

$[0001]$

This application claims priority based on Japanese Patent Application No. 2019-175605 filed in Japan on September 26, 2019, the contents of which are incorporated herein.

[0002]

In a plant equipped with a boiler such as a coal-fired boiler of a thermal power plant or a waste heat boiler for power generation provided in a refuse incinerator, a wall thickness of a heat transfer tube (boiler tube) of a boiler is periodically measured using ultrasonic waves. That is, an ultrasonic testing (UT) that is a kind of non-destructive inspection is performed. In particular, when an ultrasonic probe is inserted into a heat transfer tube filled with water, the testing is called "water immersion UT".

[0003]

An ultrasonic probe used for a water immersion UT emits an ultrasonic wave toward a tube wall of a heat transfer tube. Then, the ultrasonic probe receives an ultrasonic wave reflected by the tube wall. Accordingly, in the water immersion UT, by arranging the ultrasonic probe on the center axis of the heat transfer tube, it is possible to appropriately measure the wall thickness of the heat transfer tube.

[0004]

Therefore, as disclosed in Patent Literature 1 and Patent Literature 2, a large number of tube thickness measuring devices including an expansion and contraction mechanisms for arranging an ultrasonic probe on a center axis of a heat transfer tube and a large number of tube thickness measuring systems using such a tube thickness measuring device have been developed.

Patent Literature

[0005]

- 5 Patent Literature 1: JP 6306904 B
Patent Literature 2: JP 4768052 B

Summary of Invention
Technical Problem

10 [0006]

 However, in the tube thickness measuring device disclosed in Patent Literature 1, each of expansion and contraction mechanisms operates completely independently and does not have a relation with the operation of the other expansion and contraction mechanisms. For this reason, when a deviation occurs between the expansion of an expansion and contraction mechanism and the expansion of another expansion and contraction mechanism, an ultrasonic probe is not arranged on a center axis of a heat transfer tube. As a result, the water immersion UT may not be properly performed.

[0007]

20 In the tube thickness measuring device disclosed in Patent Literature 2, expansion and contraction mechanisms are connected to each other. Since this device performs the same operation with each other, an ultrasonic probe is appropriately arranged on a center axis of a heat transfer tube.

 However, in view of the dimensions of the tube thickness measuring device, it has been difficult to reduce the size of the tube thickness measuring device in a length direction of the center axis of the heat transfer tube due to the configuration of each expansion and contraction mechanism.

 This is because each expansion and contraction mechanism expands with the expansion of a spring and contracts with the contraction of the spring. For this reason, when the heat transfer tube has a bent portion having a small "bending radius", the tube thickness measuring device disclosed in Patent Literature 2 cannot pass through the bent portion. As a result, the number of heat transfer tubes that can be subjected to the water immersion UT may be limited.

35 [0008]

 The present disclosure provides a tube thickness measuring device and a tube thickness measuring system using the tube thickness measuring device. The tube thickness measuring device can appropriately arrange an ultrasonic probe on a center axis of a heat transfer tube so as to accurately perform the water immersion UT and can be downsized in a length direction of the center axis of the heat transfer tube so as to increase the number of heat transfer tubes that can be subjected to the water immersion UT.

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Solution to Problem

[0009]

A tube thickness measuring device according to the present disclosure is a tube thickness measuring device configured to measure a wall thickness of a heat transfer tube, and the tube thickness measuring device includes: an ultrasonic probe including a sensor unit and a cylindrical portion, the sensor unit being configured to emit an ultrasonic wave toward a tube wall of the heat transfer tube and receive an ultrasonic wave reflected by the tube wall, the cylindrical portion being configured to fix the sensor unit; a fixed portion configured to fix the cylindrical portion in such a manner that the cylindrical portion is inserted through the fixed portion; a movable portion configured to be movable with respect to the fixed portion in such a manner that the cylindrical portion is inserted through the movable portion; at least three expansion and contraction mechanisms disposed at equal intervals in a circumferential direction of the cylindrical portion, each of the at least three expansion and contraction mechanisms being connected to the fixed portion and the movable portion; and a biasing member disposed between two of the expansion and contraction mechanisms adjacent to each other in the circumferential direction, the biasing members connecting the fixed portion and the movable portion. Each of the at least three expansion and contraction mechanisms includes: a plurality of parallel legs each having a rod shape and including a wheel on both ends of the parallel leg; a first link and a second link each having a rod shape and being rotatable, the first link and the second link respectively connecting the parallel leg and the fixed portion at different positions; and a third link having a rod shape and being rotatable, the third link connecting the second link and the movable portion. When the biasing member expands to cause the movable portion to move away from the fixed portion, all of the plurality of parallel legs move parallel to each other by an identical distance in a radial direction of the cylindrical portion to come close to the cylindrical portion, and when the biasing member contracts to cause the movable portion to come close to the fixed portion, all the parallel legs move parallel to each other by an identical distance in the radial direction to move away from the cylindrical portion.

