 460°C, and then is taken out of the furnace after the temperature is kept at 460°C for 11 h. As shown n FIG. 4 and FIG. 5, a special-shaped core roller 2 and a straight-wall main roller 1 are used to perform special-shaped ring rolling of an inner hole of the heated ring blank 5, thus obtaining the ring blank 5 (with the deformation amount of 28.6%) with upper and lower inner end frame flanges shown in FIG. 6 and FIG. 7. In Embodiment 1, both ends of the special-shaped core roller 2 shown in FIG. 4 are provided with flange steps 2-1. A roller surface of the special-shaped core roller 2 is attached to a wall surface of the inner hole of the ring blank 5, the straight-wall main roller 1 is attached to an outer wall surface of the ring blank 5, the rotating speed of the straight-wall main roller 1 is controlled to be 1.4 rad/s, and the increase of speed for ring rolling is 6 mm/s.

Step 7. Axially rolling a special-shaped ring: the ring blank 5 is heated to 460°C, then is taken out of the furnace after the temperature is kept at 460°C for 10 h. The ring blank 5 is placed in the intermediate rigid mold I 3-1, and the intermediate rigid mold I 3-1 is in cooperation with the special-shaped core roller 2 and the straight-wall main roller 1 for final rolling, thus obtaining a special-shaped ring forging with an outer axial stringer and an inner end frame flange shown in FIG. 1 to FIG. 3. The final rolling in Embodiment 1 includes the specific steps as follows:

Step 7-1. The intermediate rigid mold I 3-1 is preheated to 350°C, and then placed on a working plane of a ring rolling machine.

Step 7-2. The heated ring blank 5 is placed in the intermediate rigid mold I 3-1, at this time, an outer diameter of the ring blank 5 is less than an inner diameter of the intermediate rigid mold I 3-1.

Step 7-3. The special-shaped core roller 2 penetrates through an inner hole of the ring blank 5, and the intermediate rigid mold I 3-1 and the ring blank 5 are used as an integer for rolling by the ring rolling machine.

Step 7-4. The straight-wall main roller 1 is controlled to rotate counterclockwise (in this embodiment, the counterclockwise rotation is forward rotation), the intermediate rigid mold I 3-1 is driven by the straight-wall main roller 1 to rotate clockwise, and the ring blank 5 is driven by the intermediate rigid mold I 3-1 to rotate clockwise accordingly. Meanwhile, the special-shaped core roller 2 is controlled to make a feed motion towards a direction of the straight-wall main roller 1 in a radial direction, making a hold roller in contact with the outer diameter of the intermediate rigid mold I 3-1. After the deformation amount of the ring blank 5 reaches 6.0%, as shown in FIG. 8 and FIG. 9, the outer diameter of the ring blank 5 is attached to the inner hole of the intermediate rigid mold I 3-1. The rotating speed of the straight-wall main roller 1 is 1.3 rad/s, the increase of speed for ring rolling is 3 mm/s, and the feed speed of the special-shaped core roller 2 is 0.8 mm/s.

Step 7-5. When the outer diameter of the ring blank 5 is completely attached to the inner diameter of the intermediate rigid mold I 3-1, the ring blank 5 and the intermediate rigid mold I 3-1 move synchronously, and have the consistent angular velocity and linear velocity. As shown in FIG. 10 and FIG. 11, the straight-wall main roller 1 is continuously controlled to rotate counterclockwise, and the special-shaped core roller 2 makes the feed motion towards a direction of the straight-wall main roller 1 in the radial direction, thus forming an outer axial stringer in an axial groove 4 of the intermediate rigid mold I 3-1, and finally obtaining a target ring forging shown in FIG. 1 to FIG. 3. The rotating speed of the straight-wall main roller 1 is 1 rad/s, the increase of speed for ring rolling is 0.6 mm/s, and the feed speed of the special-shaped core roller 2 is 0.4 mm/s.

[0021] The special-shaped ring forging with an outer axial stringer and upper and lower inner end frame flanges manufactured in Embodiment 1 is taken, three parallel samples are randomly selected in a chord direction of the forging to test the performance of the forging. Testing results are as follows:

Table 1 Performance test results of ring forgings in Embodiment 1

	R_m (MPa)	$R_{p0.2}$ (MPa)	A (%)	Hardness (HB)
Technical requirements	≥420	≥350	4.5-16	≥120
1	483	402	14.52	151
2	480	399	15.40	152
3	495	416	14.20	151

Embodiment 2

[0022] As shown in FIG. 12 to FIG. 14, a special-shaped ring forging with an axial stringer is provided, with specific forming steps as follows:

Step 1. Heating for forging: 1520 kg aluminum alloy bars (Φ650×1635) ≤400°C are placed into a furnace, and then taken out the furnace after the temperature is increased to 460°C and kept at 460°C for 18 h.
Step 2. Forging in multiple directions: the blank 5 is forged in multiple directions using a press to improve the structure property of the blank and obtain a cylindrical blank. The specific steps are as follows:
in a Z-axis direction of the blank (the aluminum alloy bar), the blank is upset to 825×825×800 (the deformation amount in the Z-axis direction is 51.1%), drawn out to 580×580×1600 (the deformation amount in the Z-axis direction is 50%), and upset to 825×825×800 (the deformation amount in the Z-axis direction is 50%). Afterwards, in a Y-axis direction of the blank, the blank is drawn out to 580×1600×580 (the deformation amount in the Y-axis direction is 48.4%), and upset to 825×800×825 (the deformation amount in the Y-axis direction is 50%). Then, in an X-axis direction of the blank, the blank is drawn out to 1600×580×580 (the deformation amount in the X-axis direction is 48.4%), and upset to 800×825×825 (the deformation amount in the X-axis direction is 50%). Finally, in the Z-axis direction, the blank is drawn out to 580×580×1600 (the deformation amount in the Z-axis direction is 48.4%). In this embodiment, the forging pressing speed of the press is controlled to be 30 mm/s. In the present invention, the size in all embodiments is mm in unit.
Step 3. Punching an upsetting cake: the upsetting and rounding are performed in the Z-axis direction of the cylindrical blank until the size reaches Φ930×800 (the deformation amount in the Z-axis direction is 50%). Afterwards, the cylindrical blank is punched using a cylindrical punch (in which the size of the inner hole is Φ300) to obtain a ring blank with a hole, which has the size of Φ955 (outer diameter) ×Φ300 (inner diameter) ×800.
Step 4. Heating for pre-rolling: the ring blank with a hole is heated to 460°C and then is taken out of the furnace after the temperature is kept at 460°C for 11 h.
Step 5. Pre-rolling: the ring blank with a hole is pre-rolled on a horizontal ring rolling machine to a ring blank 5 with a rectangular axial section until the size is Φ1350 (outer diameter) ×Φ1000 (inner diameter) ×800 (the deformation amount of wall thickness is 46.6%). The rotating speed of the straight-wall main roller 1 is controlled to be 1.6 rad/s, and the increase of the speed for ring rolling is 12 mm/s.
S6. Rolling a special-shaped ring on an inner hole: after the ring blank 5 is heated to 450°C, then is taken out of the furnace after the temperature is kept at 450°C for 11 h. The ring blank 5 is placed in an intermediate rigid mold II 3-2 shown in FIG. 15 and FIG. 16, and the intermediate rigid mold II 3-2 is in cooperation with the straight-wall core roller 6 and the straight-wall main roller 1 for final rolling, thus obtaining a special-shaped ring forging with an outer axial stringer shown in FIG. 12 to FIG. 14. The final rolling in Embodiment 1 includes the specific steps as follows:

