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SPEED REDUCER

Abstract

A speed reducer includes: an input unit including an input shaft and first bearing including eccentric first inner ring rotating together with the input shaft; cycloid gear; multiple inner pins, inner pin holder holding end portions of the inner pins in the axial directions and surrounding the input unit outer peripheral surface; second bearing radially outward of the cycloid gear and including a second inner ring as an output shaft, second outer ring radially outward of the second inner ring, and rolling body between the second inner and rings; and a plurality of outer pins held on a radially inner surface of the second inner ring and meshing with external teeth of the cycloid gear. The first inner ring is separate from the input shaft. The input unit includes a movement restrictor restricting movement of the first inner ring relative to the input shaft in the circumferential directions.

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Background/Summary

TECHNICAL FIELD

[0001] The present disclosure relates to a speed reducer. This application claims priority to Japanese Patent Application No. 2022-071624, which was filed on Apr. 25, 2022, and is incorporated herein by reference in its entirety.

BACKGROUND ART

[0002] Speed reducers have been used to date in control units for driving wheels in mobile devices, robots, and machine tools. Patent Literature 1, for example, describes a technique of this type.

[0003] A speed reducer described in Patent Literature 1 includes an input shaft including a pair of eccentric portions, a pair of cycloid gears to be in contact with the pair of eccentric portions, a hub serving as an output shaft, an output shaft pin holder, a plurality of outer pins, an outer pin holder holding the outer pins, and an inner pin supported by the hub. The hub is supported by the outer pin holder through a crossed roller bearing. The crossed roller bearing includes an outer ring fixed to the outer pin holder, an inner ring fixed to the hub, and a plurality of rollers between the outer ring and the inner ring.

CITATION LIST

Patent Literature

[0004] Patent Literature 1: Japanese Patent Application Laid-Open No. 2017-48852

SUMMARY OF INVENTION

Technical Problem

[0005] In speed reducers, improved productivity is required. Additionally, ensuring stable operation is also required. The technique disclosed in Patent Literature 1 is insufficient in terms of improvement of productivity and ensuring stable operation.

[0006] It is therefore an object to provide a speed reducer capable of ensuring stable operation with improved productivity.

Solution to Problems

[0007] A speed reducer according to the present disclosure includes: an input unit including an input shaft and a first bearing, the first bearing including an eccentric first inner ring that rotates together with the input shaft; a cycloid gear located radially outward of the first bearing and including a plurality of external teeth arranged on an outer peripheral surface along circumferential directions, the cycloid gear including a first through hole the input unit penetrates and a plurality of second through holes located radially outward of the first through hole and arranged with intervals in the circumferential directions; a plurality of inner pins penetrating the second through holes in axial directions; an inner pin holder holding end portions of the plurality of inner pins in the axial directions and surrounding an outer peripheral surface of the input unit; a second bearing located radially outward of the cycloid gear, and including a second inner ring that is an output shaft, a second outer ring located radially outward of the second inner ring, and a rolling body located between the second inner ring and the second outer ring; and a plurality of outer pins held on a radially inner surface of the second inner ring and meshing with the external teeth of the cycloid gear. The first inner ring is provided separately from the input shaft. The input unit includes a movement restrictor that restricts movement of the first inner ring relative to the input shaft in the circumferential directions.

Advantages of Invention
[0008] The speed reducer is capable of ensuring stable operation with improved productivity.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0009] FIG. **1** is a schematic perspective view illustrating a speed reducer according to a first embodiment of the present disclosure.
[0010] FIG. **2** is a schematic front view of the speed reducer shown in FIG. **1**.
[0011] FIG. **3** is a schematic side view of the speed reducer shown in FIG. **1**.
[0012] FIG. **4** is a schematic rear view of the speed reducer shown in FIG. **1**.
[0013] FIG. **5** is a schematic cross-sectional view taken along line V-V in FIG. **2**.
[0014] FIG. **6** is an enlarged view of a portion of the cross section of the speed reducer shown in FIG. **5**.
[0015] FIG. **7** is an enlarged view of a portion of the cross section of the speed reducer shown in FIG. **5**.
[0016] FIG. **8** is a schematic cross-sectional view taken along line VIII-VIII in FIG. **5**.
[0017] FIG. **9** is a schematic cross-sectional view taken along line IX-IX in FIG. **5**.
[0018] FIG. **10** is a schematic perspective view illustrating a portion of an input unit included in the speed reducer.
[0019] FIG. **11** is a disassembled perspective view illustrating a portion of the input unit shown in FIG. **10**.
[0020] FIG. **12** is a schematic perspective view in which a portion of the input unit shown in FIG. **10** is partially omitted and indicated by broken lines.
[0021] FIG. **13** is a schematic perspective view illustrating a portion of a first bearing included in the input unit.
[0022] FIG. **14** is a schematic cross-sectional view illustrating a portion of the input unit shown in FIG. **10**.
[0023] FIG. **15** is a schematic cross-sectional view illustrating a portion of the input unit shown in FIG. **10**.
[0024] FIG. **16** is a schematic perspective view in which a portion of inner pins is indicated by broken lines.
[0025] FIG. **17** is a schematic perspective view of an inner pin holder illustrating a state where inner pins are held by a combination of a first holder portion and a second holder portion.
[0026] FIG. **18** is a schematic perspective view of the first holder portion.
[0027] FIG. **19** is a schematic perspective view of the second holder portion.
[0028] FIG. **20** is a view of a cycloid gear as seen in an axial direction.
[0029] FIG. **21** is a schematic perspective view of a second outer ring.
[0030] FIG. **22** is an enlarged schematic cross-sectional view illustrating a portion of the speed reducer shown in FIG. **5**.
[0031] FIG. **23** is an enlarged schematic cross-sectional view illustrating a portion of the second outer ring.
[0032] FIGS. **24** and **25** are schematic perspective views of the second inner ring.
[0033] FIGS. **24** and **25** are schematic perspective views of the second inner ring.
[0034] FIG. **26** is an enlarged schematic cross-sectional view illustrating a portion of the speed reducer including the second inner ring.
[0035] FIG. **27** is an enlarged schematic cross-sectional view illustrating a portion of the second inner ring and one outer pin.
[0036] FIG. **28** is a further enlarged schematic view illustrating the portion of the second inner ring

and the outer pin shown in FIG. **27**.
[0037] FIG. **29** is a schematic view illustrating an example of a cylindrical grinder used for grinding the second inner ring.

DESCRIPTION OF EMBODIMENTS

Summary of Embodiment

[0038] A speed reducer according to the present disclosure includes: an input unit including an input shaft and a first bearing, the first bearing including an eccentric first inner ring that rotates together with the input shaft; a cycloid gear located radially outward of the first bearing and including a plurality of external teeth arranged on an outer peripheral surface along circumferential directions, the cycloid gear including a first through hole the input unit penetrates and a plurality of second through holes located radially outward of the first through hole and arranged with intervals in the circumferential directions; a plurality of inner pins penetrating the second through holes in axial directions; an inner pin holder holding end portions of the plurality of inner pins in the axial directions and surrounding an outer peripheral surface of the input unit; a second bearing located radially outward of the cycloid gear, and including a second inner ring that is an output shaft, a second outer ring located radially outward of the second inner ring, and a rolling body located between the second inner ring and the second outer ring; and a plurality of outer pins held on a radially inner surface of the second inner ring and meshing with the external teeth of the cycloid gear. The first inner ring is provided separately from the input shaft. The input unit includes a movement restrictor that restricts movement of the first inner ring relative to the input shaft in the circumferential directions.
[0039] With this configuration, the input shaft and the first inner ring that are components of the input unit can be made of different materials. Then, a material suitable for the function required for each component can be selected to assemble the input unit. In this case, since the input unit includes the movement restrictor that restricts movement of the first inner ring relative to the input shaft in the circumferential directions, the first inner ring can be reliably positioned in the circumferential directions, and the first inner ring can be reliably rotated together with the input shaft. Accordingly, stable operation of the speed reducer can be ensured. In addition, since the components are made of separate members, accuracy in grinding of, for example, the eccentric first inner ring can be easily increased so that productivity can be thereby enhanced. Further, since the first inner ring is a separate member, a change of eccentricity of the first inner ring and sorting of accuracy, which would be difficult in an integrated input unit, can be easily performed. That is, the first inner rings fabricated in accordance with requirements can be selected and combined with the separately fabricated input shaft to produce the input unit that meets requirements. Since the input shaft is also a separate member, it becomes easier to perform additional machining on the input shaft or incorporate design changes according to an application. Specifically, a material such as a light metal exemplified by aluminum or a resin is employed as a material of the input shaft that is a component constituting the input unit in consideration of weight reduction and torque resistance, whereas bearing steel is employed as a material for the first inner ring in consideration of enhancement of durability. The speed reducer described above can ensure stable operation with enhanced productivity.
[0040] In the speed reducer, the movement restrictor may restrict movement of the first inner ring relative to the input shaft in the axial directions. Thus, the first inner ring in the axial directions is reliably positioned, thereby ensuring more stable operation of the speed reducer.
[0041] In the speed reducer, the movement restrictor includes the first keyway recessed from the outer peripheral surface of the input shaft, the second keyway recessed from the inner peripheral surface of the first inner ring, and the key member fitted in both the first keyway and the second keyway. Accordingly, by fitting the key member in the first keyway and the second keyway, the first inner ring can be reliably positioned in the circumferential directions.
[0042] In the speed reducer, the first keyway extends in the axial directions in a portion of the outer

circumferential surface of the input shaft in the circumferential directions. The second keyway may be located at a position facing the first keyway. The key member may have a rod shape extending in the axial directions. Accordingly, the first inner ring can be more reliably positioned in the circumferential directions with a relatively simple structure.