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Advantageous Effects of Invention

[0010]

5 In the tube thickness measuring device according to the present disclosure, the at least three expansion and contraction mechanisms expand by an identical distance in a radial direction as the movable portion moves. Thus, the ultrasonic probe can be appropriately arranged on the center axis of the heat transfer tube so as to accurately perform the water immersion UT.

10 Further, each of the expansion and contraction mechanisms contracts with the expansion of the biasing member connecting the fixed portion and the movable portion and expands with the contraction of the biasing member. Thus, the tube thickness measuring device can be downsized in a length direction of a center axis of a heat transfer tube. This makes it possible to increase the
15 number of heat transfer tubes that can be subjected to the water immersion UT.

Accordingly, the present disclosure can provide a tube thickness measuring device and a tube thickness measuring system using the tube thickness measuring device, and the tube thickness measuring device can appropriately arrange an ultrasonic probe on a center axis of a heat transfer
20 tube so as to accurately perform the water immersion UT and can be downsized in a length direction of the center axis of the heat transfer tube so as to increase the number of heat transfer tubes that can be subjected to the water immersion UT.

25 Brief Description of Drawings

[0011]

FIG. 1 is a diagram illustrating a tube thickness measuring system 100 using a tube thickness measuring device 1 according to an embodiment of the present disclosure.

30 FIG. 2 is a diagram illustrating a state in which expansion and contraction mechanisms 17 of a tube thickness measuring device 1 are expanded.

FIG. 3 is a cross-sectional view taken along a center axis of a cylindrical portion 14, and illustrates that an expansion range is limited by a screw 31
35 when the expansion and contraction mechanisms 17 of the tube thickness measuring device 1 are expanded.

FIG. 4 is a diagram of the tube thickness measuring device 1 when viewed from an axial direction of a center axis of the cylindrical portion 14 and from a side of a cable 3, and illustrates a state in which the expansion and
40 contraction mechanisms 17 are expanded.

FIG. 5 is a diagram of the tube thickness measuring device 1 when viewed from the axial direction in FIG. 4 and from a side of a sensor unit 13,

5 and illustrates a state in which the expansion and contraction mechanisms 17 are contracted.

FIG. 6 is a diagram of the tube thickness measuring device 1 when viewed from a direction orthogonal to the axial direction in FIG. 4, and illustrates a state in which the expansion and contraction mechanisms 17 are contracted.

Description of Embodiments

[0012]

Embodiments of the tube thickness measuring device and the tube thickness measuring system using the tube thickness measuring device according to the present disclosure will be described below with reference to the drawings. First, a tube thickness measuring system 100 will be described with reference to FIG. 1, and then a tube thickness measuring device 1 will be described in detail with reference to FIGS. 2 to 6.

20 [0013]

First, the tube thickness measuring system 100 will be described with reference to FIG 1.

The tube thickness measuring system 100 is a system for measuring a wall thickness of a heat transfer tube 2 and includes at least the tube thickness measuring device 1 to be described in detail later, a cable 3 having one end connected to a cylindrical portion (to be described later) of the tube thickness measuring device 1, an analysis device 4 connected to the other end of the cable 3, and a display device 5 for displaying a result of a calculation performed by the analysis device 4.

30 The analysis device 4 performs a calculation regarding the wall thickness of the heat transfer tube 2 using an ultrasonic wave received by a sensor unit (to be described later) of the tube thickness measuring device 1. The analysis device 4 causes the display device 5 to display the result of the calculation (information about the wall thickness of the heat transfer tube 2).