Step 6-1. The intermediate rigid mold II 3-2 is preheated to 350°C, and then placed on a working plane of a ring rolling machine.
Step 6-2. The heated ring blank 5 is placed in the intermediate rigid mold II 3-2, at this time, an outer diameter of the ring blank 5 is less than an inner diameter of the intermediate rigid mold II 3-2, as shown in FIG. 15 to FIG. 16.
Step 6-3. The straight-wall core roller 6 penetrates through the inner hole of the ring blank 5, and the intermediate rigid mold II 3-2 and the ring blank 5 are used as an integer for rolling by the ring rolling machine.
Step 6-4. The straight-wall main roller 1 is controlled to rotate counterclockwise (in this embodiment, the counterclockwise rotation is forward rotation), the intermediate rigid mold II 3-2 is driven by the straight-wall main roller 1 to rotate clockwise, and the ring blank 5 is driven by the intermediate rigid mold II 3-2 to rotate clockwise accordingly. Meanwhile, the straight-wall core roller 6 is controlled to make a feed motion towards a direction of the straight-wall main roller 1 in a radial direction, making a hold roller in contact with the outer diameter

of the intermediate rigid mold II 3-2. After the deformation amount of the ring blank 5 reaches 5.7%, the outer diameter of the ring blank 5 is attached to the inner hole of the intermediate rigid mold II 3-2. The rotating speed of the straight-wall main roller 1 is 1.2 rad/s, the increase of speed for ring rolling is 2.5 mm/s, and the feed speed of the straight-wall core roller 6 is 0.5 mm/s.

Step 6-5. When the outer diameter of the ring blank 5 is completely attached to the inner diameter of the intermediate rigid mold II 3-2, as shown in FIG. 17 and FIG. 18, the ring blank 5 and the intermediate rigid mold II 3-2 move synchronously, and have the consistent angular velocity and linear velocity. The straight-wall main roller 1 is continuously controlled to rotate counterclockwise, and the straight-wall core roller 6 makes the feed motion towards a direction of the straight-wall main roller 1 in the radial direction, thus forming an outer axial stringer in an axial groove 4 of the intermediate rigid mold II 3-2, and finally obtaining a target ring forging shown in FIG. 12 to FIG. 14. The rotating speed of the straight-wall main roller 1 is controlled to be 0.9 rad/s, the increase of speed for ring rolling is 0.8 mm/s, and the feeding speed of the straight-wall core roller 6 is 0.3 mm/s.

[0023] The special-shaped ring forging with an outer axial stringer manufactured in Embodiment 2 is taken, three parallel samples are randomly selected in a chord direction of the forging to test the performance of the forging. Testing results are as follows:

Table 2 Performance test results of ring forgings in Embodiment 2

	R_m (MPa)	$R_{p0.2}$ (MPa)	A (%)	Hardness (HB)
Technical requirements	≥420	≥350	4.5-16	≥120
1	491	403	12.76	154
2	486	398	14.04	155
3	488	399	13.64	*155*

[0024] In the present invention, the axial special-shaped forming mechanism of the axial special-shaped ring forging is as follows:

(1) The intermediate rigid mold is in cooperation with the core roller and the straight-wall main roller to roll the ring blank, such that the outer diameter of the ring blank can be attached to the intermediate rigid mold.

(2) The straight-wall main roller is continuously controlled to rotate, and the feed speed of the core roller is reduced for continuous rolling. In this case, due to the constraint of the intermediate rigid mold, the outer diameter of the special-shaped ring forging no longer increases, the inner diameter of the special-shaped ring forging gradually increases, and the wall thickness decreases. According to the principle of constant volume, the outer diameter material of the ring blank will be gradually filled into the axial groove of the intermediate rigid mold, and then the outer axial stringer can be formed in an excircle of the ring blank.

[0025] According to the present invention, the arrangement of the axial groove of the intermediate rigid mold can be, but not limited to, the structure of the intermediate rigid mold in the above embodiment, and can be designed according to an outer axial special-shaped structure of the actual axial special-shaped ring forging, which is suitable for the forming of various types ring forgings with outer axial stringers.

[0026] In the present invention, a special-shaped structure of the special-shaped core roller is in fit with a special-shaped structure of the inner hole of the target ring forging.

[0027] The integral forming method for an axial special-shaped ring forging provided by the present invention can be applied to various high-temperature alloy, titanium alloy, aluminum alloy, magnesium alloy, stainless steel, steel, and other ring forgings. Meanwhile, the axial shape of the excircle may be any continuous or discontinuous shape such as circle, square and triangle, which can be implemented using this method.

[0028] This specific embodiment is not only an explanation of the present invention, and is not intended to limit the present invention. Those skilled in the art can make modifications that do not contribute to the present embodiment as needed after reading the present specification, but as long as the present invention is in the right of the present invention, all requirements are protected by the patent law.

Claims

1. An integral forming method for an axial special-shaped ring forging, comprising the following steps:

S1: heating for forging: heating a blank to 440-480°C, and taking the blank out of a furnace after heat preservation for 18-20 h;

S2: forging in multiple directions: forging the blank in multiple directions by using a press to improve structure properties of the blank, thus obtaining a cylindrical blank;

S3: punching an upsetting cake: upsetting and deforming the cylindrical blank in an axial direction, and punching the cylindrical blank with a cylindrical punch after reaching a predetermined height to obtain a ring blank with a hole;

S4: heating for pre-rolling: heating the ring blank with a hole obtained in Step S3 to 440-480°C, taking the ring blank out of the furnace after heat preservation for 9-12 h;

S5: pre-rolling: pre-rolling the ring blank with a hole, and pre-rolling the blank to a ring blank with a rectangular axial section;

S6: axially rolling a special-shaped ring: heating the ring blank to 440-480°C, taking the ring blank out of the furnace after heat preservation for 9-12 h, and then placing the ring blank obtained by heating into intermediate rigid molds, wherein the intermediate rigid molds are special-shaped molds provided with axial grooves, the intermediate rigid molds are in cooperation with core rollers and a straight-wall main roller, and final rolling is performed to obtain an axial special-shaped ring forging, wherein a specific cooperative rolling method of the intermediate rigid molds, the core rollers and the straight-wall main roller is as follows:

controlling the straight-wall main roller to rotate in a forward direction; driving, by the straight-wall main roller, the intermediate rigid mold to rotate in a reverse direction; driving, by the intermediate rigid mold, the ring blank to rotate accordingly in the reverse direction, controlling the core roller to make a feed motion towards a direction of the straight-wall main roller in a radial direction, and making a hold roller in contact with an outer diameter of the intermediate rigid mold, wherein when an outer diameter of the ring blank is completely attached to an inner diameter of the intermediate rigid mold, the ring blank and the intermediate rigid mold move synchronously, and have consistent angular velocity and linear velocity; and continuously controlling the straight-wall main roller to rotate in the forward direction, and controlling the core roller to make the feed motion towards a direction of the straight-wall main roller in the radial direction;

a specific ring rolling step is as follows:

S6-1: preheating the intermediate rigid mold to 350-400°C, and placing the intermediate rigid mold on a working plane of a ring rolling machine;

S6-2: placing the heated ring blank into the intermediate rigid mold, wherein the outer diameter of the ring blank is less than an inner diameter of the intermediate rigid mold at the moment;

S6-3: enabling the core roller to penetrate through an inner hole of the ring blank, taking the intermediate rigid mold and the ring blank as a whole, and performing rolling by the ring rolling machine;

S6-4: controlling the straight-wall main roller to rotate in a forward direction; driving, by the straight-wall main roller, the intermediate rigid mold to rotate in a reverse direction; driving, by the intermediate rigid mold, the ring blank to rotate accordingly in the reverse direction, controlling the core roller to make the feed motion towards a direction of the straight-wall main roller in the radial direction, and making a hold roller in contact with the outer diameter of the intermediate rigid mold, wherein an outer diameter of the ring blank is attached to an inner hole of the intermediate rigid mold after deformation amount of the ring blank reaches 5-8%, a rotating speed of the straight-wall main roller is 1.2-1.5 rad/s, the increase of speed for ring rolling is 2-5 mm/s, and a feed speed of the core roller is 0.5-0.8 mm/s; and

S6-5: when the outer diameter of the ring blank is completely attached to the inner diameter of the intermediate rigid mold, moving the ring blank and the intermediate rigid synchronously, and making the ring blank and the intermediate rigid have consistent angular velocity and linear velocity; continuously controlling the straight-wall main roller to rotate in the forward direction, enabling the core roller to make the feed motion towards the direction of the straight-wall main roller in the radial direction, wherein the rotating speed of the straight-wall main roller is 0.8-1.2 rad/s, the increase of speed for ring rolling is 0.5-1 mm/s, and the feed speed of the core roller is 0.3-0.6 mm/s.

2. The integral forming method for an axial special-shaped ring forging according to claim 1, wherein the core roller is a straight-wall core roller, or a special-shaped core roller.

3. The integral forming method for an axial special-shaped ring forging according to claim 2, wherein one or both ends of the special-shaped core roller are provided with flange steps for rolling special-shaped ring rolling of the inner hole of the ring blank, and an inner end frame flange is formed in an inner wall surface of the ring blank.

4. The integral forming method for an axial special-shaped ring forging according to any one of claims 2 to 3, wherein a procedure for performing special-shaped ring rolling of the inner hole using the special-shaped core roller is between Step S5 of pre-rolling and Step S6 of heating for axially rolling a special-shaped ring, and comprises specific steps as follows:
heating the ring blank obtained by pre-rolling in Step S5 to 440-480°C, taking the ring blank out the furnace after heat preservation for 9-12 h, and then performing special-shaped ring rolling of the inner hole of the heated ring blank by using the special-shaped core roller and the straight-wall main roller to obtain a ring blank with a special-shaped inner hole.

5. The integral forming method for an axial special-shaped ring forging according to claim 1, wherein Step S2 comprises specific steps as follows: performing upsetting and drawing-out and upsetting in a Z-axis direction, drawing-out and upsetting in a Y-axis direction, and drawing-out and upsetting in an X-axis direction on the blank in turn by using a press, then drawing-out in the Z-axis direction, controlling the deformation amount of each pass to be 45%-55%, and controlling a forging pressing speed of the press to be 10-50 mm/s.

6. The integral forming method for an axial special-shaped ring forging according to claim 1, wherein Step S3 comprises specific steps as follows:

S3-1: performing upsetting and rounding on the cylindrical blank in the Z-axis direction, and controlling the deformation amount to be 45-55%; and
S3-2: punching the upset blank to a ring blank with a preset size.

7. The integral forming method for an axial special-shaped ring forging according to claim 1, wherein in S5, the deformation amount of the pre-rolling is controlled to be 45%-60%, the rotating speed of the straight-wall main roller is 1.5-1.7 rad/s, the increase of speed for ring rolling is controlled to be 8-12 mm/s, and the blank is pre-rolled to a ring blank with a rectangular section.

8. The integral forming method for an axial special-shaped ring forging according to claim 4, wherein the deformation amount of special-shaped ring rolling of the inner hole is controlled to be 25%-40%, the rotating speed of the straight-wall main roller is 1.2-1.5 rad/s, and the increase of speed for ring rolling is controlled to be 5-8 mm/s.

9. The integral forming method for an axial special-shaped ring forging according to claim 1, wherein in S6, the intermediate rigid mold is a ring mold, at least one axially arranged axial groove is distributed on an inner wall surface of the ring mold in a circumferential direction, and the axial groove is in fit with an axial stringer of a target ring forging.