[0043] In the speed reducer, at least an end portion of the first inner ring on one side in the axial directions may include a flange projecting radially outward. In this manner, in a case where needle rollers included in a needle cage constituted by the needle rollers and a retainer retaining the needle rollers roll on the outer peripheral surface of the first inner ring as a raceway surface, movement of the case included in the needle cage in the axial directions is restricted by using the flange. As a result, more stable operation of the speed reducer can be ensured.

[0044] In the speed reducer, the input unit may further include a guide ring that is provided separately from the input shaft and the first inner ring, has a disc shape, is located at least on one side of the first inner ring in the axial directions, and projects radially outward relative to a raceway surface of the first inner ring. With this configuration, movement of the retainer included in the needle cage in the axial directions can also be restricted by the guide ring. As a result, more stable operation of the speed reducer can be ensured. Similarly, a material for the guide ring included in the input unit can be selected independently of materials for other components, and may be a resin such as PEEK containing fibers or a light metal such as aluminum, for example.

[0045] In the speed reducer, the first bearing may include a pair of first bearings arranged in the axial directions. The first inner ring may include a pair of first inner rings included in the pair of first bearings, and the pair of first inner rings may be arranged with a 180-degree phase shift in the circumferential directions. With this configuration, influence of the eccentric first inner ring during rotation of the input shaft is reduced so that more stable rotation of the input shaft can be thereby ensured.

[0046] In the speed reducer, the first inner ring may be fixed to the input shaft by interference fitting. This configuration can also restrict movement of the first inner ring relative to the input in the axial directions.

SPECIFIC EXAMPLES OF EMBODIMENT

[0047] Next, examples of specific embodiments of a speed reducer according to the present disclosure will be described with reference to the drawings. In the following drawings, the same or corresponding parts are denoted by the same reference numerals, and the description thereof will not be repeated.

First Embodiment

[0048] First, a first embodiment, which is an embodiment of the present disclosure, will be described. FIG. **1** is a schematic perspective view illustrating a speed reducer according to the first embodiment of the present disclosure. FIG. **2** is a schematic front view of the speed reducer shown in FIG. **1**. FIG. **3** is a schematic side view of the speed reducer shown in FIG. **1**. FIG. **4** is a schematic rear view of the speed reducer shown in FIG. **1**. FIG. **5** is a schematic cross-sectional view taken along line V-V in FIG. **2**. FIGS. **6** and **7** are enlarged views illustrating a portion of the cross section of the speed reducer shown in FIG. **5**. FIG. **6** is a cross-sectional view taken in a plane along circumferential directions excluding a lid described later. FIG. **7** is a cross-sectional view taken in a plane along the circumferential directions including the lid described later. FIG. **8** is a schematic cross-sectional view taken along line VIII-VIII in FIG. **5**. FIG. **9** is a schematic cross-sectional view taken along line IX-IX in FIG. **5**. In FIG. **5**, for example, arrow D**1** represents axial directions and arrow D**2** represents radial directions. Broken line R**1** represents a rotation center axis of a speed reducer **10***a*.

[0049] With reference to FIGS. **1** through **9**, the speed reducer **10***a* according to the first embodiment of the present disclosure reduces a rotation speed of an input shaft **11***a* that is rotating at high speed, and outputs the reduced rotation speed from an output shaft described later. In this embodiment, the deceleration rate is 1/36. That is, when the rotation speed of the input shaft is

3000 revolutions per minute (rpm), the rotation speed of the output shaft is about 83.3 rpm. The deceleration rate is, of course, set at any value as required depending on the number of teeth of cycloid gears, the number of outer pins, the degree of eccentricity of a first inner ring, and so forth.

[0050] The speed reducer **10***a* includes: an input unit **12***a* including an input shaft **11***a* and first bearings **31***a* and **31***b* respectively including eccentric first inner rings **32***a* and **32***b* that rotate together with the input shaft **11***a*; cycloid gears **13***a* and **13***b*; a plurality of inner pins **14***a*; an inner pin holder **15***a*; a second bearing **16***a* including a second inner ring **81***a* and a second outer ring **81***b*; and a plurality of outer pins **17***a*. The first bearings **31***a* and **31***b* are disposed as a pair in the axial directions, and the cycloid gears **13***a* and **13***b* are disposed as a pair in the axial directions. The components will be described below.

[0051] The input shaft **11***a* has a hollow cylindrical shape. Specifically, the input shaft **11***a* has an axial through hole **23***a* penetrating the input shaft **11***a* in the axial directions from a first axial end **21***a* that is one end in the axial directions to a second axial end **21***b* that is the other end in the axial directions. An inner peripheral surface **25***a* of the input shaft **11***a* constituting the axial through hole **23***a* has an axial inner peripheral surface keyway **24***a*. In the axial inner peripheral surface keyway **24***a*, a portion of the inner peripheral surface **25***a* in the circumferential directions is recessed radially outward. The use of this axial inner peripheral surface keyway **24***a* reduces a slip of the input shaft **11***a* relative to the rotation axis in the rotation directions when a rotation shaft (not shown) of a motor is coupled to the input shaft **11***a*. An outer peripheral surface **25***b* of the input shaft **11***a* extends straight in the axial directions. The inner peripheral surface **25***a* of the input shaft **11***a* extends straight in the axial directions except for a region where the axial inner peripheral surface keyway **24***a* is present. This input shaft **11***a* has a relatively simple structure, and thus, costs can be reduced. The input shaft **11***a* may have a solid cylindrical shape when necessary.

[0052] The input shaft **11***a* may be made of, for example, a metal. In this embodiment, aluminum is employed as a material for the input shaft **11***a*. The material for the input shaft **11***a* only needs to be a material that can receive a torque of the motor, and may be a resin, for example.

[0053] A first input shaft bearing **29***a* and a second input shaft bearing **29***b* that are two bearings supporting the input shaft **11***a* are attached to the input shaft **11***a*. The first input shaft bearing **29***a* is attached to the first axial end **21***a*, and the second input shaft bearing **29***b* is attached to the second axial end **21***b*. The first input shaft bearing **29***a* and the second input shaft bearing **29***b* are spaced in the axial directions. An inner ring of the first input shaft bearing **29***a* and an inner ring of the second input shaft bearing **29***b* are both fixed to the input shaft **11***a*. An outer ring of the first input shaft bearing **29***a* and an outer ring of the second input shaft bearing **29***b* are both fixed to an inner pin holder **15***a* described later and serving as a fixing portion. The first input shaft bearing **29***a* and the second input shaft bearing **29***b* are, for example, deep groove ball bearings. The input shaft **11***a* is rotatably supported by these first input shaft bearing **29***a* and second input shaft bearing **29***b*. The first input shaft bearing **29***a* is in contact with a step **78***a* of a first holder portion **71***a* included in the inner pin holder **15***a* described later in the axial directions to thereby restrict movement in the axial directions. The second input shaft bearing **29***b* is in contact with a step **78***b* of a second holder portion **71***b* included in the inner pin holder **15***a* described later to thereby restrict movement in the axial directions.

[0054] Next, a detailed configuration of the input unit **12***a* will be described. FIG. **10** is a schematic perspective view illustrating a portion of the input unit **12***a* included in the speed reducer **10***a*. FIG. **11** is a disassembled perspective view illustrating a portion of the input unit **12***a* shown in FIG. **10**. FIG. **12** is a schematic perspective view in which a portion of the input unit **12***a* shown in FIG. **10** is omitted and indicated by broken lines. FIG. **13** is a schematic perspective view illustrating a portion of the first bearing **31***a* included in the input unit **12***a*. FIG. **14** is a schematic cross-sectional view illustrating a portion of the input unit **12***a* shown in FIG. **10**. FIG. **14** is a cross-sectional view taken in a plane including a rotation center axis of the first bearing **31***a*. FIG. **15** is a schematic cross-sectional view illustrating a portion of the input unit **12***a* shown in FIG. **10**. FIG.

15 is a cross-sectional view taken in a plane including the first bearing **31***a* and perpendicular to the axial directions.

[0055] With reference to FIGS. **10** through **15**, the input unit **12***a* includes the input shaft **11***a*, the first bearing **31***a*, and the first bearing **31***b*, as described above. The first bearing **31***a* includes the eccentric first inner ring **32***a* that rotates together with the input shaft **11***a*, the first outer ring **33***a* located radially outward of the first inner ring **32***a*, and a needle cage **36***a*. The needle cage **36***a* is constituted by needle rollers **34***a* as a plurality of rolling bodies located between the first inner ring **32***a* and the first outer ring **33***a* in the radial directions, and a retainer **35***a* retaining the needle rollers **34***a*. The needle rollers **34***a* included in the needle cage **36***a* constituted by the needle rollers **34***a* and the retainer **35***a* retaining the needle rollers **34***a* roll on the outer peripheral surface of the first inner ring **32***a* as a raceway surface. The first bearing **31***b* includes the eccentric first inner ring **32***b* that rotates together with the input shaft **11***a*, the first outer ring **33***b* located radially outward of the first inner ring **32***b*, and a needle cage **36***b*. The needle cage **36***b* is constituted by needle rollers **34***b* as a plurality of rolling bodies located between the first inner ring **32***b* and the first outer ring **33***b* in the radial directions, and a retainer **35***b* retaining the needle rollers **34***b*. The needle rollers **34***b* included in the needle cage **36***b* constituted by the needle rollers **34***b* and the retainer **35***b* retaining the needle rollers **34***b* roll on the outer peripheral surface of the first inner ring **32***b* as a raceway surface. The first inner rings **32***a* and **32***b* are fixed to the input shaft **11***a* by interference fit. The first bearings **31***a* and **31***b* are located between the first input shaft bearing **29***a* and the second input shaft bearing **29***b* in the axial directions. The first input shaft bearing **29***a* and the first bearing **31***a* are adjacent to each other in the axial directions, and the second input shaft bearing **29***b* and the first bearing **31***b* are adjacent to each other in the axial directions.