35 The analysis device 4 is an arithmetic device such as a computer. Here, the analysis device 4 and the display device 5 such as a monitor will be described separately. However, for example, a laptop personal computer in which the analysis device 4 and the display device 5 are integrated may be used.

40 The cable 3 is a bendable cable for transmitting electrical signals (specifically, information corresponding to ultrasonic waves received by the

5 sensor unit) from the sensor unit (to be described later) of the tube thickness measuring device 1 to the analysis device 4.

In the case of the water immersion UT, the cable 3 includes a water tube for supplying water to the sensor unit (to be described later) of the tube thickness measuring device 1. The inside of the heat transfer tube 2 is filled
10 with water.
[0014]

In addition to the configuration that the tube thickness measuring system 100 at least has, another configuration illustrated in FIG. 1 will be described below.

15 In a plant equipped with a boiler such as a coal-fired boiler of a thermal power plant or a waste heat boiler for power generation provided in a refuse incinerator, the boiler includes a plurality of the heat transfer tubes 2. The plurality of the heat transfer tubes 2 included in the boiler are connected orthogonally to a header 6 extending in a horizontal direction and communicate
20 with the header 6.

The header 6 includes a tube stub 8 projecting in a horizontal direction at an end portion facing a corridor 7 that is a passage on which an operator can work. The tube stub 8 has a cylindrical shape with an outside diameter smaller than the outside diameter of the header 6 and is disposed coaxially with the
25 header 6. One end of the tube stub 8 is connected to and communicates with the header 6. The other end of the tube stub 8 is closed by welding a metal plate (or by a flange structure) so as not to have an opening. The other end is opened when the tube thickness measuring device 1 is inserted into the header 6.

A cable winding device 9 can automatically (or manually) wind and
30 automatically (or manually) draw out the cable 3.

A guide tube 10 is a device for guiding the tube thickness measuring device 1 to a predetermined heat transfer tube 2 connected to the header 6. A wire manipulation device 11 disposed on the corridor 7 and a tip of the guide tube 10 are connected by a wire. An operator can bend the tip at an angle of
35 about 90 degrees with respect to the center axis of the header 6 by operating the wire manipulation device 11. Since the center axis of the header 6 and the center axis of the heat transfer tube 2 are orthogonal to each other, the tube thickness measuring device 1 can be easily inserted into the predetermined heat transfer tube 2.

40 The wire manipulation device 11 may preferably be disposed on a work stand 12 having an appropriate height.

[0015]

5 Next, the tube thickness measuring device 1 will be described in detail with reference to FIGS. 2 to 6.

 The tube thickness measuring device 1 has at least the following configuration.

10 That is, the tube thickness measuring device 1 includes an ultrasonic probe. The ultrasonic probe includes a sensor unit 13 that emits an ultrasonic wave toward a tube wall of the heat transfer tube 2 and receives an ultrasonic wave reflected by the tube wall and a cylindrical portion 14 that fixes the sensor unit 13.

15 Further, the tube thickness measuring device 1 includes a fixed portion 15, a movable portion 16, at least three expansion and contraction mechanisms 17, and biasing members 18. The fixed portion 15 fixes the cylindrical portion 14 in such a manner that the cylindrical portion 14 is inserted through the fixed portion 15. The movable portion 16 is movable with respect to the fixed portion 15 in such a manner that the cylindrical portion 14 is inserted through the
20 movable portion 16. The expansion and contraction mechanisms 17 are disposed at equal intervals in a circumferential direction of the cylindrical portion 14 and are connected to the fixed portion 15 and the movable portion 16. Each of the biasing members 18 is disposed between two expansion and contraction mechanisms 17 adjacent to each other in the circumferential
25 direction and connects the fixed portion 15 and the movable portion 16.

 Further, in the tube thickness measuring device 1, each of the expansion and contraction mechanisms 17 includes a parallel leg 20 having a rod shape and including a wheel 19 on both ends, a first link 21 and a second link 22 each of which is rod-shaped and rotatable and connects the parallel leg 20 and the
30 fixed portion 15 at different positions, and a third link 23 which is rod-shaped and rotatable and connects the second link 22 and the movable portion 16.