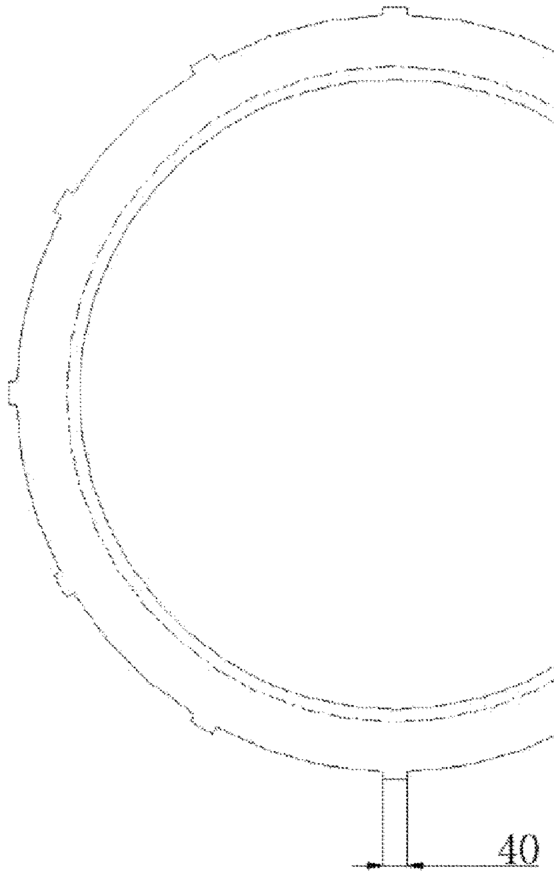

FIG. 1

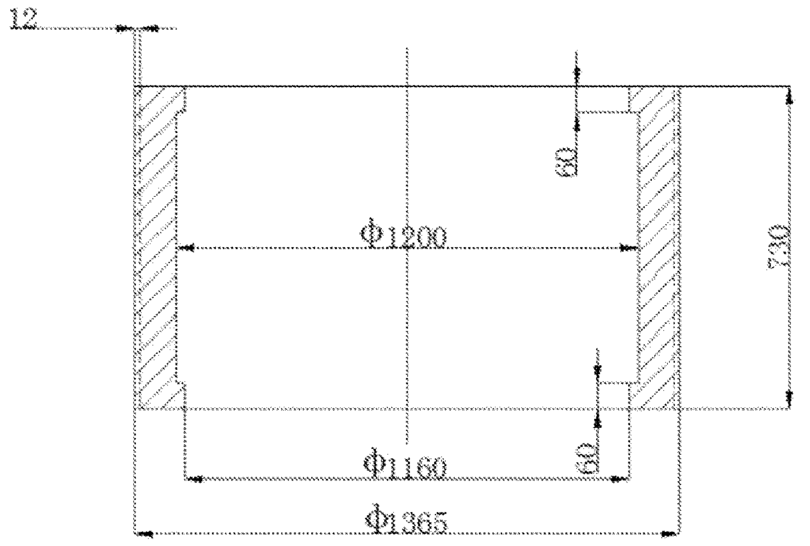

FIG. 2

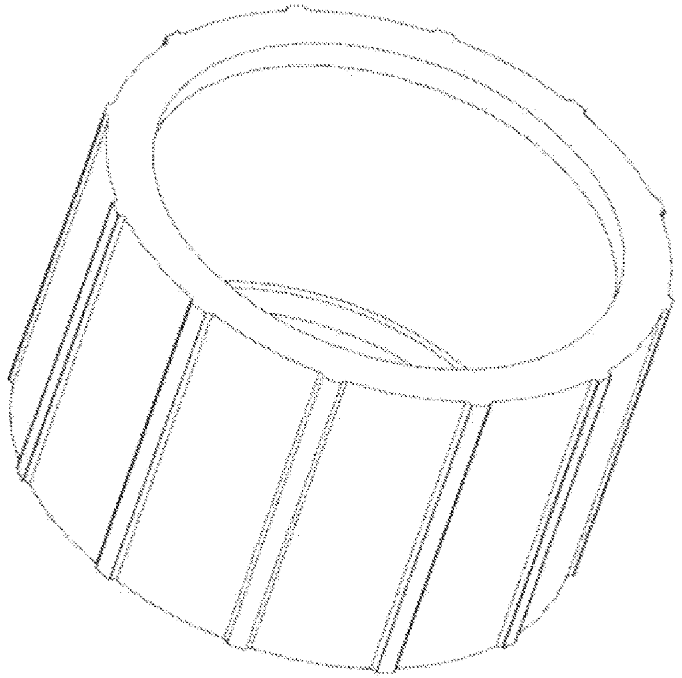

FIG. 3

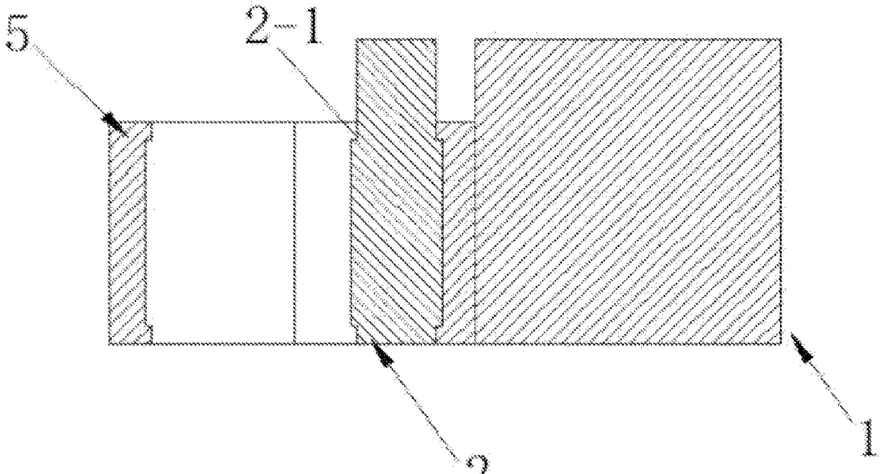

FIG. 4

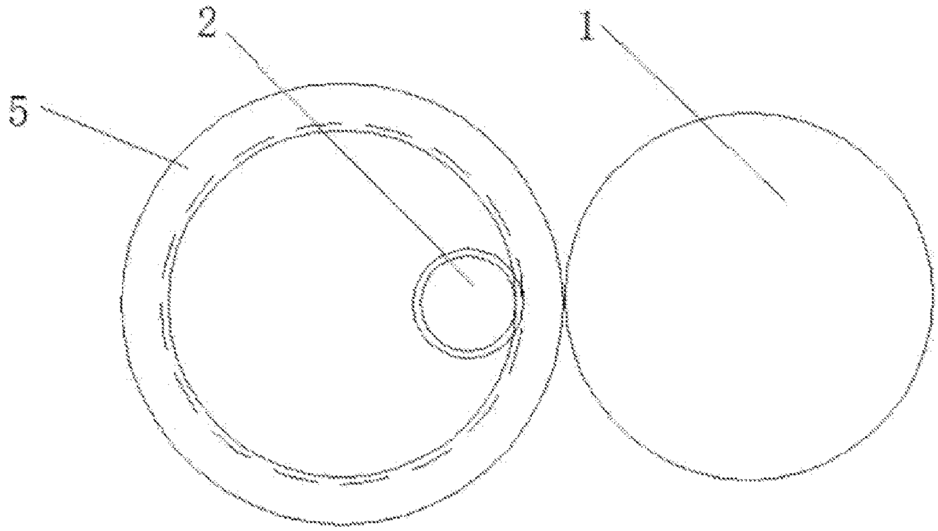

FIG. 5

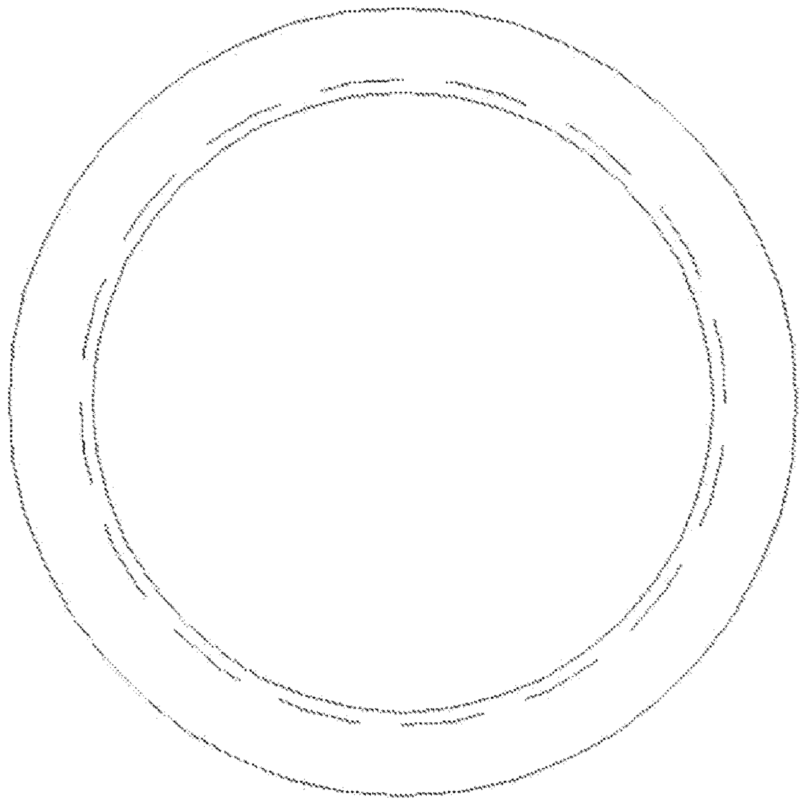

FIG. 6

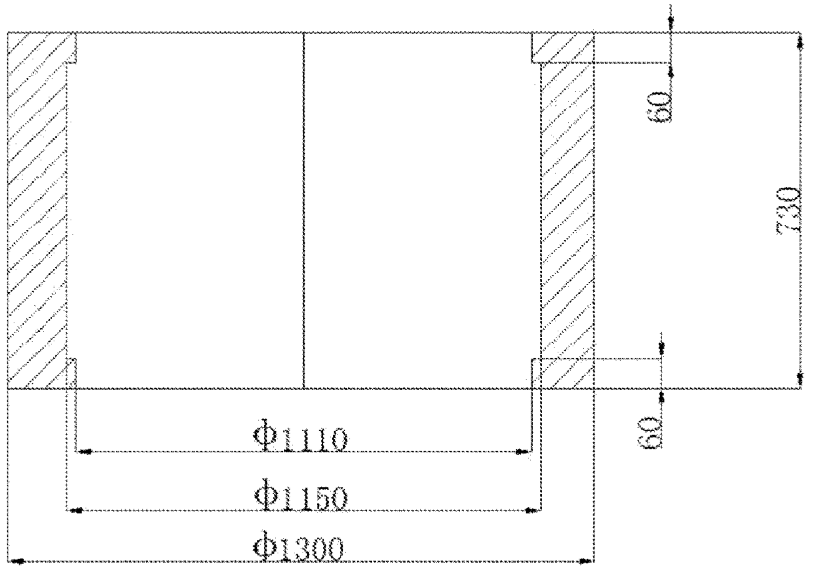

FIG. 7

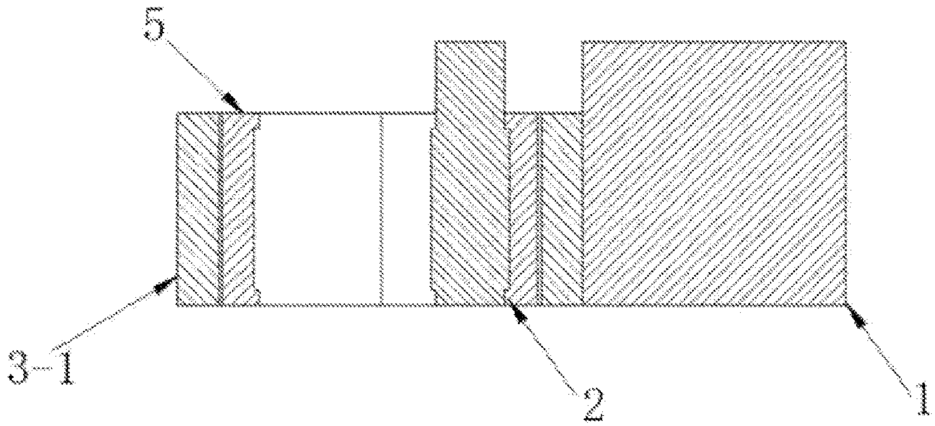

FIG. 8

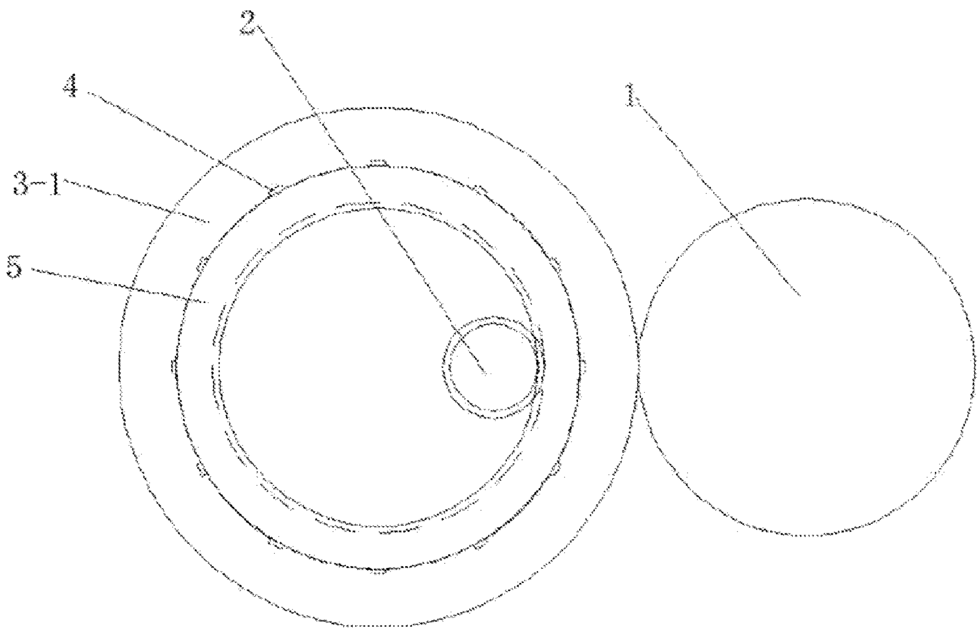

FIG. 9

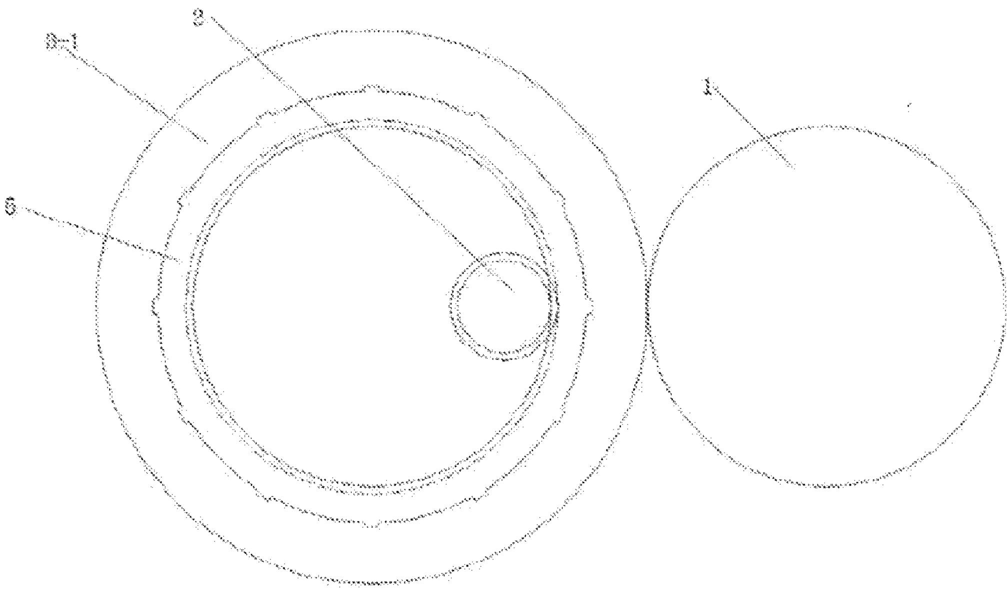

FIG. 10

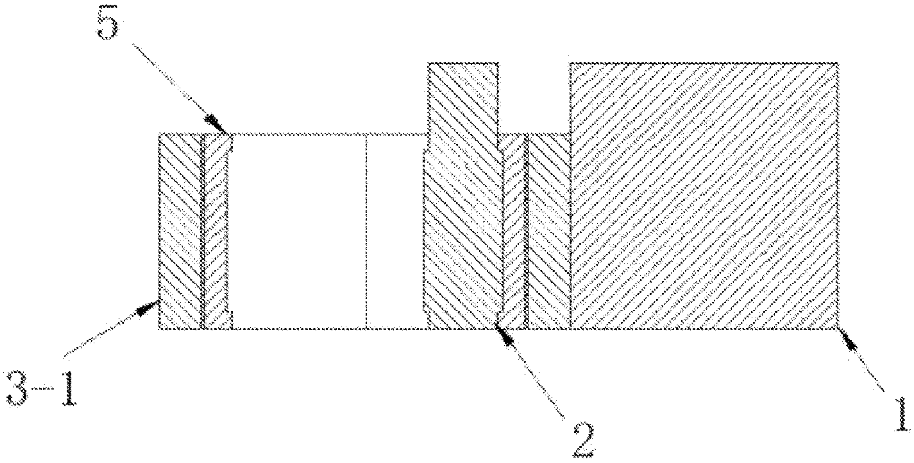

FIG. 11

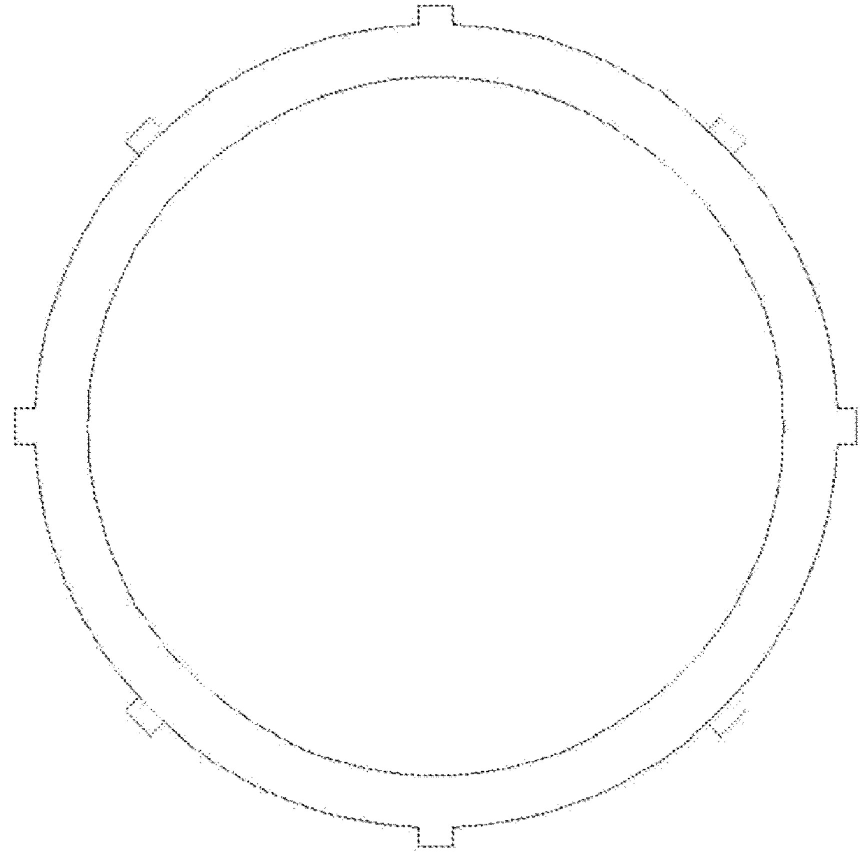

FIG. 12