[0056] In the speed reducer **10***a* of the present disclosure, the first inner ring **32***a* included in the first bearing **31***a* and the first inner ring **32***b* included in the first bearing **31***b* are each provided separately from the input shaft **11***a*. The input unit **12***a* includes movement restrictors **40***a* and **40***b* that restrict movement of the first inner rings **32***a* and **32***b* relative to the input shaft **11***a*. The movement restrictors **40***a* and **40***b* included in the input unit **12***a* include first keyways **41***a* and **41***b*, second keyways **42***a* and **42***b*, and key members **43***a* and **43***b*. Each of the first keyways **41***a* and **41***b* is recessed from the outer peripheral surface **25***b* of the input shaft **11***a*. In this embodiment, each of the first keyways **41***a* and **41***b* extends in the axial directions in a portion of the outer peripheral surface **25***b* of the input shaft **11***a* in the circumferential directions. The first keyways **41***a* and **41***b* are located at different positions in the axial directions and the circumferential directions. Specifically, in the axial directions, the first keyway **41***a* is located between the position at which a guide ring **49***a* is placed and the first axial end **21***a*, and the first keyway **41***b* is located between the position at which the guide ring **49***a* is placed and the second axial end **21***b*. In the circumferential directions, the first keyway **41***a* is located at a position that is rotated 180 degrees from the first keyway **41***b*. Each of the first keyways **41***a* and **41***b* is located at a position that is rotated 90 degrees from the position at which the axial inner peripheral surface keyway **24***a* is located in the circumferential directions.

[0057] The second keyways **42***a* and **42***b* is recessed from the inner peripheral surfaces of the first inner rings **32***a* and **32***b*, respectively. In this embodiment, the second keyways **42***a* and **42***b* penetrate portions of the first inner rings **32***a* and **32***b*, respectively, in the circumferential directions to form groove shapes in the axial directions. The second keyways **42***a* and **42***b* are located in regions of the first inner rings **32***a* and **32***b* each having largest eccentricity in the circumferential directions. The second keyways **42***a* and **42***b* are located at positions corresponding to the first keyways **41***a* and **41***b* when the first inner rings **32***a* and **32***b* are attached to the input shaft **11***a* such that the inner peripheral surfaces of the first inner rings **32***a* and **32***b* face the outer peripheral surface of the input shaft **11***a*.

[0058] Each of the key members **43***a* and **43***b* has a rod shape with a rectangular cross section. The key members **43***a* and **43***b* are fitted in spaces defined by the first keyways **41***a* and **41***b* and the second keyways **42**_a_ and **42**_b_ when the second keyways **42**_a_ and **42**_b_ are located to face the respective first keyways **41**_a_ and **41**_b_. That is, the key members **43**_a_ and **43**_b_ are shaped to be fitted in the first keyways **41**_a_ and **41**_b_ and the second keyways **42**_a_ and **42**_b_, respectively. Corners of end portions of the key members **43**_a_ and **43**_b_ are rounded.

[0059] Axial end portions of the first inner rings **32**_a_ and **32**_b_ include flanges **37**_a_ and **37**_b_ extending radially outward. The input unit **12**_a_ has a disc shape, and includes the guide ring **49**_a_ located on one side of the first inner rings **32**_a_ and **32**_b_ in the axial directions and projecting radially outward relative to the raceway surface of the first inner ring **32**_a_. The guide ring **49**_a_ is located on the other side of the first inner rings **32**_a_ and **32**_b_ in the axial directions. That is, the first bearing **31**_a_ and the first bearing **31**_b_ sandwich the guide ring **49**_a_ in the axial directions. The flange **37**_a_ is located at one end of the raceway surface of the first inner ring **32**_a_ in the axial directions, and the guide ring **49**_a_ is located at the other end of the raceway surface of the first inner ring **32**_a_ in the axial directions. A ring-shaped collar **48**_a_ for adjusting a gap in the axial directions formed in attaching the first inner ring **32**_a_ is located on one side of the first inner ring **32**_a_ in the axial directions. The flange **37**_b_ is located at one end of the raceway surface of the first inner ring **32**_b_ in the axial directions, and the guide ring **49**_a_ is located at the other end of the raceway surface of the first inner ring **32**_b_ in the axial directions. A ring-shaped collar **48**_b_ for adjusting a gap in the axial directions formed in attaching the first inner ring **32**_b_ is located on one side of the first inner ring **32**_b_ in the axial directions. The guide ring **49**_a_ is made of a metal in this embodiment, and may be subjected to heat treatment and grinding finish. Specifically, the guide ring **49**_a_ is made of duralumin, and may be anodized or subjected to other treatments.

[0060] Next, assembly of the input unit **12**_a_ will be described briefly. First, the input shaft **11**_a_ is prepared. Then, the guide ring **49**_a_ is fitted onto the input shaft **11**_a_ from one side in the axial directions, and then, the key members **43**_a_ and **43**_b_ are fitted in the first keyways **41**_a_ and **41**_b_, respectively. The guide ring **49**_a_ is sandwiched between axial ends of the two opposed key members **43**_a_ and **43**_b_ to be fixed in the axial directions. In this manner, the guide ring **49**_a_ is positioned in the axial directions. Then, the first inner ring **32**_a_ to which the needle cage **36**_a_ is attached on the radially outer side from the side where the flange **37**_a_ is not located, is fitted onto the input shaft **11**_a_ from one side in the axial directions. At this time, the first inner ring **32**_a_ is fitted such that the circumferential position of the second keyway **42**_a_ coincides with the position of the key member **43**_a_. Then, the first inner ring **32**_a_ is pushed along the axial directions such that the end surface of the first inner ring **32**_a_ where the flange **37**_a_ is not located contacts the guide ring **49**_a_. In this manner, the first inner ring **32**_a_ is fitted onto the input shaft **11**_a_. The retainer **35**_a_ of the needle cage **36**_a_ is sandwiched between the guide ring **49**_a_ and the flange **37**_a_ of the first inner ring **32**_a_ to be restricted in the axial directions. Further, the first inner ring **32**_b_ to which the needle cage **36**_b_ is attached on the radially outer side from the side where the flange **37**_b_ is not located, is fitted onto the input shaft **11**_a_ from the other side in the axial directions. Then, the first inner ring **32**_b_ is pushed along the axial directions such that the end surface of the first inner ring **32**_b_ where the flange **37**_b_ is not located contacts the guide ring **49**_a_. At this time, in a manner similar to the case of the first inner ring **32**_a_, the first inner ring **32**_b_ is also fitted such that the circumferential position of the second keyway **42**_b_ coincides with the position of the key member **43**_b_. The retainer **35**_b_ of the needle cage **36**_b_ is sandwiched between the guide ring **49**_b_ and the flange **37**_b_ of the first inner ring **32**_b_ to be restricted in the axial directions. In this manner, the first inner rings **32**_a_ and **32**_b_ are fitted onto the input shaft **11**_a_. The fitting of the first inner rings **32**_a_ and **32**_b_ onto the input shaft **11**_a_ is interference fitting. Specifically, for example, the first inner rings **32**_a_ and **32**_b_ are press fitted onto the input shaft **11**_a_, and are also assembled by shrink fitting. Thereafter, the collars **48**_a_ and **48**_b_ are fitted onto the input shaft **11**_a_ in the axial directions. In this manner, the input unit **12**_a_ is assembled.

[0061] A configuration of the inner pins **14**_a_ will now be described. FIG. **16** is a schematic perspective view in which a portion of the inner pins **14**_a_ is indicated by broken lines. With reference to FIG. **16**, the inner pin **14***a* includes a hollow cylindrical shank **61***a*, two annular inner pin outer rings **62***a* and **62***b* each having an inner diameter larger than the outer diameter of the shank **61***a*, rollers **63***a* as a plurality of rolling bodies disposed between the outer peripheral surface of the shank **61***a* and the inner peripheral surfaces of the inner pin outer rings **62***a* and **62***b*, and a plurality of thrust washers **64***a*, **64***b*, **64***c*, and **64***d* arranged in the thrust directions. That is, the inner pin **14***a* is constituted as a rolling bearing using the plurality of rollers **63***a* as rolling bodies. The inner pin outer rings **62***a* and **62***b* are arranged in the axial directions while sandwiching the thrust washers **64***b* and **64***c* therebetween. Each of the thrust washers **64***a*, **64***b*, **64***c*, and **64***d* is made of a thermoplastic resin such as a polyetheretherketone (PEEK), but is not limited to this example. The inner pin **14***a* does not include a so-called retainer, and is of a full component roller type. The inner pin **14***a* may be a plain bearing. The inner pin **14***a* functions as a so-called planet shaft. In this embodiment, a total of eight inner pins **14***a* are provided.