 In the tube thickness measuring device 1, when the biasing members 18 expand to cause the movable portion 16 to move away from the fixed portion 15, all the parallel legs 20 move parallel to each other by an identical distance
35 in a radial direction of the cylindrical portion 14 to come close to the cylindrical portion 14. When the biasing members 18 contract to cause the movable portion 16 to come close to the fixed portion 15, all the parallel legs 20 move parallel to each other by an identical distance in the radial direction of the cylindrical portion 14 to move away from the cylindrical portion 14.

40 [0016]

 In addition to the configuration that the tube thickness measuring device 1 at least has, other configurations illustrated in FIGS. 2 to 6 will be described

5 below. Basically, the ultrasonic probe, the fixed portion 15, and the movable portion 16 will be described in this order, and finally the expansion and contraction mechanism 17 will be described.

First, the cylindrical portion 14 and the sensor unit 13 included in the ultrasonic probe will be described in sequence.

10 The cylindrical portion 14 has a cylindrical shape formed of, for example, metal or resin. The sensor unit 13 is fixed to one end of the cylindrical portion 14. The cable 3 is fixed to the other end of the cylindrical portion 14. The center axis of the cylindrical portion 14 is coaxial with the center axis of the cable 3. Note that the cylindrical portion 14 fixes the cable 3
15 by sandwiching the outer circumference of the cable 3. For this reason, the inside diameter of the other end of the cylindrical portion 14 is designed to be substantially identical to or slightly larger than the outside diameter of the cable 3. Accordingly, the outside diameter of the cylindrical portion 14 is larger than the outside diameter of the cable 3.

20 The sensor unit 13 emits an ultrasonic wave toward the tube wall of the heat transfer tube 2, that is, in a radial direction D_r orthogonal to an axial direction D_a of the center axis of the heat transfer tube 2. Then, the sensor unit 13 receives an ultrasonic wave (reflected wave) reflected by the tube wall. The center axis of the sensor unit 13 is coaxial with the center axis of the
25 cylindrical portion 14 and coaxial with the center axis of the heat transfer tube 2.

Note that the sensor unit 13 includes a mirror that reflects ultrasonic waves. The mirror is disposed at an angle of 45° with respect to the center axis of the sensor unit 13. When water is jetted from a water tube included in the
30 cable 3 to rotate a water wheel connected to the mirror by water pressure, the mirror is rotated with the center axis of the sensor unit 13 as a rotation axis. Thus, an ultrasonic wave emitted on the center axis by the sensor unit 13 is emitted toward the tube wall in all directions around the center axis of the heat transfer tube 2. Further, the sensor unit 13 receives ultrasonic waves reflected
35 by the tube wall with the mirror.

[0017]

Next, the fixed portion 15 and the movable portion 16 will be described in sequence.

40 The fixed portion 15 includes a through-hole 24 (24a) having a cylindrical shape and having a center axis coaxial with the center axis of the cylindrical portion 14 (see FIG. 3). The diameter of the through-hole 24a is

5 substantially identical to the outside diameter of the cylindrical portion 14, and thus the cylindrical portion 14 can be inserted into the through-hole 24a.

However, the cylindrical portion 14 is fixed so as not to be easily removed from the fixed portion 15. Although not illustrated, for example, a screw may be screwed from a radial direction of the fixed portion 15 toward the
10 cylindrical portion 14 inserted into the through-hole 24 so that the cylindrical portion 14 is held and fixed by the tip of the screw so as not to allow the cylindrical portion 14 to be removed from the fixed portion 15. It is obvious that the cylindrical portion 14 may be designed not to be easily removed from the fixed portion 15 only by being inserted into the fixed portion 15.

15 [0018]

The fixed portion 15 has two different shapes in the axial direction (length direction) Da. That is, a first fixed portion 15a having a plate shape and a second fixed portion 15b having a prism shape. The first fixed portion 15a is formed in a substantially circular shape (see FIG. 4) when viewed from the
20 axial direction Da and from a side of the cable 3 or when viewed from a radial direction (width direction) Dr perpendicular to the axial direction Da. The second fixed portion 15b is formed in a substantially regular polygon shape corresponding to the total number of the expansion and contraction mechanisms 17 when viewed from the axial direction Da and from the side of the sensor
25 unit 13 or when viewed from the radial direction Dr. The first fixed portion 15a and the second fixed portion 15b may be formed separately and then joined together or may be integrally formed at a time by molding using a "mold".