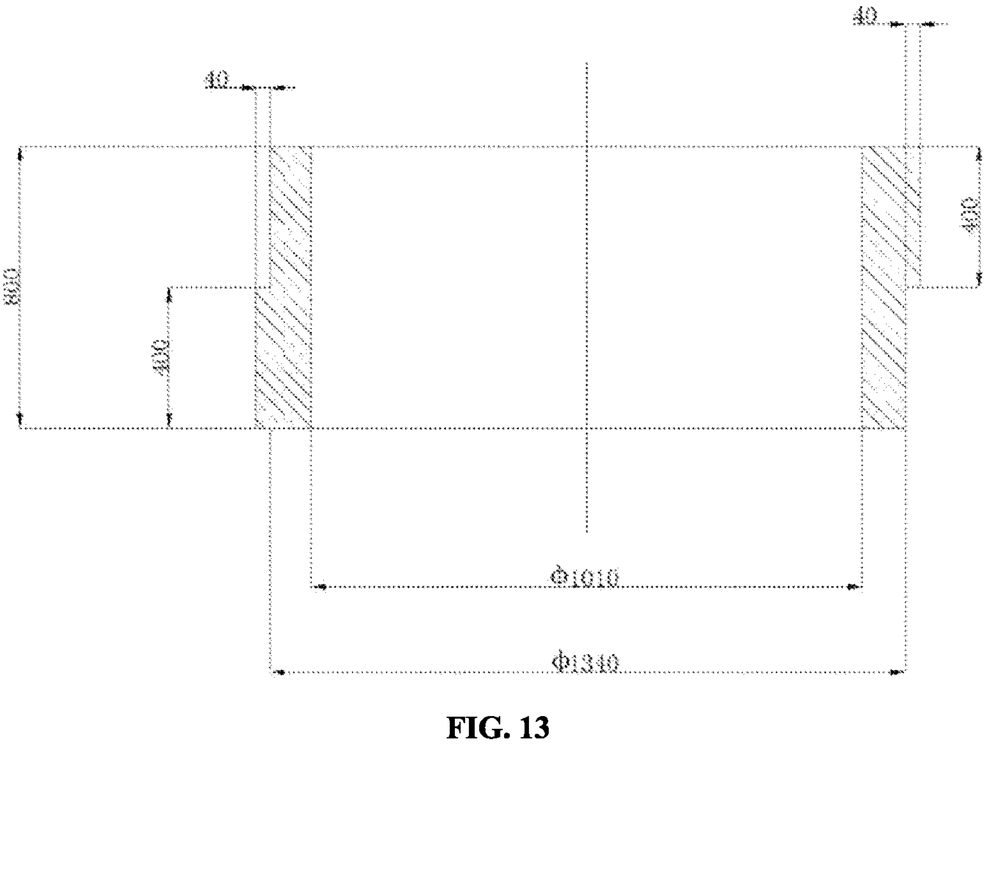

FIG. 13

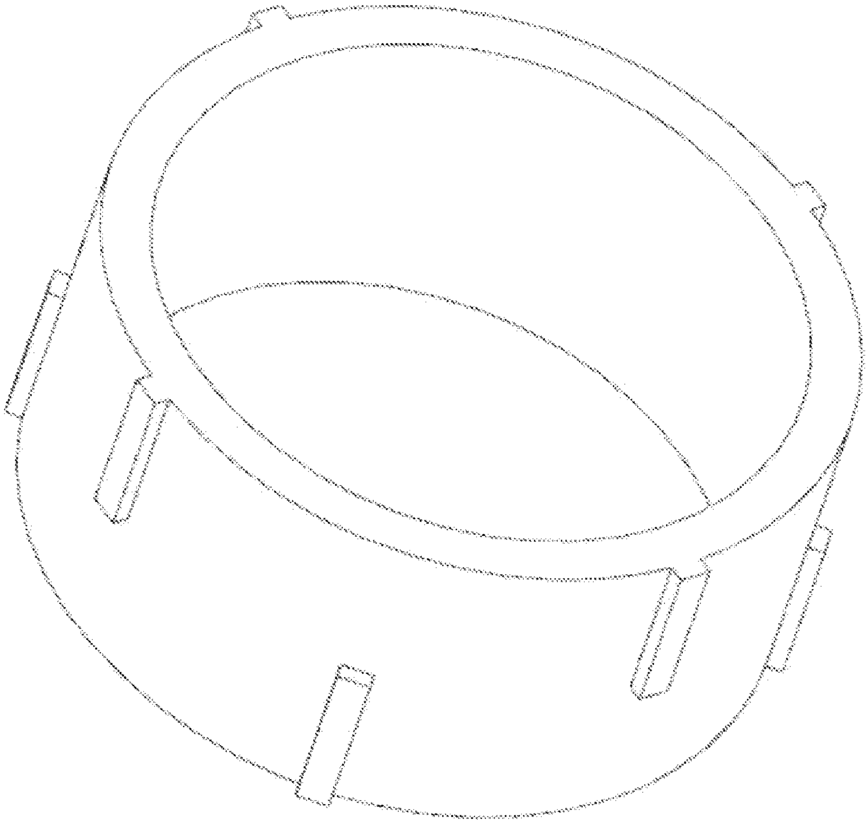

FIG. 14

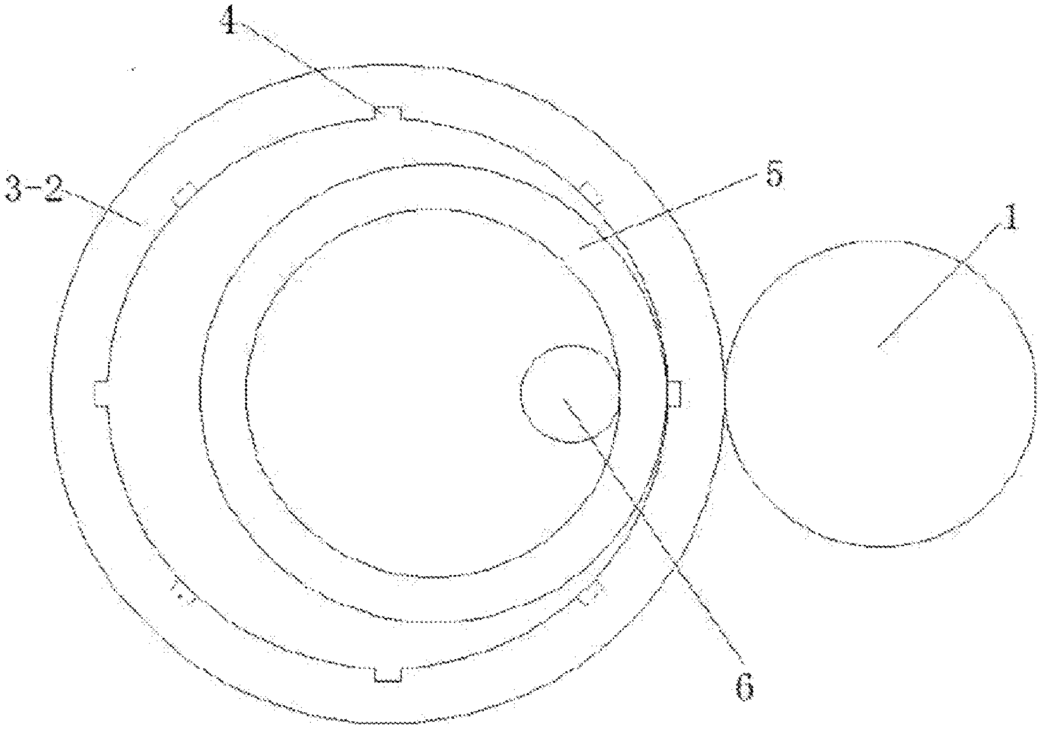

FIG. 15

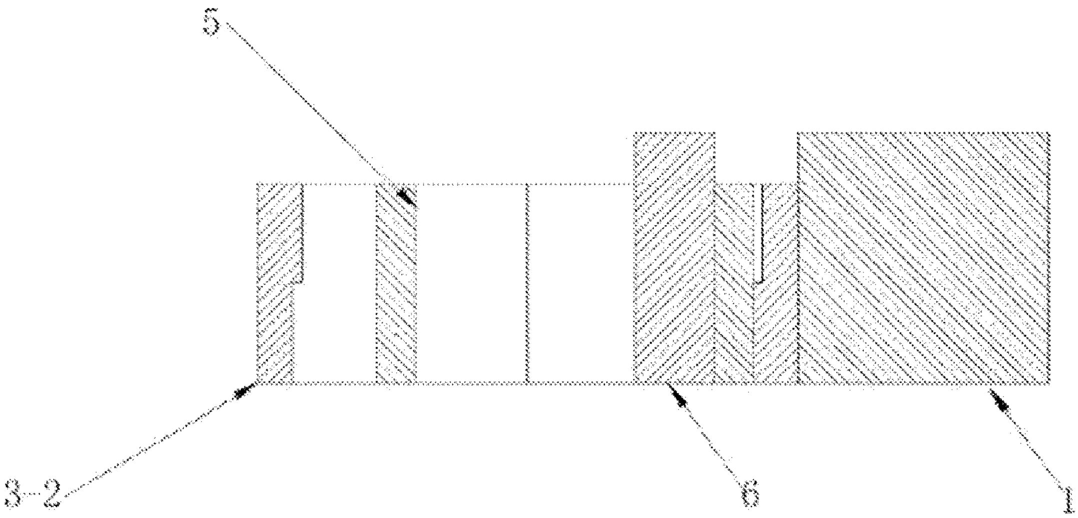

FIG. 16

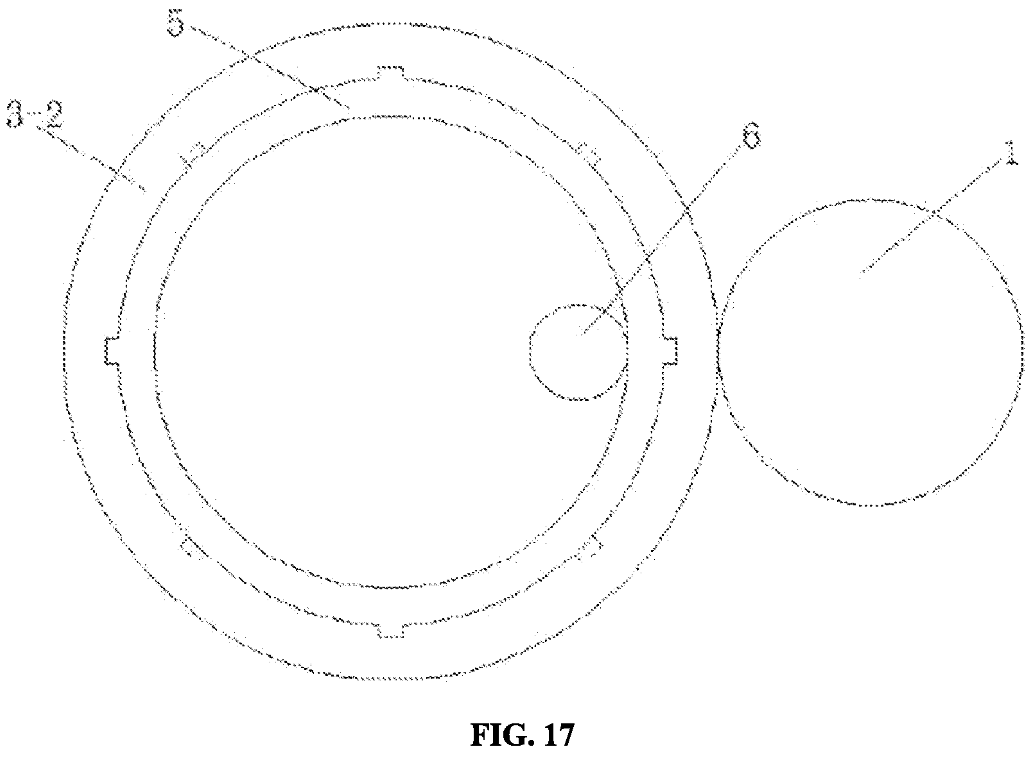

FIG. 17

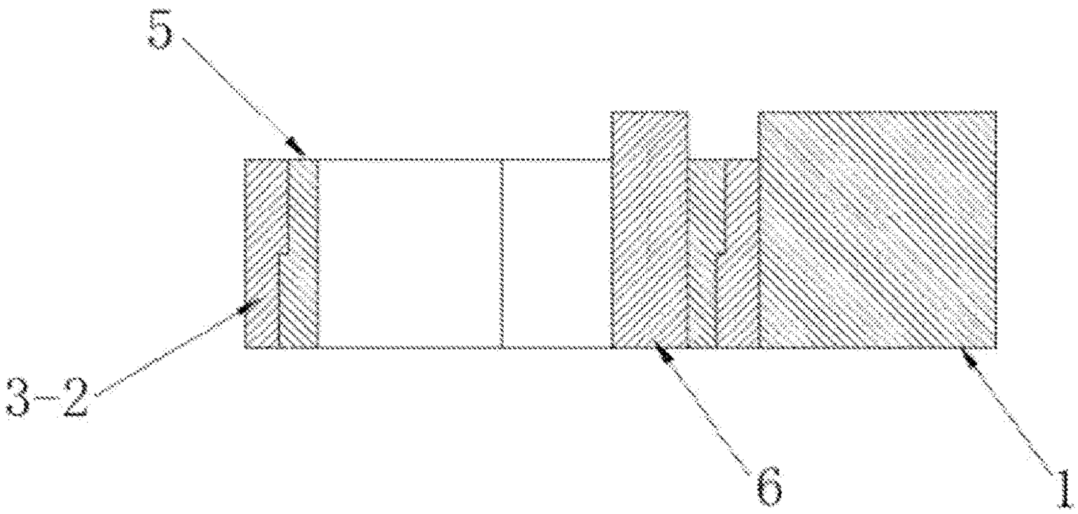

FIG. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/116748

A. CLASSIFICATION OF SUBJECT MATTER

B21H1/06(2006.01)i; B21K1/76(2006.01)i; B21J5/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B21H, B21K, B21J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT, ENTXT, VEN, CNKI: 异形, 异型, 环锻, 轧环, 辗环, 轴向, 凹槽, 