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CARBON-FIBER FIXATION JIG, METHOD FOR MANUFACTURING CARBON-FIBER REINFORCED RESIN PIPE BODY, AND POWER TRANSMISSION SHAFT

Abstract

A carbon-fiber fixation jig is provided to implement efficiently removing unnecessary portions of carbon fibers while a carbon-fiber reinforced resin pipe body is manufactured. A jig (**60**A) is attached to a first metal member (**40**A), which is set to have a carbon-fiber layer (**31**) wound around an outer circumferential surface thereof, at an axial end of said outer circumferential surface, so as to be non-rotatable relative to each other, wherein the jig includes a first recess (**62***a*) at a boundary with said outer circumferential surface, the recess having a diameter smaller than said outer circumferential surface.

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Background/Summary

TECHNICAL FIELD

[0001] The present invention relates to a carbon-fiber fixation jig used when a fiber reinforced resin pipe body is manufactured, with carbon fibers wound around outer circumferential surfaces of a mandrel and metal members provided at ends of the mandrel, a method for manufacturing a carbon-fiber reinforced resin pipe body, and a power transmission shaft.

BACKGROUND OF THE INVENTION

[0002] Filament winding (FW) is used as a technique to manufacture a tube body (shaft member) with carbon-fiber reinforced resin. FW involves winding resin-impregnated carbon fibers individually around a core member and heating them, to form a tube body.

[0003] Such a technique of winding carbon fibers around a core member is described in Patent Documents 1 and 2 that jigs each having a plurality of radially oriented pins are provided at ends of the core member, and the fibers are hooked around the pins and wound around the core member. With this technique, jigs are attached to the core member, so as to be non-rotatable relative to each other, and not to be moved in an axial direction, to prevent the carbon fibers wound around the core member from being moved in a rotational direction or the axial direction in subsequent steps.

[0004] In addition, multi-thread filament winding (MFW) is described in Patent Document 3. MFW involves winding a plurality of carbon fibers at one time around an outer circumferential surface of a core member, to allow for improving productivity.

[0005] In order to manufacture a product having metal joint members provided at ends of a shaft member, the technique described in Patent Document 3 involves winding and layering carbon fibers, with ends of an assembly of a core member and the joint members fixed, with a metal tape or the like, onto the outer circumferential surface of the joint members. Next, the assembly provided with the carbon fibers is placed in a mold and a resin transfer molding (RTM) of impregnating the carbon fibers with resin and curing the resin by heat treatment is used to manufacture a shaft member provided with joint members.

PRIOR ART DOCUMENT

Patent Document

[0006] Patent Document 1, Japanese Patent Application Publication No. 2000-102983 A; [0007] Patent Document 2, Japanese Patent Application Publication No. H07-205317 A; and [0008] Patent Document 3, Japanese Patent No. 6873369 B1.

SUMMARY OF THE INVENTION

Problems to be Solved

[0009] The technique of Patent Document 3 includes a step of removing the carbon fibers on the outer circumferential surfaces of the joint members. Here, as a pipe body made of the carbon fibers impregnated with resin is elongated, the pipe body needs to be set in a finishing machine to have unnecessary portions of the carbon fibers removed for finishing, so that it is desired to improve productivity.

[0010] The present invention has been devised in order to solve such problems, and is intended to provide a carbon-fiber fixation jig to allow for efficiently removing unnecessary portions of carbon fibers when manufacturing a carbon-fiber reinforced resin pipe body, a method for manufacturing a carbon-fiber reinforced resin pipe body, and a power transmission shaft.

Solution to Problems

[0011] The present disclosure provides a carbon-fiber fixation jig to be attached to a metal member, which is set to have carbon fibers wound around an outer circumferential surface thereof, at an axial end of said outer circumferential surface, so as to be non-rotatable relative to each other, wherein the jig includes a first small-diameter section at a boundary with said outer circumferential

surface, the section having a diameter smaller than said outer circumferential surface.
Advantageous Effects of the Invention
[0012] According to the present invention, unnecessary portions of fibers are efficiently removed at a time of manufacturing a fiber reinforced resin pipe body.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0013] FIG. **1** is a schematic cross-sectional view of a mandrel according to a first embodiment of the present invention;
[0014] FIG. **2** is a diagram schematically showing a power transmission shaft manufactured using a mandrel according to the first embodiment of the present invention;
[0015] FIG. **3** is a schematic cross-sectional view of a power transmission shaft according to the first embodiment of the present invention;
[0016] FIG. **4** is a schematic cross-sectional view of a jig assembly, at a first metal member, according to the first embodiment of the present invention;
[0017] FIG. **5** is a cross-sectional view, taken along a line V-V in FIG. **4**;
[0018] FIG. **6** is a cross-sectional view, taken along a line VI-VI in FIG. **4**;
[0019] FIG. **7** is a cross-sectional view, taken along a line VII-VII in FIG. **4**;
[0020] FIG. **8** is a schematic cross-sectional view of the jig assembly, at a second metal member, according to the first embodiment of the present invention;
[0021] FIG. **9** is a flowchart of a method for manufacturing a power transmission shaft according to the first embodiment of the present invention;
[0022] FIG. **10** is a schematic cross-sectional view to illustrate the method for manufacturing the power transmission shaft according to the first embodiment of the present invention;
[0023] FIG. **11** is a schematic cross-sectional view to illustrate the method for manufacturing the power transmission shaft according to the first embodiment of the present invention;
[0024] FIG. **12** is a schematic cross-sectional view to illustrate the method for manufacturing the power transmission shaft according to the first embodiment of the present invention;
[0025] FIG. **13** is a schematic cross-sectional view to illustrate the method for manufacturing the power transmission shaft according to the first embodiment of the present invention;
[0026] FIG. **14** is a schematic cross-sectional view to illustrate the method for manufacturing the power transmission shaft according to the first embodiment of the present invention;
[0027] FIG. **15** is a schematic cross-sectional view to illustrate the method for manufacturing the power transmission shaft according to the first embodiment of the present invention;
[0028] FIG. **16** is a schematic cross-sectional view to illustrate the method for manufacturing the power transmission shaft according to the first embodiment of the present invention;
[0029] FIG. **17** is a schematic cross-sectional view of a jig assembly according to a modification to the first embodiment of the present invention;
[0030] FIG. **18** is a cross-sectional view, taken along a line XVIII-XVIII in FIG. **17**;
[0031] FIG. **19** is a schematic cross-sectional view of a jig assembly according to a second embodiment of the present invention;
[0032] FIG. **20** is a cross-sectional view, taken along a line XX-XX in FIG. **19**;
[0033] FIG. **21** is a schematic cross-sectional view of a jig assembly according to a modification to the second embodiment of the present invention; and
[0034] FIG. **22** is a schematic cross-sectional view of a jig assembly according to a third embodiment of the present invention.
EMBODIMENTS OF THE INVENTION
[0035] Embodiments of the present invention are described in detail with reference to the drawings,

taking a case of manufacturing a power transmission shaft (propeller shaft) of a vehicle, as an example of a fiber reinforced resin pipe body, from carbon-fiber reinforced plastic. In the following description, the same elements are denoted by the same reference numerals, and duplicate descriptions are omitted. Additionally, the referred drawings are deformed for the purpose of illustration.