The dimension of the first fixed portion 15a in the axial direction Da, that is, the thickness of "plate shape" portion is approximately 1/3 of the
30 dimension of the second fixed portion 15b.

Here, it is assumed as an example that three expansion and contraction mechanisms 17 are totally provided, and thus the second fixed portion 15b has a substantially regular triangular prism shape (see FIG. 5). Each of the three expansion and contraction mechanisms 17 is disposed on each of three side
35 surfaces of the substantially regular triangular prism.

However, each corner of the substantially regular polygon is chamfered to dispose the biasing member 18 such as a spring (for example, a coil spring) or rubber. Accordingly, when the total number of the expansion and contraction mechanisms 17 is three, the second fixed portion 15b has an approximately
40 regular triangular prism shape, but can be also assumed to have a hexagonal prism shape in consideration of chamfering (see FIG. 5). Note that, since the biasing member 18 is disposed on each of chamfered portions, the number of

5 the biasing members 18 disposed corresponds to the total number of the expansion and contraction mechanisms 17. Here, since three expansion and contraction mechanisms 17 are totally disposed in the example, three biasing members 18 are also disposed.

10 In the first fixed portion 15a, a locking section 27 (27a) to which one end of the biasing member 18 is fixed is disposed on each of portions corresponding to the chamfered portions (see FIG. 6).
[0019]

When viewed from the axial direction Da and from the side of the sensor unit 13 or when viewed from the radial direction Dr, the second fixed portion 15b is formed in a size that fits inside the first fixed portion 15a (see FIG. 5).

15 All the components of the expansion and contraction mechanisms 17 (the parallel legs 20, the first links 21, the second links 22, the third links 23, and the wheels 19), the biasing members 18, and the ultrasonic probe including the sensor unit 13 are designed to sizes that fit inside the first fixed portion 15a when viewed from the axial direction Da and from the side of the sensor unit 13 or when viewed from the radial direction Dr, when the expansion and contraction mechanisms 17 to be described later are contracted to the maximum extent, that is, when the wheels 19 disposed in the parallel legs 20 are housed in housing grooves 25 to be described later (see FIG. 5).

25 When the cable 3 is wound by the cable winding device 9 to retrieve the tube thickness measuring device 1 from the heat transfer tube 2, the first fixed portion 15a is located at a foremost position in a travel direction of the tube thickness measuring device 1. At this time, the first fixed portion 15a serves as a protective wall to protect the expansion and contraction mechanisms 17, the biasing members 18, and the ultrasonic probe from floating matters in the heat transfer tube 2, welded portions (for example, penetration beads) protruding from an inner wall of the heat transfer tube 2, and the like, to prevent them from being damaged. That is, the tube thickness measuring system 100 can retrieve the tube thickness measuring device 1 without damage by winding the cable 3 with the cable winding device 9.

35 [0020]

The first fixed portion 15a includes a plurality of housing grooves 25 corresponding to the respective positions of all the expansion and contraction mechanisms 17, specifically the respective positions of all the parallel legs 20. Each of the housing grooves 25 is recessed toward the center axis when viewed from the radial direction Dr and smoothly continuous with the outer surface of the second fixed portion 15b in the axial direction Da (see FIGS. 2 and 5).

5 When the movable portion 16 is farthest from the fixed portion 15 within a range in which the movable portion 16 can move along the axial direction Da, the wheels 19 on one sides of all the parallel legs 20 are housed in the corresponding housing grooves 25.

[0021]

10 Further, the first fixed portion 15a includes a chamfered portion 26 formed into a curved surface by chamfering an outer peripheral corner of a surface opposite to the second fixed portion 15b in the axial direction Da (see FIGS. 2, 3, and 6). When the tube thickness measuring device 1 is retrieved from the heat transfer tube 2, the chamfered portion 26 can prevent the tube
15 thickness measuring device 1 from being caught on penetration beads protruding inside the heat transfer tube 2 and becoming unable to move. Consequently, the tube thickness measuring system 100 can quickly retrieve the tube thickness measuring device 1 by winding the cable 3 with the cable winding device 9. In addition, during retrieval, the resistance that the tube
20 thickness measuring device 1 receives from water in a heat transfer tube is reduced, which allows stable travel.