[0062] Next, a configuration of the inner pin holder **15***a* will be described. The inner pin holder **15***a* includes the first holder portion **71***a* and the second holder portion **71***b*. The inner pin holder **15***a* supports the inner pins **14***a*, specifically, both ends of the shanks **61***a* included in the inner pins **14***a*. The inner pin holder **15***a* functions as a planet shaft supporter that supports planet shafts in a case where the shanks **61***a* of the inner pins **14***a* are the planet shafts. FIG. **17** is a schematic perspective view of the inner pin holder **15***a* illustrating a state where the inner pins **14***a* are held by a combination of the first holder portion **71***a* and the second holder portion **71***b*. FIG. **18** is a schematic perspective view of the first holder portion **71***a*. FIG. **19** is a schematic perspective view of the second holder portion **71***b*. FIG. **17** also shows the thrust washers **65***a*, **65***b*, **65***c*, and **65***d*.

[0063] With reference to FIGS. **17**, **18**, and **19**, the first holder portion **71***a* includes a disc-shaped plate portion **72***a* in which a through hole penetrating the plate portion **72***a* in the thickness directions is located at the center in the radial directions, and a plurality of support columns **73***a* projecting along the thickness directions from one surface of the plate portion **72***a* on one side in the thickness directions. The plate portion **72***a* and the plurality of support columns **73***a* are integrated. In this embodiment, four support columns **73***a* are provided at 90-degree intervals. The plate portion **72***a* has a plurality of press-fitting holes **74***a* in which end portions of the shanks **61***a* of the inner pins **14***a* on one side can be press fitted, with intervals in the circumferential directions. The press-fitting holes **74***a* penetrate the plate portion **72***a* in the thickness directions, and a total of eight press-fitting holes **74***a* are provided, corresponding to the number of the inner pins **14***a*. From the viewpoint of weight reduction, the outer peripheral surface of the plate portion **72***a* has an annular recessed groove **75***a* that is recessed radially inward.

[0064] The support columns **73***a* connect the plate portion **72***a* of the first holder portion **71***a* to the second holder portion **71***b*. A total of four support columns **73***a* are provided. The support columns **73***a* are located within second through holes **52***a* and **52***b* of the cycloid gears **13***a* and **13***b* described later when assembled into the speed reducer **10***a*. End surfaces of the support columns **73***a* in the circumferential directions are recessed in arc shapes in the circumferential directions as seen in the axial direction along the outer shapes of the inner pin outer rings **62***a* and **62***b* included in the inner pins **14***a*. The end surfaces of the support columns **73***a* in the radial directions have arc shapes as seen in the axial direction. The support columns **73***a* have screw holes **76***a* that are recessed along the thickness directions of the plate portion **72***a* and used for attaching the first holder portion **71***a* to the second holder portion **71***b*. In this embodiment, four screw holes **76***a* are provided at 90-degree intervals in the circumferential directions. From the viewpoint of weight reduction, in the thickness directions of the plate portion **72***a*, the surface opposite to the surface from which the support columns **73***a* project has an annular recessed groove **77***a* recessed in the thickness directions, on the radially outer side of the through hole at the center in the radial directions.

[0065] The second holder portion **71***b* has a disc shape having a through hole penetrating the second holder portion **71***b* in the thickness directions at the center in the radial directions. The second holder portion **71**_b_ includes a first portion **72**_b_ located at a center side in the radial directions, and a second portion **73**_b_ located radially outward of the first portion **72**_b_ and thinner than the first portion **72**_b_. The first portion **72**_b_ has a plurality of press-fitting holes **74**_b_ in which end portions of the shanks **61**_a_ of the inner pins **14**_a_ on the other side can be press fitted, with intervals in the circumferential directions. The press-fitting holes **74**_b_ penetrate the second holder portion **71**_b_ in the thickness directions, and a total of eight press-fitting holes **74**_b_ are provided, corresponding to the number of the inner pins **14**_a_. From the viewpoint of weight reduction, the outer peripheral surface of the first portion **72**_b_ has an annular recessed groove **75**_b_ that is recessed radially inward. The first portion **72**_b_ has a plurality of through holes **76**_b_ penetrating the first portion **72**_b_ along the thickness directions of the first portion **72**_b_ and used for attaching the first holder portion **71**_a_ to the second holder portion **71**_b_, with intervals in the circumferential directions. In this embodiment, four through holes **76**_b_ are provided at 90-degree intervals, in accordance with the number and arrangement of the screw holes **76**_a_. The second portion **73**_b_ of the second holder portion **71**_b_ has notches **79**_b_ that are arranged along the outer peripheral surface with intervals in the circumferential directions to reduce the thickness. Through holes penetrating the second holder portion **71**_b_ in the axial directions are provided in regions where the notches **79**_b_ are provided. The notches **79**_b_ and the through holes are located at positions corresponding to bolt holes **89**_b_ of the second outer ring **81**_b_ described later, and the second outer ring **81**_b_ is fixed to the second holder portion **71**_b_ with bolts **27**_a_.

[0066] An example of a method for assembling the inner pin holder **15**_a_ will be described briefly as follows. First, end portions of the shanks **61**_a_ of the eight inner pins **14**_a_ on one side are press fitted in the eight press-fitting holes **74**_a_ of the first holder portion **71**_a_. End portions of the shanks **61**_a_ of the inner pins **14**_a_ on the other side are press fitted in the eight press-fitting holes **74**_b_ of the second holder portion **71**_b_. Thereafter, with four bolts **26**_a_ prepared beforehand, the bodies of the bolts **26**_a_ are inserted through the four through holes **76**_b_ and fastened by using the four screw holes **76**_a_, thereby assembling the inner pin holder **15**_a_. The support columns **73**_a_ located between the two inner pins **14**_a_ and the two inner pins **14**_a_ in the circumferential directions are located within the second through holes **52**_a_ of the cycloid gears **13**_a_ and **13**_b_ described later.

[0067] Next, a configuration of the cycloid gear **13**_b_ will be described. FIG. **20** is a view of the cycloid gear **13**_b_ as seen in an axial direction. With reference to FIG. **20**, the cycloid gear **13**_b_ is located radially outward of the first bearing **31**_a_. The cycloid gear **13**_b_ includes a plurality of external teeth **50**_b_ arranged on the outer peripheral surface along the circumferential directions. In this embodiment, the external teeth **50**_b_ have an epitrochoid parallel curve. The number of the external teeth **50**_b_ is 35 in this embodiment. The cycloid gear **13**_b_ have a circular first through hole **51**_b_ the input unit **12**_a_ penetrates, and a plurality of second through holes **52**_b_ located radially outward of the first through hole **51**_b_ and arranged with intervals in the circumferential directions. From the viewpoint of weight reduction of the speed reducer **10**_a_, the cycloid gear **13**_b_ has a plurality of circular third through holes **53**_b_ located further radially outward of the first through hole **51**_b_ and each located between the plurality of second through holes **52**_b_ arranged with intervals in the circumferential directions. Each of the plurality of third through holes **53**_b_ is located between adjacent ones of the second through holes **52**_b_ in the circumferential directions. In this embodiment, four second through holes **52**_b_ and four third through holes **53**_b_ are provided. The first outer ring **33**_b_ of the first bearing **31**_b_ is fitted in the first through hole **51**_b_ of the cycloid gear **13**_b_. The second through holes **52**_b_ are elongated holes extending along the circumferential directions, and wall surfaces positioned in the radial directions have arc-shaped portions. A gap in the circumferential directions is defined between each of the second through holes **52**_b_ and two inner pins **14**_a_ in this second through hole **52**_b_. A gap is also defined between the cycloid gear **13**_b_ and outer pins **17**_a_ described later.

[0068] In a manner similar to the cycloid gear **13**_b_, the cycloid gear **13**_a_ includes a plurality of external teeth **50**_a_ arranged on the outer peripheral surface along the circumferential directions. In a manner similar to the cycloid gear **13***b*, the cycloid gear **13***a* includes a first through hole **51***a*, a plurality of second through holes **52***a*, and a plurality of third through holes **53***a*. A configuration of the cycloid gear **13***a* is similar to that of the cycloid gears **13***b*, and thus, will not be described in detail.

[0069] Then, a configuration of the outer pins **17***a* will be described briefly. The outer pins **17***a* have solid cylindrical shapes. Ends of the outer pins **17***a* in the axial directions are chamfered. The outer pins **17***a* are oriented in the speed reducer **10***a* such that the axial directions coincide with the directions indicated by arrow D**1**. In this embodiment, the number of the outer pins **17***a* is 36. That is, the number of the outer pins **17***a* is larger, by one, than the number of the external teeth **50***a* and **50***b* of the cycloid gears **13***a* and **13***b* described above. To restrict movement of the outer pins **17***a* in the axial directions, an annular outer pin guide plate **66***a* and a retaining ring **67***a* are provided on one side of the outer pins **17***a* in the axial directions. The retaining ring **67***a* is formed by partially cutting out an annular member and is shrunk radially inward, and can be placed radially inside the second inner ring **81***a*. After the placement, the retaining ring **67***a* returns to the original shape by elastic deformation.