First Embodiment

[0036] A mandrel **1**A according to a first embodiment of the present invention is used for manufacturing a fiber reinforced resin pipe body **30** (see FIG. **2**), and includes a mandrel body **10**A and a fitted-into member **20**, as shown in FIG. **1**.

<Mandrel Body>

[0037] The mandrel body **10**A is a resin member having a cylindrical shape. The mandrel body **10**A may be made of a material that can withstand heating while resin of the fiber reinforced resin pipe body **30** being cured. Examples of such materials include PP (polypropylene resin), PET (polyethylene terephthalate resin), SMP (shape memory polymer). The mandrel body **10**A includes as a single member: a large-diameter section **11** at a center in an axial direction thereof; a first end having a first stepped section **12**, a second stepped section **13**, and a first small-diameter section **14** in an order from the large-diameter section **11**; and a second end having a tapered section **15**, a second small-diameter section **16**, and a protruding section **17** in an order from the large-diameter section **11**.

[0038] An outer diameter of the first stepped section **12** is smaller than that of the large-diameter section **11** by a radial dimension of a first metal member **40**A. An outer diameter of the second stepped section **13** is smaller than that of the first stepped section **12**. An outer diameter of the first small-diameter section **14** is smaller than that of the second stepped section **13**. An outer diameter of the tapered section **15** decreases from the large-diameter section **11** toward the second small-diameter section **16**. Size relationship between outer diameters of the first small-diameter section **14** and second small-diameter section **16** can be suitably set. An outer diameter of the protruding section **17** is smaller than that of the second small-diameter section **16**.

[0039] The first stepped section **12**, second stepped section **13**, and first small-diameter section **14** of the present embodiment constitute the first end of the mandrel body **10**A. Likewise, the tapered section **15**, the second small-diameter section **16**, and the protruding section **17** constitute the second end of the mandrel body **10**A. The large-diameter section **11** constitutes a body section between the first and second ends that is radially inflated (increases in diameter) and then deflated (decreases in diameter). The first and second ends are not inflated in an inflation step to be described below, and an outer diameter of the second end (the tapered section **15** except an end next to the large-diameter section **11**, the second small-diameter section **16**, and the protruding section **17**) is smaller, prior to the inflation step, than that of an first end (first stepped section **12**) through which the mandrel body **10**A is pulled out of the fiber reinforced resin pipe body **30**.

<Fitted-into Member>

[0040] The fitted-into member **20** is a cylindrical metal member fitted into the first small-diameter section **14** of the first end of the mandrel body **10**A. The fitted-into member **20** prevents the first small-diameter section **14** from being deformed radially inward, and is formed with a flow path **20***a* through which pressurizing fluid F (see FIG. **14**) (e.g., pressurized air) is filled into the mandrel body **10**A. The pressurizing fluid F of the present embodiment is used in a molding apparatus **100** for pressurizing from inside to inflate (increase in diameter) the mandrel body **10**A. The pressurizing fluid F also works as heating fluid to heat a thermosetting resin (resin **32** to be described below) on an outer circumferential surface of the mandrel body **10**A in the molding apparatus **100** to be described below. Note that the mandrel **1**A may be a metal member having the mandrel body **10**A formed with the fitted-into member **20**, as a single member.

<Power Transmission Shaft>

[0041] A power transmission shaft **2** manufactured with the mandrel **1**A (see FIG. **1**) runs in a front-rear direction of a vehicle and transmits power generated by a power source as rotation about an axis thereof, as shown in FIGS. **2** and **3**. The power transmission shaft **2** includes the fiber reinforced resin pipe body **30**, the first metal member **40**A, a second metal member **50**, a first joint member **3**, and a second joint member **4**. Note that the first joint member **3** and second joint member **4** are not shown in FIG. **4**.

<Fiber Reinforced Resin Pipe Body>

[0042] The fiber reinforced resin pipe body **30** is made of a resin impregnated fiber layer formed into a pipe shape so as to run along an outer circumferential surface of the mandrel body **10**A. The fiber reinforced resin pipe body **30** is molded as a single member, together with the first metal member **40**A and second metal member **50**. The fiber reinforced resin pipe body **30** is formed so as to run along outer circumferential surfaces of: the large-diameter section **11** (see FIG. **1**), tapered section **15** (see FIG. **1**) and second small-diameter section **16** (see FIG. **1**) of the mandrel body **10**A; an axial end (next to the large-diameter section **11**) of the first metal member **40**A; and an axial end (next to the large-diameter section **11**) of the second metal member **50**. The fiber reinforced resin pipe body **30** includes as a carbon-fiber layer **31** (see FIG. **4**): a first carbon-fiber layer; a second carbon-fiber layer; and a third carbon-fiber layer, in an order from radially inside (closer to the mandrel body **10**A). Note that the other axial end of the second metal member **50** (on an opposite side to the large-diameter section **11**) has an outer circumferential surface thereof not covered with the fiber reinforced resin pipe body **30**, and protrudes from the fiber reinforced resin pipe body **30**.

<<First Carbon-Fiber Layer>>

[0043] The first carbon-fiber layer is composed of a plurality of carbon fibers provided on the outer circumferential surface of the mandrel body **10**A (see FIG. **1**) and the like so as to cover the mandrel body **10**A. More specifically, a plurality of carbon fibers are gathered into a band or a bundle to form a carbon-fiber aggregate, and a plurality of the carbon-fiber aggregates are provided circumferentially at equal intervals, to form the first carbon-fiber layer. The carbon fibers of the first carbon-fiber layer runs parallel to the axial direction of the mandrel body **10**A. That is, an orientation angle of the carbon fibers of the first carbon-fiber layer is zero degrees with respect to an axis X of the mandrel body **10**A.