[0022]

Furthermore, the first fixed portion 15a includes a screw hole 28 (a second screw hole) extending toward the second fixed portion 15b on a surface
25 opposite to the second fixed portion 15b in the axial direction Da. It is designed in a manner such that, when a screw 29 (a second screw), which is a male screw having a head, is screwed and fixed in the screw hole 28, a part of the head of the screw 29 protrudes to the through-hole 24a toward the center axis when viewed from the axial direction Da or when viewed from the radial
30 direction Dr (see FIGS. 3 and 4).

With this configuration, when the tube thickness measuring device 1 is retrieved from the heat transfer tube 2, even if the cylindrical portion 14 is about to come off from the through-hole 24a of the fixed portion 15, the head of the screw 29 is surely caught on a part of the cylindrical portion 14.
35 Accordingly, it is possible to prevent the cylindrical portion 14 from being removed from the through-hole 24a of the fixed portion 15. Thus, the tube thickness measuring system 100 can surely retrieve all the components of the tube thickness measuring device 1 by winding the cable 3 with the cable winding device 9.

40 [0023]

The movable portion 16 will be described below.

5 The movable portion 16 has a shape similar to the second fixed portion 15b. The dimension of the movable portion 16 in the axial direction Da is approximately 1/3 of the dimension of the second fixed portion 15b.

10 The movable portion 16 includes a through-hole 24 (24b) having a cylindrical shape and having a center axis coaxial with the center axis of the cylindrical portion 14. The diameter of the through-hole 24b is substantially identical to the outside diameter of the cylindrical portion 14, and thus the cylindrical portion 14 can be inserted into the through-hole 24b.

15 However, unlike the fixed portion 15, the movable portion 16 can move easily and smoothly while being in contact with the outside surface of the cylindrical portion 14. That is, although the diameter of the through-hole 24 is substantially identical to the outside diameter of the cylindrical portions 14, the diameter of the through-hole 24 (24a) of the fixed portion 15 and the diameter of the through-hole 24 (24b) of the movable portion 16 do not need to be identical to each other. The diameter of the through-hole 24b of the movable
20 portion 16 may be designed to be slightly larger (for example, a few micrometers (μm) larger) than the diameter of the through-hole 24a of the fixed portion 15.

25 In the movable portion 16, a plurality of locking sections 27 (27b) to which the other ends of the biasing members 18 are fixed are disposed in correspondence with the locking sections 27 (27a) of the first fixed portion 15a (see FIG. 6).

30 One end of the biasing member 18 is connected and fixed to the locking section 27a of the first fixed portion 15a, and the other end thereof is connected and fixed to the locking section 27b of the movable portion 16 so as to bias the fixed portion 15 and the movable portion 16 in directions toward each other.
[0024]

35 The movable portion 16 includes a screw hole 30 (a first screw hole) penetrating in the axial direction Da. A screw 31 (a first screw), which is a male screw, is screwed into the screw hole 30 from a surface opposite to the second fixed portion 15b in the axial direction Da. The screw 31 is appropriately selected so that a head of the screw 31 does not come into contact with the cylindrical portion 14 when the screw 31 is screwed into the screw hole 30 (see FIGS. 3 and 5). In addition, the screw 31 is selected so as to be longer by a predetermined length than the dimension of the movable portion 16
40 in the axial direction Da (see FIG. 3).

5 With this configuration, when the screw 31 is screwed into the screw hole 30, a tip of the screw 31 can be protruded from the movable portion 16 toward the second fixed portion 15b.

As will be described later, when the movable portion 16 comes close to the fixed portion 15 in the axial direction Da, all of the expansion and contraction mechanisms 17 extend and expand. In the tube thickness measuring device 1, when the movable portion 16 comes into contact with the fixed portion 15, the expansion and contraction mechanism 17 expands most.