[0070] Next, a configuration of the second bearing **16***a* as a main bearing will be described. In this embodiment, the second bearing **16***a* as the main bearing of the speed reducer **10***a* includes the second inner ring **81***a* having raceway surfaces **82***a* and **82***b*, the second outer ring **81***b* having raceway surfaces **83***a* and **83***b*, and a plurality of cylindrical rollers **84***a* and **84***b*. In the speed reducer **10***a* according to the first embodiment of the present disclosure, the second inner ring **81***a* of the second bearing **16***a* serves as an output shaft that reduces the rotation speed of the input shaft **11***a* and outputs the reduced rotation speed. The second bearing **16***a* is a crossed roller bearing. That is, the cylindrical rollers **84***a* and **84***b* included in the main bearing alternately crossed at right angles to each other in a space between the second inner ring **81***a* and the second outer ring **81***b* in the radial directions. Specifically, the rolling axes of the two cylindrical rollers **84***a* and **84***b* adjacent to each other in the circumferential directions are orthogonal to each other. In this embodiment, the second bearing **16***a* is a multi-row crossed roller bearing. Specifically, a row of the cylindrical rollers **84***a* and a row of the cylindrical rollers **84***b* are located adjacent to each other in the axial directions. The second bearing **16***a* is of a full component roller type. That is, the second bearing **16***a* does not include a retainer for retaining the plurality of cylindrical rollers **84***a* and **84***b*.

[0071] Then, a specific configuration of the second inner ring **81***a* and the second outer ring **81***b* that are components of the second bearing **16***a* will be described. First, a configuration of the second outer ring **81***b* will be described. FIG. **21** is a schematic perspective view of the second outer ring **81***b*. FIG. **22** is an enlarged schematic cross-sectional view illustrating a portion of the speed reducer **10***a* shown in FIG. **5**. FIG. **23** is an enlarged schematic cross-sectional view illustrating a portion of the second outer ring **81***b*. With reference to FIGS. **21**, **22**, and **23**, the second outer ring **81***b* has an annular shape, and the inner peripheral surface of the second outer ring **81***b* includes the raceway surfaces **83***a* and **83***b* each provided in a plurality of rows on which the cylindrical rollers **84***a* and **84***b* roll. The raceway surfaces **83***a* and **83***b* are adjacent to each other in the axial directions. The raceway surfaces **83***a* and **83***b* are provided as a pair and arranged in the axial directions. Each of the raceway surfaces **83***a* and **83***b* is recessed radially outward in a V shape in cross section. The pair of raceway surfaces **83***a* and **83***b* tilts at 45 degrees relative to the axial directions. An annular oil groove **85***a* that is recessed radially outward in a V shape in cross section is provided between the raceway surfaces **83***a* and **83***b* in the axial directions. An annular oil groove **85***a* that is recessed radially inward in a V shape in cross section is also provided on the outer peripheral surface of the second outer ring **81***b*. In the axial directions, the position of the oil groove **85***a* and the position of the oil groove **85***b* are the same. An oil hole **86***a* penetrating the second outer ring **81***b* in the axial directions is provided to connect the oil groove **85***a* and the oil groove **85***b*. An opening portion of the second outer ring **81***b* on the side opposite to the bolt holes

89*b* described later in the axial direction has an annular groove **87***a* that is recessed radially outward. The annular groove **87***a* is used for attaching a seal for enhancing hermeticity. In this embodiment, no seals are used and shown in the drawings.

[0072] The second outer ring **81***b* has insertion holes **44***a* and **44***b* penetrating the second outer ring **81***b* from the outer peripheral surface to a region where the cylindrical rollers **84***a* and **84***b* are located, and the cylindrical rollers **84***a* and **84***b* are inserted in the insertion holes **44***a* and **44***b*. The plurality of cylindrical rollers **84***a* and **84***b* are sequentially inserted in the insertion holes **44***a* and **44***b*. After all the cylindrical rollers **84***a* and **84***b* have been inserted, a spacer **45***a* for adjusting a gap between the cylindrical rollers **84***a* and **84***b* in the circumferential directions is inserted. After all the members have been inserted, the insertion holes **44***a* and **44***b* are closed by lids **46***a* and **46***b*. The lids **46***a* and **46***b* are fixed by lid fixing pins **47***b* penetrating the lids **46***a* and **46***b* and portions of the second outer ring **81***b* in the axial directions. From the viewpoint of weight reduction, the second outer ring **81***b* has elongated holes **55***a* each having the longitudinal directions in the circumferential directions, penetrating the second outer ring **81***b* in the radial directions, and arranged at regular intervals in the circumferential directions. The second outer ring **81***b* has a plurality of bolt holes **89***b* arranged with intervals in the circumferential directions. The bolt holes **89***b* are used for attaching the second outer ring **81***b* to the inner pin holder **15***a*, specifically, the second holder portion **71***b*, with the bolts **27***a*. That is, the second outer ring **81***b* is also a fixing portion and neither rotates nor revolves, in a manner similar to the inner pin holder **15***a*.

[0073] Then, a configuration of the second inner ring **81***a* will be described. FIGS. **24** and **25** are schematic perspective views of the second inner ring **81***a*. FIGS. **24** and **25** show the second inner ring **81***a* as seen in different directions. FIG. **26** is an enlarged schematic cross-sectional view illustrating a portion of the speed reducer **10***a* including the second inner ring **81***a*. FIG. **26** does not show some members. FIG. **27** is an enlarged schematic cross-sectional view illustrating a portion of the second inner ring **81***a* and one outer pin **17***a*. FIG. **28** is a further enlarged schematic view illustrating the portion of the second inner ring **81***a* and the outer pin **17***a* shown in FIG. **27**. For facilitating understanding, FIGS. **24** through **28** also show the outer pin **17***a*.

[0074] With reference to FIGS. **24**, **25**, **26**, **27**, and **28**, the second inner ring **81***a* is an annular member, and the outer peripheral surface of the second inner ring **81***a* has raceway surfaces **82***a* and **82***a* on which the cylindrical rollers **84***a* and **84***b* roll. From the viewpoint of weight reduction, the second inner ring **81***a* has elongated holes **54***a* each having the longitudinal directions in the circumferential directions, penetrating the second inner ring **81***a* in the radial directions, and arranged at regular intervals in the circumferential directions. The second inner ring **81***a* has a plurality of oil holes **58***a* each having the longitudinal directions in the circumferential directions, penetrating the second inner ring **81***a* in the radial directions, and arranged at regular intervals in the circumferential directions.

[0075] The raceway surfaces **82***a* and **82***b* are adjacent to each other in the axial directions. The raceway surfaces **82***a* and **82***b* are provided as a pair and arranged in the axial directions. Each of the raceway surfaces **82***a* and **82***b* is recessed radially inward in a V shape in cross section. The pair of the raceway surfaces **82***a* and **82***b* tilts at 45 degrees relative to the axial directions. The raceway surfaces **82***a* and **82***b* can accommodate the cylindrical rollers **84***a* and **84***b* in a space between the raceway surfaces **82***a* and **82***b* and the raceway surfaces **83***a* and **83***b* of the second outer ring **81***b* opposed to the raceway surfaces **82***a* and **82***b* in the radial directions. The cylindrical rollers **84***a* and **84***b* are arranged in the form of a crossed roller bearing, that is, the rolling axes of the cylindrical rollers **84***a* and **84***b* are alternately crossed at right angles to each other, between the raceway surfaces **82***a* and **82***b* and the raceway surfaces **83***a* and **83***b*.

[0076] Here, the inner peripheral surface of the second inner ring **81***a* has a plurality of outer pin housing grooves **90***a* that are recessed radially outward as seen the axial direction, arranged along the circumferential directions, and configured to house the outer pins **17***a*. A wall surface **91***a* constituting each of the outer pin housing grooves **90***a* includes a curved surface constituting a portion of an arc surface as seen in the axial direction. The wall surface **91***a* constituting each outer pin housing groove **90***a* is constituted by a so-called an R surface as seen in the axial direction. The inner peripheral surface of the second inner ring **81***a* also has slots **90***b* that are simply recessed radially outward as seen in the axial direction. The outer pin housing grooves **90***a* and the slots **90***b* are arranged alternately along the circumferential directions. That is, the outer pins **17***a* are arranged alternately in the circumferential directions in a groove-like recessed portion on a radially inner side of the second inner ring **81***a*.

[0077] The wall surface **91***a* along the circumferential directions constituting the outer pin housing grooves **90***a* have nails **92***a* and **92***b* that restrict radially inward movement of the outer pins **17***a* form the outer pin housing grooves **90***a*. In this embodiment, the second bearing **16***a* are crossed roller bearings arranged in multiple rows, specifically, two rows in the axial directions. In the inner peripheral surface of the second inner ring **81***a*, axial center portions **95***a* and **95***b* project radially inward relative to the axial end portions **93***a*, **93***b*, **94***a*, and **94***b* in each of the rows of the cylindrical rollers **84***a* and **84***b* (see especially FIG. **22**). This configuration in which the axial center portions **95***a* and **95***b* project radially inward can make the thickness of a portion of the second inner ring **81***a* having the raceway surfaces **82***a* and **82***b* equal to other portions, such as the axial end portions **93***a*, **93***b*, **94***a*, and **94***b*. This can suppress a decrease in rigidity of a portion having the nails **92***a* and **92***b*. The nails **92***a* and **92***b* are located on the axial center portions **95***a* and **95***b*. An oil sump **97***a* in which lubricating oil is accumulated is formed between the axial center portions **95***a* and **95***b* in the axial directions.