<<Second Carbon-Fiber Layer>>

[0044] The second carbon-fiber layer is provided on a radially outer side of the first carbon-fiber layer, and is composed of a plurality of carbon fibers provided so as to cover the first carbon-fiber layer. More specifically, a plurality of carbon fibers are gathered into a band or a bundle to form a carbon-fiber aggregate, and a plurality of the carbon-fiber aggregates are provided circumferentially at equal intervals, to form the second carbon-fiber layer. The carbon fibers of the second carbon-fiber layer are wound one or more turns at an angle of 45 degrees with respect to the axial direction of the mandrel body **10**A (see FIG. **1**), so as to run in a spiral shape with respect to the axial direction of the mandrel body **10**A. That is, an orientation angle of the carbon fibers of the second carbon-fiber layer is 45 degrees with respect to the axis X of the mandrel body **10**A.

<<Third Carbon-Fiber Layer>>

[0045] The third carbon-fiber layer is provided on a radially outer side of the second carbon-fiber layer, and is composed of a plurality of carbon fibers provided so as to cover the second carbon-fiber layer. More specifically, a plurality of carbon fibers are gathered into a band or a bundle to form a carbon-fiber aggregate, and a plurality of the carbon-fiber aggregates are provided circumferentially at equal intervals, to form the third carbon-fiber layer. The carbon fibers of the third carbon-fiber layer are wound one or more turns at an angle of minus 45 degrees with respect to the axial direction of the mandrel body **10**A (see FIG. **1**), so as to run in a spiral shape with respect to the axial direction of the mandrel body **10**A. That is, an orientation angle of the carbon fibers of the third carbon-fiber layer is minus 45 degrees with respect to the axis X of the mandrel body **10**A. Note that the first carbon-fiber layer, second carbon-fiber layer, and third carbon-fiber layer may be wound individually or may be wound simultaneously with respect to the mandrel body **10**A.

[0046] As shown in FIGS. **2** and **3**, the fiber reinforced resin pipe body **30** has a tapered section **30***b* decreasing in diameter from a large-diameter section **30***a* at the center in the axial direction thereof toward a small-diameter section **30***c* at the second end thereof. The large-diameter section **30***a* is a body section having a shape to follow the outer circumferential surface of the large-diameter section **11** (see FIG. **1**) of the mandrel body **10**A. The tapered section **30***b* has a shape to follow the outer circumferential surface of the tapered section **15** (see FIG. **1**) of the mandrel body **10**A. The small-diameter section **30***c* is an end having a shape to follow the second small-diameter section **16** (see FIG. **1**) of the mandrel body **10**A and a part of the outer circumferential surface of the second metal member **50**.

<First Metal Member and First Joint Member>

[0047] The first metal member **40**A is a member having a substantially cylindrical shape. During manufacturing, the first metal member **40**A is fitted onto the first stepped section **12** (see FIG. **1**). The first metal member **40**A has an axial dimension larger than the first stepped section **12**, and the axial dimension of the present embodiment is equal to a sum of axial dimensions of the first stepped section **12** and second stepped section **13** (see FIG. **1**). That is, the first metal member **40**A covers the second stepped section **13**, at a distance, by an end portion thereof from radially outside. The first metal member **40**A has an inner circumferential surface thereof formed with a female spline **40***a*, axially end-to-end, to engage with a male spline **12***a* of an outer circumferential surface of the first stepped section **12** (see FIG. **5**). The first metal member **40**A is a member of the first joint member (yoke assembly) **3** of the power transmission shaft **2**. The first joint member (yoke assembly) **3** is formed by assembling a trunnion, needle bearings, and a yoke (none of these are shown) to the first metal member **40**A.

<Second Metal Member and Second Joint Member>

[0048] The second metal member **50** is a member (shaft) having a substantially cylindrical shape. During manufacturing, the second metal member **50** is fitted onto the protruding section **17** (see FIG. **1**).

[0049] As shown in FIGS. **1** and **3**, the second metal member **50** is formed, at the other axial end thereof, with a bottomed hole **50***a* into which the protruding section **17** of the mandrel body **10**A can be inserted. The second metal member **50** includes, as a single member, a fitted-onto portion **51** to be fitted onto the protruding section **17** and an axle section **52** to axially extend from the fitted-onto portion **51**. An outer diameter of the axle section **52** is smaller than that of the fitted-onto portion **51**.

[0050] The second metal member **50** is a part of the second joint member (plunge joint assembly) **4** of the power transmission shaft **2**. The second joint member (plunge joint assembly) **4** is formed by assembling a boot and a plunge joint (either one is not shown) to the second metal member **50**.

<Jig Assembly (at First Metal Member)>

[0051] A jig assembly **3**A according to the first embodiment of the present invention is used at the first metal member **40**, and includes a jig **60**A, a fixation member **70**A, and an end fixation member **80**A, as shown in FIG. **4**.

<<Jig>>

[0052] The jig **60**A is a carbon-fiber fixation jig attached to the first metal member **40**A during manufacturing the fiber reinforced resin pipe body **30** (see FIG. **2**), so as to be non-rotatable relative to each other, and having an end portion of the carbon-fiber layer **31** set and fixed on an outer circumferential surface thereof. The jig **60**A is a metal member in a cylindrical shape, and includes, as a single member, a first end section **61**, a large-diameter section **62**, a small-diameter section **63**, and a second end section **64** in an axial order.

[0053] The first end section **61** is positioned closer to the center in the axial direction of the mandrel **1**A (see FIG. **1**), and is attached to the first metal member **40**A, so as to be non-rotatable relative to each other. The first end section **61** is fitted onto the second stepped section **13** of the mandrel body **10**A. The first end section **61** has an outer circumferential surface thereof formed with a male spline **61***a* to engage with the female spline **40***a* of the first metal member **40**A (see FIG. **6**).