Thus, as described above, by protruding the tip of the screw 31 from the movable portion 16 and appropriately adjusting the length of a part of the screw 31 protruding from the movable portion 16 including the tip (hereinafter referred to as "tip portion"), the tip portion serves as a "prop bar" or a "tension rod" that prevents the movable portion 16 and the fixed portion 15 from coming closer to each other. As a result, an expansion range of the expansion and contraction mechanism 17 can be narrowed. Thus, it is possible to limit the expansion range of the expansion and contraction mechanism 17 to an inner wall diameter of the heat transfer tube 2 or a dimension corresponding to an inner side of a welded part (for example, a penetration bead) protruding from the inner wall of the heat transfer tube 2. Therefore, the tube thickness measuring device 1 and the tube thickness measuring system 100 using the tube thickness measuring device 1 can appropriately measure the wall thicknesses of a large number of heat transfer tubes 2 having different diameters and the wall thicknesses over a longer distance beyond a weld part (for example, penetration bead) protruding from the inner wall of the heat transfer tube 2.

[0025]

30 Finally, the expansion and contraction mechanism 17 will be described. Described here is an example in which the tube thickness measuring device 1 includes three expansion and contraction mechanisms 17 disposed at equal intervals in a circumferential direction Dc. However, as long as the expansion and contraction mechanisms 17 are disposed at equal intervals in the circumferential direction Dc, the tube thickness measuring device 1 may include three or more (a plurality of, for example four or five) expansion and contraction mechanisms 17 according to specifications.

Each of the expansion and contraction mechanisms 17 includes the parallel leg 20 that is rod-shaped and includes the wheel 19 on both ends, the first link 21 that is rod-shaped and rotatable and connects the parallel leg 20 and the fixed portion 15, the second link 22 that is rod-shaped and rotatable and connects the parallel leg 20 and the fixed portion 15 at a position different from

5 the first link 21, and the third link 23 that is rod-shaped and rotatable and connects the second link 22 and the movable portion 16.

The length of the parallel leg 20 is designed to be substantially identical to the length from the fixed portion 15 to the sensor unit 13 in the axial direction Da in a state where the movable portion 16 is farthest from the fixed
10 portion 15 within a possible range (in a state where the expansion and contraction mechanism 17 is most contracted). Both ends of the parallel leg 20 have a substantially U-shape that sandwiches the wheel 19 in a rotatable manner.

The first link 21 and the second link 22 are rotatably fixed to the side
15 surface of the second fixed portion 15b. However, the first link 21 and the second link 22 are fixed at different positions in the axial direction Da. When these two positions are compared with each other, the first link 21 is disposed so as to be close to the movable portion 16 and far from the first fixed portion 15a, and the second link 22 is disposed so as to be far from the movable portion
20 16 and close to the first fixed portion 15a.

In addition, the first link 21 and the second link 22 are rotatably fixed to the parallel leg 20 so as not to intersect each other.

The third link 23 includes a pair of rod-shaped members. One ends of the rod-shaped members are rotatably fixed to a side surface of the movable
25 portion 16 corresponding to the side surface. The other ends of the rod-shaped members are rotatably fixed to the second link by sandwiching the second link at a position slightly away from the position where the second link 22 is fixed to the second fixed portion 15b (near the middle of the second link 22). The pair of rod-shaped members is disposed on both sides of the first link 21, but is
30 designed not to come in contact with the first link 21.

[0026]

Each of the expansion and contraction mechanisms 17 is formed as described above, and each end of the biasing member 18 is connected to the locking section 27a of the first fixed portion 15a and the locking section 27b of
35 the movable portion 16, respectively. Thus, the tube thickness measuring device 1 can be downsized in the axial direction Da (the length direction).

Consequently, even when the heat transfer tube has a bent portion having a small "bending radius", the tube thickness measuring device 1 can pass through the bent portion. Therefore, the tube thickness measuring device 1
40 and the tube thickness measuring system 100 using the tube thickness measuring device 1 can measure the wall thickness of a heat transfer tube bent with a small "bending radius" which cannot be measured by a known technique.

5 This makes it possible to increase the number of heat transfer tubes that are subject to the wall thickness measurement.