套模, 模套, 模环, 中间 3w 模, special, variant, irregular, shape+, profile+, ring roll+, axial, groove, concave, cover die, die ring, middle 3w die

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 115430801 A (WUXI PAIKE NEW MATERIAL TECHNOLOGY CO., LTD.) 06 December 2022 (2022-12-06) claims 1-10	1-9
A	CN 109351896 A (HUBEI UNIVERSITY OF AUTOMOTIVE TECHNOLOGY) 19 February 2019 (2019-02-19) description, paragraphs 4-11, and figures 1-2	1-9
A	JP S6440128 A (MITSUBISHI METAL CORP.) 10 February 1989 (1989-02-10) entire document	1-9
A	JP H03198939 A (MITSUBISHI MATERIALS CORP.) 30 August 1991 (1991-08-30) entire document	1-9
A	CN 113579130 A (WUHAN UNIVERSITY OF TECHNOLOGY) 02 November 2021 (2021-11-02) entire document	1-9
A	CN 102085548 A (GUIZHOU ANDA AVIATION FORGING CO., LTD.) 08 June 2011 (2011-06-08) entire document	1-9

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 November 2023	**15 November 2023**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/116748

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 210450757 U (ZHANGJIAGANG HENGTONG ANNULAR FORGING MANUFACTURE CO., LTD.) 05 May 2020 (2020-05-05) entire document	1-9
A	CN 214108649 U (CHONGQING JIAOHANG TECHNOLOGY CO., LTD.) 03 September 2021 (2021-09-03) entire document	1-9

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/116748

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	115430801	A	06 December 2022	None			
CN	109351896	A	19 February 2019	None			
JP	S6440128	A	10 February 1989	None			
JP	H03198939	A	30 August 1991	JP	2643505	B2	20 August 1997
CN	113579130	A	02 November 2021	None			
CN	102085548	A	08 June 2011	None			
CN	210450757	U	05 May 2020	None			
CN	214108649	U	03 September 2021	None			

Form PCT/ISA/210 (patent family annex) (July 2022)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 102085549 B **[0004]**