[0054] The large-diameter section **62** is positioned between the first end section **61** and the second end section **64** and is closer to the first end section **61**, to have the carbon-fiber layer **31** wound therearound. The large-diameter section **62** is fitted onto the second stepped section **13** of the mandrel body **10**A (see FIG. **1**). The large-diameter section **62** is axially external to the first metal member **40**A, and has an end surface thereof, next to the first end section **61**, set to abut against an end surface of the first metal member **40**A. The large-diameter section **62** includes, at a portion thereof next to the first end section **61**, a recess **62***a* recessed radially inward. The recessed **62***a* opens in the axial direction, and a bottom surface (radially outer end surface) thereof defines a first small-diameter section which is smaller in diameter than the large-diameter section **62**. The recess **62***a* defines an annular groove, together with the end surface of the first metal member **40**A. The other section, closer to the second end section **64**, of the large-diameter section **62** includes an inclined surface **62***b* decreasing in diameter toward the second end section **64**.

[0055] The small-diameter section **63** is positioned between the first end section **61** and the second end section **64** and is closer to the second end section **64**, to have an end of the carbon-fiber layer **31** set thereon and fixed by the end fixation member **80**A. An outer diameter of the small-diameter section **63** is smaller than that of the large-diameter section **62**. The small-diameter section **63** is fitted onto the second stepped section **13** of the mandrel body **10**A.

[0056] The second end section **64** is positioned at an end axially opposite to the first end section **61**, and has the fixation member **70**A attached thereto (screwed thereonto). The second end section **64** is fitted onto the first small-diameter section **14** of the mandrel body **10**A. The second end portion **64** is formed, on an outer circumferential surface thereof, with a male thread **64***a*.

<<Fixation Member>>

[0057] The fixation member **70**A is a metal member in a cylindrical shape, and includes as a single member, a small-diameter section **71** and a large-diameter section **72** extending from the small-diameter section **71** toward the center in the axial direction of the mandrel **1**A.

[0058] The small-diameter section **71** is fitted onto the second end section **64** of the jig **60**A. The small-diameter section **71** is formed in an inner circumferential surface thereof with a female thread **71***a* into which the male thread **64***a* of the jig **60**A is screwed. An outer circumferential surface of the small-diameter section **71** has a hexagonal shape when axially viewed (see FIG. **7**).

[0059] The large-diameter section **72** is fitted onto the inclined surface **62***b* of the large-diameter section **62** of the jig **60**A. The large-diameter section **72** has an inner diameter larger than the small-diameter section **71**. The large-diameter section **72** has an inner circumferential surface inclined along the inclined surface **62***b*, and holds the carbon-fiber layer **31** to the inclined surface **62***b* with said inner circumferential surface.

<<End Fixation Member>>

[0060] The end fixation member **80**A is a tape or band made of metal wound, at an outer circumferential surface of the small-diameter section **63**, on an outer circumferential surface of the end of the carbon-fiber layer **31**, to temporarily fix the end of the carbon-fiber layer **31**. The end fixation member **80**A fixes the carbon-fiber layer **31** to the small-diameter section **71** so as to restrict at least the end of the carbon-fiber layer **31** moving in the axial direction. Note that the end fixation member **80**A may not be required if the carbon-fiber layer **31** can be fixed only with the fixation member **70**A.

<Jig Assembly (at Second Metal Member)>

[0061] A jig assembly **3**Z according to the first embodiment of the present invention is used at the second metal member **50**, and includes a jig **60**Z, a fixation member **70**Z, an end fixation member **80**Z, and a rotation restriction member **90**Z, as shown in FIG. **8**.

<<Jig>>

[0062] The jig **60**Z is a carbon-fiber fixation jig attached to the second metal member **50**, so as to be non-rotatable relative to each other, during manufacturing the fiber reinforced resin pipe body **30**, and having an end portion of the carbon-fiber layer **31** provided and fixed on an outer circumferential surface thereof. The jig **60**Z is a metal member in a cylindrical shape, and includes, as a single member, a first end section **61**, a large-diameter section **62**, a small-diameter section **63**, and a second end section **64** in an axial order.

[0063] The first end section **61** is positioned closer to the center in the axial direction of the mandrel **1**A (see FIG. **1**). The first end portion **61** is fitted onto the axle section **52** of the second metal member **50**.

[0064] The large-diameter section **62** is positioned between the first end section **61** and the second end section **64** and is closer to the first end section **61**, to have the carbon-fiber layer **31** wound therearound. The large-diameter section **62** is fitted onto the axle section **52** of the second metal member **60**. The large-diameter section **62** has an end surface thereof closer to the first end section **61** to abut against a radially extending end surface at a boundary between the fitted-onto section **51** and axle section **52** of the second metal member **50**.

[0065] The small-diameter section **63** is between the first end section **61** and the second end section **64** and is closer to the second end section **64**, to have an end of the carbon-fiber layer **31** set thereon and fixed by the end fixation member **80**Z. An outer diameter of the small-diameter section **63** is smaller than that of the large-diameter section **62**. The small-diameter section **63** is fitted onto the axle section **52** of the second metal member **60**.

[0066] The second end section **64** is an end axially opposite to the first end section **61**, and is attached to the second metal member **50**, so as to be non-rotatable relative to each other, and has the fixation member **70**Z attached thereto (screwed thereonto). The second end section **64** is fitted onto the axle section **52** of the second metal member **60**. The second end section **64** is formed on an outer circumferential surface thereof with a male thread **64***a*. The second end section **64** is formed in an inner circumferential surface thereof with a groove **64***b* extending in the axial direction.

<<Fixation Member>>

[0067] The fixation member **70**Z is a metal member in a cylindrical shape, and includes as a single member, a small-diameter section **71** and a large-diameter section **72** extending from the small-diameter section **71** toward the center in the axial direction of the mandrel **1**A.

[0068] The small-diameter section **71** is screwed onto the second end section **64** of the jig **60**Z. The small-diameter section **71** is formed in an inner circumferential surface thereof with a female thread **71***a* into which the male thread **64***a* of the jig **60**Z is screwed. An outer circumferential surface of the small-diameter section **71** has a hexagonal shape when axially viewed.

[0069] The large-diameter section **72** is fitted onto the inclined surface **62***b* of the large-diameter section **62** of the jig **60**Z. The large-diameter section **72** has an inner diameter larger than the small-diameter section **71**. The large-diameter section **72** has an inner circumferential surface inclined along the inclined surface **62***b*, and holds the carbon-fiber layer **31** to the inclined surface **62***b* with said inner circumferential surface.