[0078] As seen in the axial direction, a pitch circle diameter (PCD) of the outer pins **17***a* is larger than a diameter of an imaginary circle connecting the positions of the nails **92***a* in the circumferential directions. Specifically, as seen suppose a pitch circle diameter corresponding to an imaginary circle connecting the rotation centers of the outer pins **17***a* is a diameter P**1** and the diameter of the imaginary circle connecting the positions of the nails **92***a* in the circumferential directions is a diameter P**2**, the diameter P**1** is larger than the diameter P**2**. The inner diameter surface of each of the nails **92***a* is formed in a curved shape with a single curvature radius from the center of the imaginary circle connecting the positions of the nails **92***a* in the circumferential directions. A curvature radius R in this case is represented as a diameter P**2**/2.

[0079] A wall surface **91***b* in the circumferential directions not constituting each outer pin housing groove **90***a* has a relief portion **96***b* that is recessed radially outward to reduce the thickness. The relief portions **96***b* are located such that the external teeth **50***a* and **50***b* of the cycloid gears **13***a* and **13***b* do not interfere with the relief portions **96***b*. The wall surface constituting each of the relief portions **96***b* has an arc shape as seen in the axial direction.

[0080] Next, an example of a method for assembling the speed reducer **10***a* described above will be described. First, the input shaft **11***a* and the first bearings **31***a* and **31***b* are prepared as described above to assemble the input unit **12***a*. In this assembly, the first outer rings **33***a* and **33***b* are press fitted in the first through holes **51***a* and **51***b* of the cycloid gears **13***a* and **13***b* beforehand such that the assembly is performed in a state where the cycloid gears **13***a* and **13***b* are attached to the input unit **12***a*. Thereafter, the inner pins **14***a* are placed in the second through holes **52***a* and **52***b* of the cycloid gears **13***a* and **13***b*, and the inner pin holder **15***a* is attached to the input unit **12***a* in the axial directions. The outer pins **17***a* are housed in the outer pin housing grooves **90***a* formed on the inner peripheral surface of the second inner ring **81***a*. At this time, the outer pins **17***a* are fitted in the outer pin housing grooves **90***a* from the rear side (side where the outer pin guide plate **66***a* and the retaining ring **67***a* are to be located) of the second inner ring **81***a*. Thereafter, the outer pin guide plate **66***a* and the retaining ring **67***a* are attached to the second inner ring **81***a*. Then, the second outer ring **81***b* is attached to the radially outer side of the second inner ring **81***a*. Subsequently, the plurality of cylindrical rollers **84***a* and **84***b* are alternately inserted through the insertion holes **44***a* and **44***b* such that the rolling axes intersect perpendicularly to each other, and after all the cylindrical rollers **84***a* and **84***b* have been inserted, the spacer **45***a* is inserted. Thereafter, the lids

46*a* and **46***b* are fitted in the insertion holes **44***a* and **44***b*, and the lid fixing pins **47***b* are attached to fix the lids **46***a* and **46***b*. Then, the input unit **12***a* to which the cycloid gears **13***a* and **13***b*, the inner pins **14***a*, and the inner pin holder **15***a* are attached, is attached to the radially inner side of the second inner ring **81***a* housing the outer pins **17***a*. At this time, even when the second inner ring **81***a* is tilted with the front side (side opposite to the rear side in the axial directions) facing upward, since the nails **92***a* on the wall surface constituting the outer pin housing grooves **90***a* prevent the outer pins **17***a* in the outer pin housing grooves **90***a* from falling off from the rear side. In this manner, the cycloid gears **13***a* and **13***b* and the input unit **12***a* are attached to the radially inner side of the second inner ring **81***a*, thereby assembling the speed reducer **10***a*.
[0081] Next, operation of the speed reducer **10***a* in the first embodiment of the present disclosure will be described. When the input shaft **11***a* rotates (spins) at high speed, the eccentric first inner rings **32***a* and **32***b* of the first bearings **31***a* and **31***b* rotate (spin) accordingly. Here, in the cycloid gears **13***a* and **13***b* in which the first outer rings **33***a* and **33***b* of the first bearings **31***a* and **31***b* are press fitted in the first through holes **51***a* and **51***b*, the inner pins **14***a* are located in the second through holes **52***a* and **52***b*. Since the shanks **61***a* of the inner pins **14***a* are press fitted in the inner pin holder **15***a* as a fixing portion, the inner pins **14***a* themselves do not rotate. Thus, the cycloid gears **13***a* and **13***b* do not revolve, and spin, shifting by one pitch at each turn of the input shaft **11***a* while maintaining eccentric motion. With the spinning of the cycloid gears **13***a* and **13***b* by one pitch, the outer pins **17***a* meshing with the external teeth **50***a* and **50***b* of the cycloid gears **13***a* and **13***b* revolve while spinning in the outer pin housing grooves **90***a* formed on the inner peripheral surface of the second inner ring **81***a*. With the revolution of the outer pins **17***a* housed in the outer pin housing grooves **90***a*, the wall surface on the inner circumferential side of the second inner ring **81***a* constituting the outer pin housing grooves **90***a* is pushed in the rotation direction (spinning direction), and the second inner ring **81***a* spins at low speed, that is, spins by one pitch. In this manner, the rotation speed input from the input shaft **11***a* is reduced and output from the second inner ring **81***a*. In this case, the direction of rotation of the input shaft **11***a* is the same as the direction of rotation of the second inner ring **81***a*. In this embodiment, since the number of the outer pins **17***a* is 36 and the number of the external teeth **50***a* and **50***b* of the cycloid gears **13***a* and **13***b* is 35, the rotation speed of the second inner ring **81***a* as the output shaft is 1/36 of the rotation speed of the input shaft **11***a*. That is, in this embodiment, one pitch corresponds to 1/36 of the circumference.
[0082] In the speed reducer **10***a* of the present disclosure, the inner peripheral surface of the second inner ring **81** a has the plurality of outer pin housing grooves **90***a* that are recessed radially outward in the axial directions, are arranged along the circumferential directions, and houses the outer pins **17***a*. The wall surface **91***a* along the circumferential directions constituting the outer pin housing grooves **90***a* have the nails **92***a* and **92***b* that restrict radially inward movement of the outer pins **17***a* form the outer pin housing grooves **90***a*. With this configuration, in rotation of the cycloid gears **13***a* and **13***b* during operation of the speed reducer **10***a*, even when a gap between the cycloid gears **13***a* and **13***b* and the outer pins **17***a* is enlarged, the nails **92***a* and **92***b* restrict falling of the outer pins **17***a* radially inward. Then, the posture of the outer pins **17***a* in the outer pin housing grooves **90***a* is stabilized so that rattles of the outer pins **17***a* can be thereby reduced. Accordingly, even when a gap between the cycloid gears **13***a* and **13***b* and the outer pins **17***a* is enlarged, snagging between the cycloid gears **13***a* and **13***b* and the outer pins **17***a* is reduced so that rotation of the outer pins **17***a* housed in the outer pin housing grooves **90***a* and rotation of the cycloid gears **13***a* and **13***b* thereby become smoother. As a result, occurrence of rotation noise during operation of the speed reducer **10***a* is reduced, and quietness is enhanced. In this case, rotational smoothness of the rotating parts relative to the fixed parts of the speed reducer **10***a* can be enhanced.
[0083] In the second inner ring **81***a* including the nails **92***a* and **92***b* described above, the outer pins **17***a* can be housed and held in the outer pin housing grooves **90***a* beforehand. In this case, even when the second inner ring **81***a* is tilted with the front side facing upward in a state where the outer

pins **17***a* are housed in the outer pin housing grooves **90***a*, falling off of the outer pins **17***a* in the outer pin housing grooves **90***a* from the rear side can be prevented. Accordingly, assembly can be performed by tilting the second inner ring **81***a* with the outer pins **17***a* placed in the outer pin housing grooves **90***a* beforehand, and workability in assembling the speed reducer **10***a* can be enhanced.

[0084] In this embodiment, the wall surface **91***b* in the circumferential directions not constituting the outer pin housing grooves **90***a* has the relief portion **96***b* that is recessed radially outward to reduce the thickness. This reduces the probability of interference between the external teeth **50***a* and **50***b* of the cycloid gears **13***a* and **13***b* and the inner peripheral surface of the second inner ring **81***a* during rotation of the cycloid gears **13***a* and **13***b*. Accordingly, the cycloid gears **13***a* and **13***b* rotate more smoothly, and quietness is enhanced.

[0085] In this embodiment, as seen in the axial direction, the pitch circle diameter of the outer pins **17***a* is larger than the diameter of the imaginary circle connecting the positions of the nails **92***a* and **92***b* in the circumferential directions. This further ensures restriction of radially inward movement of the outer pins **17***a* by the nails **92***a* and **92***b*.

[0086] In this embodiment, on the inner peripheral surface of the second inner ring **81***a*, the axial center portions **95***a* and **95***b* project radially inward relative to the axial end portions **93***a*, **93***b*, **94***a*, and **94***b*. The axial center portions **95***a* and **95***b* have the nails **92***a* and **92***b*. Thus, the contact area between the nails **92***a* and **92***b* and the outer pins **17***a* is reduced so that smooth rotation of the outer pins **17***a* can be ensured. In the axial center portions **95***a* and **95***b*, the outer pins **17***a* are guided by the nails **92***a* and **92***b*. This reduces the risk of tilting of the outer pins **17***a* in the axial directions, and more stable rotation can be ensured.