<<End Fixation Member>>

[0070] The end fixation member **80**Z is a metal tape wound, at an outer circumferential surface of the small-diameter section **71**, on an outer circumferential surface of the end of the carbon-fiber layer **31**, to temporarily fix the end of the carbon-fiber layer **31**. The end fixation member **80**Z fixes the carbon-fiber layer **31** to the small-diameter section **71** so as to restrict at least the end of the carbon-fiber layer **31** moving in the axial direction. Note that the end fixation member **80**Z may not be required if the carbon-fiber layer **31** can be fixed only with the fixation member **70**Z.

<<Rotation Restriction Member>>

[0071] The rotation restriction member **90**Z is a spherical metal member interposed between the recess **52***a* of the second metal member **50** and the groove **64***b* of the jig **60**Z, to restrict the jig **60**Z from being rotated about the axis relative to the second metal member **50**. Note that the fixation member **70**Z may be connected by spline connection with the second metal member **50**, so as to be non-rotatable relative to each other.

<Manufacturing Method>

[0072] Next, a description is given of a method for manufacturing the power transmission shaft **2** with the mandrel **1**A and jig assemblies **3**A, **3**B according to the first embodiment of the present invention, with reference to a flowchart in FIG. **9** (see FIGS. **1** to **8**, as appropriate). The method for manufacturing the power transmission shaft **2** includes a step of forming a mandrel body (step S**1**), a step of setting a fitted-into member (step S**2**) executed after the step of forming a mandrel body, a step of first connection (step S**3**) executed after the step of setting a fitted-into member, and a step of second connection (step S**4**) executed after the step of first connection. The method for manufacturing the power transmission shaft **2** further includes a step of setting fibers (steps S**5**A to S**5**C) executed after the step of second connection, and a step of fixing fiber ends (step S**6**) executed after the step of setting fibers. The method for manufacturing the power transmission shaft **2** still further includes a holding step (step S**7**) executed after the step of fixing fiber ends, and a step of setting in a mold (step S**8**) executed after the holding step. The method for manufacturing the power transmission shaft **2** still further includes an inflating step (step S**9**) executed after the step of setting in a mold, and a molding step (step S**10**) executed after the inflating step. The method for manufacturing the power transmission shaft **2** still further includes a depressurizing step (step S**11**) executed after the molding step, and a withdrawing step (step S**12**) executed after the depressurizing step. The method for manufacturing the power transmission shaft **2** still further includes a removing step (step S**13**) executed after the withdrawing step, and a depressurizing step (step S**14**) executed after the removing step. The method for manufacturing the power transmission shaft **2** still further includes a pulling out step (step S**15**) executed after the depressurizing step, and a step of assembling joints (step S**16**) executed after the pulling out step.

[0073] Step S**1** is a step of forming the resin mandrel body **10**A in FIG. **1**, using a molding apparatus (not shown).

[0074] In step S**2** after step S**1**, the fitted-into member **20** is press-fitted into the first small-diameter section **13** of the mandrel body **10**A. Note that step S**2** only needs to be executed prior to step S**10**.

[0075] In step S**3** after step S**2**, the first metal member (collar) **40**A and jig **60**A are set at the first end of the mandrel body **10**A (see FIG. **10**). In step S**3**, the first metal member **40**A and jig **60**A may be assembled to each other, followed by such an assembly being assembled to the mandrel body **10**A. Alternatively, in step S**3**, the first metal member **40**A may be assembled to the mandrel body **10**A, followed by the jig **60**A being assembled to such an assembly.

[0076] In step S**4** after step S**3**, the second metal member **50**, jig **60**Z, and rotation restriction member **90**Z are set at the second end of the mandrel body **10**A (see FIG. **11**). In step S**4**, the second metal member **50**, jig **60**Z, and rotation restriction member **90**Z may be assembled to each other, followed by such an assembly being assembled to the mandrel body **10**A. Alternatively, in step S**4**, the second metal member **50** may be assembled to the mandrel body **10**A, followed by the jig **60**Z and rotation restriction member **90**Z being assembled to the second metal member **50**. Here, an order of steps S**3** and S**4** can be changed as appropriate, to have step S**4** executed first or both steps executed simultaneously.

[0077] In step S**5**A after step S**4**, the first carbon-fiber layer is formed on the outer circumferential surfaces of the mandrel body **10**A, first metal member **40**A, jig **60**A, second metal member **50**, and the jig **60**Z. In step S**5**B after step S**5**A, the second carbon-fiber layer is formed on an outer circumferential surface of the first carbon-fiber layer on the mandrel body **10**A, first metal member **40**A, jig **60**A, second metal member **50**, and jig **60**Z. In step S**5**C after step S**5**B, the third carbon-fiber layer is formed on an outer circumferential surface of the second carbon-fiber layer on the mandrel body **10**A, first metal member **40**A, jig **60**A, second metal member **50**, and jig **60**Z.

[0078] In steps S5A to S5C, the carbon-fiber layer **31** is not made of resin-impregnated fibers but made of so-called raw fibers. Additionally, the carbon-fiber layer **31** is set up on the outer circumferential surfaces of the mandrel body **10**A, first metal member **40**A, jig **60**A, second metal member **50**, and jig **60**Z, respectively, by multi-thread filament winding. The carbon-fiber layer **31** threaded through multi-thread filament winding makes a so-called non-crimp structure in which threads are not interwoven with each other and are independent as layers.

[0079] In step S**6** after step S**5**, the end of the carbon-fiber layer **31** set on the outer circumferential surface of the small-diameter section **63** of the jig **60**A is temporarily fixed by the end fixation member **80**A, and the end of the carbon-fiber layer **31** set on the outer circumferential surface of the small-diameter section of the jig **60**Z is temporarily fixed by the end fixation member **80**Z.

[0080] In step S**7** after step S**6**, the fixation member **70**A is assembled to the jig **60**A, to hold the carbon-fiber layer **31** between the large-diameter section **72** of the fixation member **70**A and the outer circumferential surface **62***b* of the jig **60**A, and the fixation member **70**Z is assembled to the jig **60**Z, to hold the carbon-fiber layer **31** between the large-diameter section **72** of the fixation member **70**Z and the outer circumferential surface **62***b* of the jig **60**Z.

[0081] In step S**8** after step S**7**, an assembly of the mandrel **1**A, first metal member **40**A, second metal member **50**, jig assemblies **3**A and **3**Z, and carbon-fiber layer **31** are placed in the molding apparatus (die) **100**, as shown in FIG. **14**.

[0082] In step S**9** after step S**8**, the mandrel body **10**A is inflated. As shown in FIG. **14**, the molding apparatus **100** of the first embodiment has a communication path **104** provided so as to communicate with an inside of the mandrel body **10**A via the flow path **20***a*. In step S**9**, a hollow in the mandrel body **10**A is filled with a pressurizing fluid F (e.g., pressurized air at a temperature of 140° C. or higher) via the communication path **104** coupled with a supply device (not shown). The mandrel body **10**A heated by the high-temperature pressurizing fluid F softens when the temperature thereof reaches such a temperature (transformation temperature of 80° C.) lower than the temperature at which the resin **32** cures, and is pressurized from inside by the pressurizing fluid F, to be inflated and deformed to follow an inner circumferential surface of the molding apparatus **100**. Such pressurization prevents the mandrel body **10**A from being deformed in a direction of being reduced in diameter due to the filled resin **32**. Additionally, applying such pressure allows for reducing a filling amount of the resin **32**, to prevent the fiber reinforced resin pipe body **30**, as a finished product, from increasing in weight.

[0083] In step S**10** after step S**9**, the resin **32** is supplied into the molding apparatus **100**. This causes the resin **32** to be impregnated into the carbon-fiber layer **31** set on the outer circumferential surface of the mandrel body **10**A. Besides, the molding apparatus **100** is heated to cure the resin **32**, to form the fiber reinforced resin pipe body **30** and mold the fiber reinforced resin pipe body **30**, first metal member **40**A, and second metal member **50**, as a single piece. The resin **32** is a thermosetting resin, for example. A die of the molding apparatus **100** of the present embodiment is divided into two or more parts. In step S**10**, the above-described assembly is heated and the die of the molding apparatus **100** is closed, and then the die is clamped with pressure applied to the closed die to increase pressure in the die to promote curing of the resin **32**. Note that the present embodiment is described based on a configuration of the die being divided into two or more parts, so that closing the die and clamping the die are executed, but clamping the die is not essential. In a case where the die is not divided into two or more parts, such closing the die and clamping the die are not essential. The molding apparatus **100** is formed therein with a gate **101**, through which the molten resin **32** is injected thereinto, and a space (resin pool **102**) at an exit of the gate **101**. The resin **32** injected into the molding apparatus **100** is stored in the resin pool **102** formed laterally next to the axial end of the carbon-fiber layer **31**. The resin **32** stored in the resin pool **102** is moved in the axial direction of the mandrel body **10**A by vacuum suction from a suction port **103** formed on an opposite side in a direction of the carbon-fiber layer **31** being aligned (closer to the outer circumferential surface of the other end in the axial direction of the carbon-fiber layer **31**) to the gate **101**, to impregnate the carbon-fiber layer **31**. Heat is applied to the molding apparatus **100**, with the resin **32** impregnated into the carbon-fiber layer **31**, and additionally pressure is applied into the molding apparatus **100**, to form the fiber reinforced resin pipe body **30**.

[0084] In step S**10**, the carbon-fiber layer **31** has a load applied thereto, in the axial direction, due to flow of the resin **32**. Here, the jig assemblies **3**A and **3**Z prevent the carbon-fiber layer **31** from being shifted in the axial direction due to the load. The jig assemblies **3**A and **3**Z also prevent the carbon-fiber layer **31** from being shifted in the axial direction due to a load associated with volume change caused by the resin **32** being heated (and cooled).

[0085] In step S**11** after step S**10**, the mandrel body **10**A is depressurized inside to about atmospheric pressure. In step S**12** after step S**11**, the molded assembly or a semifinished product is withdrawn from the molding apparatus **100**. In step S**13** after step S**12**, the jig assemblies **3**A and **3**Z are removed from the fiber reinforced resin pipe body **30**. In step S**13**, a portion of the fiber reinforced resin pipe body **30** held by a device (not shown), positioned radially on an outer side of the recess **62***a* in the jig assembly **3**A, is cut with a cutting tool **110**, as shown in FIG. **15**. That is, the end of the fiber reinforced resin pipe body **30** is cut at the same position in the axial direction as the axial end of the outer circumferential surface of the first metal member **40**A, around which the carbon-fiber layer **31** is wound. This causes the jig assembly **3**A to be removed from the fiber reinforced resin pipe body **30** and first metal member **40**A. Likewise, in step S**13**, a portion of the fiber reinforced resin pipe body **30**, positioned radially on an outer side of the recess **62***a* in the jig assembly **3**Z, is cut with the cutting tool **110**, as shown in FIG. **16**. This causes the jig assembly **3**Z to be removed from the fiber reinforced resin pipe body **30** and second metal member **50**.

[0086] Here, the cutting tool **110** is a tool like a side cutter circumferentially moved along the recess **62***a*, to cut the fiber reinforced resin pipe body **30**. This allows for cutting the fiber reinforced resin pipe body **30**, so as to be held by a simple device, to improve productivity.

[0087] Note that the jigs **60**A and **60**Z are reusable after the fiber reinforced resin pipe body **30** (cut portions), formed on the outer circumferential surfaces thereof, having been removed. The jigs **60**A and **60**Z may have portions of the outer circumferential surfaces thereof, around which the fiber layer **31** is wound, applied in advance with a mold release agent, to facilitate removing the fiber reinforced resin pipe body **30** (cut portions). Alternatively, the fiber reinforced resin pipe body **30** (cut portions), formed on the outer circumferential surfaces of the jigs **60**A and **60**Z, may be removed with a solvent from the jigs **60**A and **60**Z.

[0088] In step S**14** after step S**13**, the mandrel body **10**A is further depressurized inside. The mandrel body **10**A of the present embodiment is made under negative pressure internally so as to be reduced in diameter (radially contracted). In step S**15** after step S**14**, the mandrel **1**A is pulled out from the fiber reinforced resin pipe body **30**. Here, the first metal member **40**A and second metal member **50** remain with the fiber reinforced resin pipe body **30**. In step S**16** after step S**15**, the semifinished product has the first joint member (yoke assembly) **3** attached to the first metal member **40**A thereof, and has the second joint member (plunge joint assembly) **4** attached to the second metal member **50** thereof.