[0087] In this embodiment, inner peripheral surfaces **98***a* and **98***b* of the nails **92***a* and **92***b* are each formed in a curved shape with a single curvature radius from the center of the imaginary circle connecting the positions of the nails **92***a* and **92***b* in the circumferential directions. Thus, during rotation of the cycloid gears **13***a* and **13***b*, the external teeth **50***a* and **50***b* of the cycloid gears **13***a* and **13***b* can easily pass over the positions where the nails **92***a* and **92***b* are provided. Accordingly, the cycloid gears **13***a* and **13***b* rotate more smoothly, and quietness is enhanced.

[0088] In this embodiment, the second bearing **16***a* includes a multi-row crossed roller bearing in which the cylindrical rollers **84***a* and **84***b* are arranged in multiple rows in the axial directions. Thus, loads applied in various directions can be appropriately received by the second bearing **16***a* with a compact configuration. Accordingly, the size of the speed reducer **10***a* can be easily reduced. In addition, the rotation center axis of the crossed roller bearing and the rotation center axes of components constituting of the speed reducer mechanism can be easily placed on the same plane, thus making it possible to reduce torsion between the input shaft **11***a* and the second inner ring **81***a* as an output shaft caused by a load torque.

[0089] In this embodiment, in the inner peripheral surface of the second inner ring **81***a*, the axial center portions **95***a* and **95***b* project radially inward relative to the axial end portions **93***a*, **93***b*, **94***a*, and **94***b* in each of the rows of the cylindrical rollers **84***a* and **84***b*. The nails **92***a* and **92***b* are located on the axial center portions **95***a* and **95***b*. Thus, it is possible to bring the nails **92***a* and **92***b* on the axial center portions **95***a* and **95***b* corresponding to the cylindrical rollers **84***a* and **84***b* in each row into contact with the outer pins **17***a*. Then, the outer pins **17***a* are guided by the plurality of nails **92***a* and **92***b* in the axial directions so that the risk of tilting of the outer pins **17***a* in the axial directions can be further reduced. As a result, more stable rotation can be ensured.

[0090] Here, in regard to the input shaft **11***a* included in the input unit **12***a* and the first bearings **31***a* and **31***b*, specifically, the input shaft **11***a* and the eccentric first inner rings **32***a* and **32***b* included in the first bearings **31***a* and **31***b*, the first inner rings **32***a* and **32***b* need to be rotated together with the input shaft **11***a*, and thus, are possibly formed integrally with the input shaft **11***a*. In this case, the input shaft **11***a* and the first inner rings **32***a* and **32***b* can be possibly formed from rod-shaped members of the same metal by shaving, for example. However, in this structure, functions required for the components, specifically, the input shaft **11***a* and the first inner rings **32***a* and **32***b*, cannot be made different. For this reason, this structure is not preferable.

[0091] In the speed reducer **10***a* of the present disclosure, the first inner rings **32***a* and **32***b* are provided separately from the input shaft **11***a*. The input unit **12***a* includes the movement restrictors **40***a* and **40***b* that restrict movement of the first inner rings **32***a* and **32***b* relative to the input shaft **11***a* in the circumferential directions. This configuration enables the input shaft **11***a* and the first inner rings **32***a* and **32***b* that are components of the input unit **12***a* to be made of different materials. Then, a material suitable for the function required for each component can be selected to assemble the input unit **12***a*. In this case, since the input unit **12***a* includes the movement restrictor **40***a* that restricts movement of the first inner rings **32***a* and **32***b* relative to the input shaft **11***a* in the circumferential directions, the first inner rings **32***a* and **32***b* can be reliably positioned in the circumferential directions, and the first inner rings **32***a* and **32***b* can be reliably rotated together with the input shaft **11***a*. Accordingly, stable operation of the speed reducer **10***a* can be ensured. In addition, since the components are made of separate members, accuracy in grinding of, for example, the eccentric first inner rings **32***a* and **32***b* can be easily increased so that productivity can be thereby enhanced. Further, since the first inner rings **32***a* and **32***b* are separate members, a change of eccentricity of the first inner rings **32***a* and **32***b* and sorting of accuracy, which would be difficult in an integrated-type input unit **12***a*, can be easily performed. That is, the first inner rings **32***a* and **32***b* fabricated in accordance with requirements can be selected and combined with the separately fabricated input shaft **11***a* to produce the input unit **12***a* that meets requirements. Since the input shaft **11***a* is also a separate member, it becomes easier to perform additional machining on the input shaft **11***a* or incorporate design changes according to an application. Specifically, a material exemplified by a light metal, such as aluminum, or a resin is employed as a material for the input shaft **11***a* that is a component constituting the input unit **12***a* in consideration of weight reduction and torque resistance, whereas bearing steel is employed as a material for the first inner rings **32***a* and **32***b* from the viewpoint of enhancement of durability. The foregoing speed reducer **10***a* can ensure stable operation with enhanced productivity.

[0092] In this embodiment, the movement restrictors **40***a* and **40***b* restrict movement of the first inner rings **32***a* and **32***b* relative to the input shaft **11***a* in the axial directions. Thus, the first inner rings **32***a* and **32***b* are reliably positioned in the axial directions, thereby ensuring more stable operation of the speed reducer **10***a*.

[0093] In this embodiment, the movement restrictors **40***a* and **40***b* include the first keyways **41***a* and **41***b* recessed from the outer peripheral surface of the input shaft **11***a*, the second keyways **42***a* and **42***b* recessed from the inner peripheral surfaces of the first inner rings **32***a* and **32***b*, and the key members **43***a* and **43***b* fitted in both the first keyways **41***a* and **41***b* and the second keyways **42***a* and **42***b*. Accordingly, by fitting the key members **43***a* and **43***b* in the first keyways **41***a* and **41***b* and the second keyways **42***a* and **42***b*, the first inner rings **32***a* and **32***b* can be reliably positioned in the circumferential directions.

[0094] In this embodiment, the first keyways **41***a* and **41***b* extend in the axial directions on a portion of the outer peripheral surface of the input shaft **11***a* in the circumferential directions. The second keyways **42***a* and **42***b* are located at positions facing the first keyways **41***a* and **41***b*. The key members **43***a* and **43***b* have rod shapes extending in the axial directions. Accordingly, the first inner rings **32***a* and **32***b* can be more reliably positioned in the circumferential directions with a relatively simple structure.

[0095] In this embodiment, the flanges **37***a* and **37***b* projecting radially outward are provided at least on end portions of the first inner rings **32***a* and **32***b* on one side in the axial directions. Thus, it is possible to restrict movement of the retainers **35***a* and **35***b* included in the needle cages **36***a* and **36***b* in the axial directions by using the flanges **37***a* and **37***b*. As a result, more stable operation of the speed reducer **10***a* can be ensured.

[0096] In this embodiment, the input unit **12***a* includes the guide ring **49***a* provided separately from the input shaft **11***a* and the first inner rings **32***a* and **32***b*, having the disc shape, located at least on one side of the first inner rings **32***a* and **32***b* in the axial directions, and projecting radially outward relative to the raceway surfaces of the first inner rings **32***a* and **32***b*. Thus, it is also possible to restrict movement of the retainers **35***a* and **35***b* included in the needle cages **36***a* and **36***b* in the axial directions by using the guide ring **49***a*. As a result, more stable operation of the speed reducer **10***a* can be ensured. Similarly, a material for the guide ring **49***a* included in the input unit **12***a* can be selected independently of materials for other components, and may be a resin such as PEEK containing fibers or a light metal such as aluminum, for example.

[0097] In this embodiment, the pair of first bearings **31***a* and **31***b* is disposed in the axial directions. The first inner rings **32***a* and **32***b* as a pair included in the pair of first bearings **31***a* and **31***b*, respectively, are disposed with a 180-degree phase shift in the circumferential directions. Thus, influence of the eccentric first inner rings **32***a* and **32***b* during rotation of the input shaft **11***a* can be reduced, and more stable rotation of the input shaft **11***a* can be ensured.

[0098] In this embodiment, the first inner rings **32***a* and **32***b* are fixed to the input shaft **11***a* by interference fitting. This also restricts movement of the first inner rings **32***a* and **32***b* relative to the input shaft **11***a* in the axial directions.

[0099] An example of a method for fabricating the second inner ring **81***a* in the members constituting the speed reducer **10***a* will be briefly described. First, an annular metal member is prepared and subjected to a treatment such as shaving to have an outer diameter shape of the second inner ring **81***a*. Then, grinding is performed on the raceway surfaces **82***a* and **82***b* that require smoothness. FIG. **29** is a schematic view illustrating an example of a cylindrical grinder used for grinding the second inner ring **81***a*. With reference to FIG. **29**, a cylindrical grinder **101***a* includes a grindstone part **102***a* and a rotary dresser **103***a*. The cylindrical grindstone part **102***a* for grinding an object includes projections **104***a* and **104***b* projecting radially outward and corresponding to the raceway surfaces **82***a* and **82***b* of the second inner ring **81***a*. An interval between the projections **104***a* and **104***b* is substantially equal to an interval between the raceway surfaces **82***a* and **82***b*. The rotary dresser **103***a* having a cylindrical portion includes recesses **105***a* and **105***b* that are recessed radially inward and correspond to the inner peripheral surface of the second inner ring **81***a*.