[0089] The jig **60**A according to the first embodiment of the present invention is attached to a metal member (first metal member **40**A) which is set to have carbon fibers (carbon-fiber layer **31**) wound around an outer circumferential surface thereof, at an axial end of the outer circumferential surface, so as to be non-rotatable relative to each other, and includes a first small-diameter section (recess **62***a*) at a boundary with the outer circumferential surface, the section having a diameter smaller than the outer circumferential surface. Accordingly, the carbon fibers are wound at a distance from the first small-diameter section, so that the jig **60**A allows the fiber reinforced resin pipe body **30** to be cut around the outer circumferential surface of the first small-diameter section and allows itself to be removed from the fiber reinforced resin pipe body **30** and metal member after the cutting, to implement efficiently removing unnecessary portions of the carbon fibers.

[0090] Additionally, the jig **60**A has a second small-diameter section (small-diameter section **63**) to which the carbon fibers are fixed, with tension toward a direction of coming away from the metal member. Accordingly, the jig **60**A suitably prevents ends of the carbon fibers from being moved and entering the first small-diameter section.

[0091] In addition, a method for manufacturing the fiber reinforced resin pipe body **30** according to the first embodiment of the present invention includes: a step of winding carbon fibers (carbon-fiber layer **31**) around an outer circumferential surface of a metal member (first metal member **40**A) and an outer circumferential surface of the jig **60**A, the jig being attached to the metal member so as to be non-rotatable relative to each other; a step of impregnating the carbon fibers with resin **32**; a step of cutting the carbon fibers impregnated with the resin **32** at a radially outer side of a small-diameter section (recess **62***a*) formed between the outer circumferential surface of the metal member and the outer circumferential surface of the jig; and a step of removing the jig **60**A from the metal member. Accordingly, the method for manufacturing the fiber reinforced resin pipe body **30** implements efficiently removing unnecessary portions of the carbon fibers.

[0092] Further, the power transmission shaft **2** according to the first embodiment of the present invention includes: a metal member (first metal member **40**A); and a carbon-fiber reinforced resin pipe body **30** molded as a single piece, with carbon fibers (carbon-fiber layer **31**) wound around an outer circumferential surface of the metal member and impregnated with a resin **32**, wherein an end of the carbon-fiber reinforced resin pipe body **30** is cut at an axial end of the outer circumferential surface of the metal member, the surface having the carbon fibers wound therearound. Accordingly, the power transmission shaft **2** is free from carbon fibers being removed from joint members thereof, to allow for obtaining a product with improved productivity and reduced manufacturing costs.

Modification to First Embodiment

[0093] Next, a description is given of a modification to the jig assembly according to the first embodiment of the present invention, focusing on differences from the jig assembly **3**A according to the first embodiment.

[0094] As shown in FIGS. **17** and **18**, a mandrel body **10**B according to a modification to the first embodiment of the present invention does not include the male spline **12***a* in the first stepped section **12**. A first metal member **40**B is formed in an inner circumferential surface thereof with a recess **40***b* instead of the female spline **40***a*. The recess **40***b* is formed to open at an axial end of the first metal member **40**B, the end being next to a jig **60**B.

<Jig Assembly>

[0095] A jig assembly **3**B according to a modification to the first embodiment of the present invention includes the jig **60**B in place of the jig **60**A.

[0096] The jig **60**B is formed, on an outer circumferential surface of the first end section **61**, with a protrusion **61***b*. The jig **60**B is attached to the first metal member **40**B, so as to be non-rotatable relative to each other, with the protrusion **61***b* fitted into the recess **40***b*.

[0097] The jig assembly **3**B according to the modification to the first embodiment of the present invention restricts the jig **60**B from being rotated relative to the first metal member **40**B, with a simple structure of the protrusion **61***b* and recess **40***b* provided circumferentially at a single point.

Second Embodiment

[0098] Next, a description is given of a jig assembly according to a second embodiment of the present invention, focusing on differences from the jig assembly **3**A according to the first embodiment.

[0099] As shown in FIGS. **19** and **20**, a jig assembly **3**C according to the second embodiment of the present invention includes a jig **60**C in place of the jig **60**A, and further includes a washer member **150**C, a seal member **160**, and a ring member **170**.

<Jig>

[0100] The jig **60**C is formed, on an outer circumferential surface of the second end section **64**, with a concave portion **64***c* extending in the axial direction. The concave portion **64***c* is open at an end surface of the second end section **64**.

<Washer Member>

[0101] The washer member **150**C is a metal washer interposed between the jig **60**A and the fixation member **70**A. The washer member **150**C includes, as a single member, a radially inner portion **151** and a radially outer portion **152**. The washer member **150**C is formed in an inner circumferential surface thereof with a convex portion **151***a* to be engaged with the concave portion **64***c*. The washer member **150**C is attached to the jig **60**A, so as to be non-rotatable about the axis relative to each other, with the convex portion **151***a* engaged with the concave portion **64***c*. The radially outer portion **152** of the washer member **150**C is inclined to correspond to the inclined surface **62***b* of the jig **60**A, and is interposed between the carbon-fiber layer **31** and the large-diameter section **72** of the fixation member **70**A.

<Seal Member>

[0102] The seal member **160** is an annular resin member to be fitted onto the second stepped section **12** of the mandrel body **10**A. The seal member **160** closes the female spline **40***a* at an end of the first metal member **40**A, the end being next to the large-diameter section **11**.

<Ring Member>

[0103] The ring member **170** is an annular resin member accommodated in an annular groove defined by the end surface of the first metal member **40**A and the recess **62***a* of the large-diameter section **62**. The ring member **170** is a resin flow prevention ring placed to closely contact the end surface of the first metal member **40**A before the resin **32** is filled into the molding apparatus **100** and impregnated into the carbon-fiber layer **31**, to prevent the resin **32** from entering the groove and being cured. The ring member **170** can be suitably formed of a material (rubber, urethane foam, and the like) softer than the first metal member **40**A.

[0104] The jig **60**C according to the second embodiment of the present invention has the resin flow prevention ring (ring member **170**) placed on the first small-diameter section. Accordingly, the jig assembly **3**C facilitates cutting a portion of the fiber reinforced resin pipe body **30** on a radially outer side of the first small-diameter section, to implement efficiently removing unnecessary portions of the carbon fibers and reducing waste from the resin **32**.

Modification to Second Embodiment

[0105] Next, a description is given of a jig assembly according to a modification to the second embodiment of the present invention, focusing on differences from the jig assembly **3**C according to the second embodiment.

[0106] As shown in FIG. **21**, a jig assembly **3**D according to a modification to the second embodiment of the present invention includes a jig **60**D, a fixation member **70**D, and a washer member **150**D in place of the jig **60**C, fixation member **70**A, and washer member **150**C.

<Jig>

[0107] The large-diameter section **62** of the jig **60**D has a uniform diameter surface **62***c* axially having a uniform diameter, in place of the inclined surface **62***b*.

<Washer Member>

[0108] The washer member **150**D includes, as a single member, a radially inner portion **151**, an axially-extending radially-inner portion **153**, and a radially outer portion **154**. The radially outer portion **154** is closer to the first metal member **40** than the radially inner portion **151**, and is interposed between the carbon-fiber layer **31** and an axial end surface of the large-diameter section **72** of the fixation member **70**D.

[0109] The large-diameter section **72** of the fixation member **70**D of the present embodiment holds the carbon-fiber layer **31** to a radially extending end surface at a boundary between the large-diameter section **62** and small-diameter section **63** of the jig **60**D, with said axial end surface via the washer member **150**D.

Third Embodiment

[0110] Next, a description is given of a jig assembly according to a third embodiment of the present invention, focusing on differences from the jig assembly **3**A according to the first embodiment.

[0111] As shown in FIG. **22**, a mandrel body **10**E according to the third embodiment of the present invention has a structure in which the second stepped section **13** is omitted. Additionally, a first metal member **40**E according to the third embodiment of the present invention includes, as a single member, a large-diameter section **41** and a small-diameter section **42**.

[0112] A jig assembly **3**E according to the third embodiment of the present invention includes a jig **60**E and a rotation restriction member **90**E, in place of the jig **60**A.

<Jig>

[0113] The first end section **61**, large-diameter section **62**, and small-diameter section **63** of the jig **60**E are fitted onto the small-diameter section **42** of the first metal member **40**E. The large-diameter section **62** is formed therein with a hole **62***d* penetrating therethrough in the radial direction.

<Rotation Restriction Member>

[0114] The rotation restriction member **90**E is a spherical metal member interposed between the recess **42***a* formed in the outer circumferential surface of the small-diameter section **42** of the first metal member **40**E and the hole **62***d* in the jig **60**E, to restrict the jig **60**E from being rotated about the axis relative to the first metal member **40**E. Note that the jig **60**E may be non-rotatably coupled by spline connection with the first metal member **40**E.

<Manufacturing Method>

[0115] Next, a description is given of a method for manufacturing the power transmission shaft **2** using a mandrel **1**E and the jig assembly **3**E according to the third embodiment of the present invention, focusing on differences from the first embodiment.

[0116] In step S**3**, the first metal member **40**E and jig **60**E may be assembled to each other, followed by the rotation restriction member **90**E being placed in the recess **42***a* through the hole **62***d*, and then such an assembly may be assembled to the mandrel body **10**E. Alternatively, in step S**3**, the first metal member **40**E may be assembled to the mandrel body **10**E, followed by the jig **60**E being assembled to such an assembly, and then the rotation restriction member **90**E may be placed in the recess **42***a* through the hole **62***d*.

[0117] In step S**6**, the end of the carbon-fiber layer **31** set on the outer circumferential surface of the large-diameter section **62** (hole **62***d*) of the jig **60**E is temporarily fixed by the end fixation member **80**A.

[0118] In step S**13**, the cutting tool **110** cuts a portion of the fiber reinforced resin pipe body **30**, positioned on a radially outer side of the small-diameter section **61** of the jig assembly **3**E.

[0119] Hereinabove, the embodiments of the present invention have been described, but the present invention is not limited to these and can be modified as appropriate within the scope thereof. For example, the fluid flowing into and filling the mandrel body **10**A or **10**E may be used to heat the thermosetting resin set on the outer circumferential surface of the mandrel body **10**A or **10**E in order to cure the resin, in addition to pressurizing the mandrel body **10**A or **10**E inside. Note that in a case where the fluid is a pressurizing fluid which is not used for heating, the thermosetting resin is heated by another heat source.

[0120] As another example, the carbon-fiber layer **31** may have a so-called crimp structure in which threads are interwoven with each other. As a modification to the embodiments, fibers are not limited to carbon fibers and may be any fibers (such as glass fibers and cellulose fibers) to reinforce a resin layer.

LEGEND FOR REFERENCE NUMERALS

[0121] **1**A, mandrel; **3**A, **3**B, **3**C, **3**D, **3**E, **3**Z, jig assembly; **10**A, **10**E, mandrel body; **30**, fiber reinforced resin pipe body (resin pipe body, carbon-fiber reinforced resin pipe body); **40**A, first metal member (metal member); **50**, second metal member (metal member); **60**A, **60**B, **60**C, **60**D, **60**E, **60**Z, jig (carbon-fiber fixation jig); **70**A, **70**D, **70**Z, fixation member; **80**A, **80**Z, end fixation member; and **150**D, **150**E, washer member.

Claims

1. A carbon-fiber fixation jig to be attached to a metal member, which is set to have carbon fibers wound around an outer circumferential surface thereof, at an axial end of said outer circumferential surface, so as to be non-rotatable relative to each other, wherein the jig includes a first small-diameter section at a boundary with said outer circumferential surface, the section having a diameter smaller than said outer circumferential surface.

2. The carbon-fiber fixation jig according to claim 1, wherein the first small-diameter section has a resin flow prevention ring placed thereon.

3. The carbon-fiber fixation jig according to claim 1, wherein the jig has a second small-diameter section to which the carbon fibers are fixed, with tension toward a direction of coming away from the metal member.

4. A method for manufacturing a carbon-fiber reinforced resin pipe body, the method comprising: a step of winding carbon fibers around an outer circumferential surface of a metal member and an outer circumferential surface of a jig, the jig being attached to the metal member so as to be non-rotatable relative to each other; a step of impregnating the carbon fibers with resin; a step of cutting the carbon fibers impregnated with the resin at a radially outer side of a small-diameter section formed between the outer circumferential surface of the metal member and the outer circumferential surface of the jig; and a step of removing the jig from the metal member.

5. A power transmission shaft comprising: a metal member; and a carbon-fiber reinforced resin pipe body molded as a single piece, with carbon fibers wound around an outer circumferential surface of the metal member and impregnated with resin, wherein an end of the carbon-fiber reinforced resin pipe body is cut at an axial end of the outer circumferential surface of the metal member, the surface having the carbon fibers wound therearound.

6. The carbon-fiber fixation jig according to claim 2, wherein the jig has a second small-diameter section to which the carbon fibers are fixed, with tension toward a direction of coming away from the metal member.