[0100] With this cylindrical grinder **101***a*, the raceway surfaces **82***a* and **82***b* of the second inner ring **81***a* are ground. Specifically, although not shown, the second inner ring **81***a* is attached to the radially outer side of the rotary dresser **103***a*. In a state where the projections **104***a* and **104***b* are pushed against the raceway surfaces **82***a* and **82***b* from the radially outer side of the second inner ring **81***a*, the grindstone part **102***a* attached to the spindle **106***a* is rotated to grind the raceway surfaces **82***a* and **82***b*.

[0101] In this manner, even when the spindle **106***a* thermally expands during grinding, the risk of shift of the interval between the raceway surfaces **82***a* and **82***b* can be significantly reduced. Specifically, if the raceway surfaces **82***a* and **82***b* are ground one by one, grinding is performed with a shift of the interval between the raceway surfaces **82***a* and **82***b* because of thermal expansion of the spindle **106***a* during grinding, machining errors of the cylindrical grinder **101***a*, and other reasons, resulting in degradation of dimensional accuracy. On the other hand, the fabrication method described above can significantly reduce shifts of the interval and depth of the raceway surfaces **82***a* and **82***b*. Accordingly, the second inner ring **81***a* can be accurately fabricated. In addition, since the raceway surfaces **82***a* and **82***b* can be ground at a time, lead time can be shortened, as compared to the case where the raceway surfaces **82***a* and **82***b* are ground one by one. A similar configuration is also employed for the raceway surfaces **83***a* and **83***b* of the second outer ring **81***b*, and the raceway surfaces **83***a* and **83***b* are ground at a time. Then, dimensional accuracy can be increased and the lead time can be shortened.

OTHER EMBODIMENTS

[0102] In the embodiment described above, the pair of cycloid gears is arranged in the axial directions. However, the present disclosure is not limited to this example, and the speed reducer may include one cycloid gear.

[0103] In the embodiment described above, the lids are provided at the same positions in the circumferential directions as the positions of the multi-row crossed roller bearings. However, the present disclosure is not limited to this example, and the lids may be provided with a shift in the circumferential directions.

[0104] The embodiment described above employs the multi-row crossed roller bearing. However, the present disclosure is not limited to this example, a multi-row angular bearing may be employed. At least one of the first bearing or the second bearing may employ another bearing, for example, a combination of a radial bearing and an axial bearing. A plain bearing may also be employed.

[0105] In the embodiment described above, in the crossed roller bearing, a gap between the cylindrical rollers is adjusted with the spacer. However, the present disclosure is not limited to this example, the crossed roller bearing may include a retainer retaining cylindrical rollers or may include a separator located between cylindrical rollers.

[0106] It should be understood that the embodiment disclosed here is illustrative and non-restrictive in every respect. The scope of the present invention is defined by the claims and is intended to include any modifications within the scope and meaning equivalent to the claims.

DESCRIPTION OF REFERENCE NUMERALS

[0107] **10***a* speed reducer, **11***a* input shaft, **12***a* input unit, **13***a*, **13***b* cycloid gear, **14***a* inner pin, **15***a* inner pin holder, **16***a* second bearing, **17***a* outer pin, **21***a* first axial end, **21***b* second axial end, **23***a* axial through hole, **24***a* axial inner peripheral surface keyway, **25***a*, **98***a* inner peripheral surface, **25***b* outer peripheral surface, **26***a*, **27***a* bolt, **29***a* first input shaft bearing, **29***b* second input shaft bearing, **31***a*, **31***b* first bearing, **32***a*, **32***b* first inner ring, **33***a*, **33***b* first outer ring, **34***a*, **34***b* needle roller, **35***a*, **35***b* retainer, **36***a*, **36***b* needle cage, **37***a*, **37***b* flange, **40***a*, **40***b* movement restrictor, **41***a*, **41***b* first keyway, **42***a*, **42***b* second keyway, **43***a*, **43***b* key member, **44***a*, **44***b* insertion hole, **45***a* spacer, **46***a*, **46***b* lid, **47***b* lid fixing pin, **48***a*, **48***b* collar, **49***a* guide ring, **50***a*, **50***b* external teeth, **51***a*, **51***b* first through hole, **52***a*, **52***b* second through hole, **53***a*, **53***b* third through hole, **54***a*, **55***a* elongated hole, **58***a*, **86***a* oil hole, **61***a* shank, **62***a*, **62***b* inner pin outer ring, **63***a* roller, **64***a*, **64***b*, **64***c*, **64***d*, **65***a*, **65***b*, **65***c*, **65***d* thrust washer, **66***a* outer pin guide plate, **67***a* retaining ring, **71***a* first holder portion, **71***b* second holder portion, **72***a* plate portion, **72***b* first portion, **73***a* support column, **73***b* second portion, **74***a*, **74***b* press-fitting hole, **75***a*, **75***b*, **77***a* recessed groove, **76***a* screw hole, **76***b* through hole, **78***a*, **78***b* step, **79***b* notch, **81***a* second inner ring, **81***b* second outer ring, **82***a*, **82***b*, **83***a*, **83***b* raceway surface, **84***a*, **84***b* cylindrical roller, **85***a*, **85***b* oil groove, **87***a* annular groove, **89***b* bolt hole, **90***a* outer pin housing groove, **90***b* slot, **91***a*, **91***b* wall surface, **92***a*, **92***b* nail, **93***a*, **93***b*, **94***a*, **94***b* end portion, **95***a*, **95***b* center portion, **96***b* relief portion, **97***a* oil sump, **101***a* cylindrical grinder, **102***a* grindstone part, **103***a* rotary dresser, **104***a*, **104***b* projection, **105***a*, **105***b* recess, **106***a* spindle.

Claims

1. A speed reducer comprising: an input unit including an input shaft and a first bearing, the first bearing including an eccentric first inner ring that rotates together with the input shaft; a cycloid gear located radially outward of the first bearing and including a plurality of external teeth arranged on an outer peripheral surface along circumferential directions, the cycloid gear including a first through hole the input unit penetrates and a plurality of second through holes located radially outward of the first through hole and arranged with intervals in the circumferential directions; a plurality of inner pins penetrating the second through holes in axial directions; an inner pin holder holding end portions of the plurality of inner pins in the axial directions and surrounding an outer peripheral surface of the input unit; a second bearing located radially outward of the cycloid gear, and including a second inner ring that is an output shaft, a second outer ring located radially outward of the second inner ring, and a rolling body located between the second inner ring and the second outer ring; and a plurality of outer pins held on a radially inner surface of the second inner ring and meshing with the external teeth of the cycloid gear, wherein the first inner ring is provided separately from the input shaft, and the input unit includes a movement restrictor that restricts movement of the first inner ring relative to the input shaft in the circumferential directions.

2. The speed reducer according to claim 1, wherein the movement restrictor restricts movement of the first inner ring relative to the input shaft in the axial directions.

3. The speed reducer according to claim 1, wherein the movement restrictor includes a first keyway recessed from an outer peripheral surface of the input shaft, a second keyway recessed from an inner peripheral surface of the first inner ring, and a key member fitted in both the first keyway and the second keyway.

4. The speed reducer according to claim 3, wherein the first keyway extends in the axial directions in a portion of the outer peripheral surface of the input shaft in the circumferential directions, the second keyway is located at a position facing the first keyway, and the key member has a rod shape extending in the axial directions.

5. The speed reducer according to claim 1, wherein at least an end portion of the first inner ring on one side in the axial directions includes a flange projecting radially outward.

6. The speed reducer according to claim 1, wherein the input unit further includes a guide ring that is provided separately from the input shaft and the first inner ring, has a disc shape, is located at least on one side of the first inner ring in the axial directions, and projects radially outward relative to a raceway surface of the first inner ring.

7. The speed reducer according to claim 1, wherein the first bearing comprises a pair of first bearings arranged in the axial directions, and the first inner ring comprises a pair of first inner rings included in the pair of first bearings, and the pair of first inner rings are arranged with a 180-degree phase shift in the circumferential directions.

8. The speed reducer according to claim 1, wherein the first inner ring is fixed to the input shaft by interference fitting.

9. The speed reducer according to claim 2, wherein the movement restrictor includes a first keyway recessed from an outer peripheral surface of the input shaft, a second keyway recessed from an inner peripheral surface of the first inner ring, and a key member fitted in both the first keyway and the second keyway.

10. The speed reducer according to claim 9, wherein the first keyway extends in the axial directions in a portion of the outer peripheral surface of the input shaft in the circumferential directions, the second keyway is located at a position facing the first keyway, and the key member has a rod shape extending in the axial directions.

11. The speed reducer according to claim 2, wherein at least an end portion of the first inner ring on one side in the axial directions includes a flange projecting radially outward.

12. The speed reducer according to claim 2, wherein the input unit further includes a guide ring that is provided separately from the input shaft and the first inner ring, has a disc shape, is located at least on one side of the first inner ring in the axial directions, and projects radially outward relative to a raceway surface of the first inner ring.

13. The speed reducer according to claim 2, wherein the first bearing comprises a pair of first bearings arranged in the axial directions, and the first inner ring comprises a pair of first inner rings included in the pair of first bearings, and the pair of first inner rings are arranged with a 180-degree phase shift in the circumferential directions.

14. The speed reducer according to claim 2, wherein the first inner ring is fixed to the input shaft by interference fitting.