Further, by being downsized as described above, the tube thickness measuring device 1 can be housed in the tip of the guide tube 10. As a result, the tube thickness measuring device 1 can be moved to a position of a heat transfer tube to be measured in the header 6, without any trouble.
10 [0027]

The expansion and contraction mechanisms 17 operate as follows when the tube thickness measuring device 1 or the tube thickness measuring system 100 performs the water immersion UT.

15 First, in the tube thickness measuring system 100, the tube thickness measuring device 1 is housed in the tip of the guide tube 10 with the biasing members 18 expanded and the movable portion 16 separated from the fixed portion 15 within a possible range (in a state where the expansion and contraction mechanisms 17 are contracted most as illustrated in FIG. 6).

20 At this time, when the biasing members 18 expand, all the parallel legs 20 move parallel to each other at a time by an identical distance in the axial direction D_a to come close to the cylindrical portion 14, and the wheels 19 are housed in the housing grooves 25. That is, the tube thickness measuring device 1 becomes smallest in the radial direction D_r when being housed in the tip of the guide tube 10. This corresponds to a state in which each of the expansion and contraction mechanisms 17 is contracted most (see FIGS. 5 and 6).
25

Next, in the tube thickness measuring system 100, the guide tube 10 housing the tube thickness measuring device 1 is inserted into the header 6, and the tip of the guide tube 10 is aligned with the position of a predetermined heat transfer tube 2. Then, the tube thickness measuring device 1 housed in the tip of the guide tube 10 is released, and the tube thickness measuring device 1 is fed into the predetermined heat transfer tube 2.
30

At this time, when the tube thickness measuring device 1 moves away from the tip of the guide tube 10, the biasing members 18 contract by their own force to allow the movable portion 16 to come close to the fixed portion 15. Accordingly, all the parallel legs 20 move parallel to each other at a time by an identical distance in the radial direction D_r to move away from the cylindrical portion 14. The tube thickness measuring device 1 becomes largest in the axial direction D_a when the movable portion 16 is brought into contact with the fixed portion 15 by the forces of the biasing members 18 (or, in a case where the tip portion of the screw 31 protrudes from the movable portion 16, the tip portion is brought into contact with the fixed portion 15). This corresponds to a state in
35
40

5 which the respective expansion and contraction mechanisms 17 are mutually expanded as much as possible (see FIGS. 2 and 4). The wheels 19 of all the expansion and contraction mechanisms 17 are designed (or the length of the tip portion of the screw 31 is adjusted) to come into contact with the inner wall of the heat transfer tube 2 in a state where the expansion and contraction
10 mechanisms 17 are expanded as much as possible. This allows the sensor unit 13 of the tube thickness measuring device 1 to be surely arranged on the center axis of the heat transfer tube 2.

[0028]

15 Then, the tube thickness measuring system 100 draws out the cable from the cable winding device 9 and sinks the tube thickness measuring device 1 to a predetermined position deep inside the heat transfer tube 2 filled with water.

Subsequently, the tube thickness measuring system 100 activates the sensor unit 13 of the tube thickness measuring device 1 and measures the wall thickness of the heat transfer tube 2 while winding the cable 3 at a constant
20 speed with the cable winding device 9.

When the tube thickness measuring system 100 measures the wall thickness of the heat transfer tube 2, the tube thickness measuring device 1 may move from a place where the diameter of the heat transfer tube 2 is wide to a place where the diameter of the heat transfer tube 2 is slightly narrow, for
25 convenience of design. Also in that case, all the expansion and contraction mechanisms 17 of the tube thickness measuring device 1 come in contact with the inner wall of the heat transfer tube 2 while equally contracting in conjunction and synchronization with each other. This allows the sensor unit 13 to be accurately arranged on the center axis of the heat transfer tube 2.

30 As described above, when measuring the wall thickness of the heat transfer tube 2, the tube thickness measuring device 1 appropriately arranges the sensor unit 13 on the center axis of the heat transfer tube 2 without deviation from the center axis. Thus, the tube thickness measuring system 100 can accurately measure the wall thickness of the heat transfer tube 2 with the
35 tube thickness measuring device 1.

[0029]

Further, according to the configuration of the tube thickness measuring device 1 described above, in a case where some of the parallel legs 20 are caught on penetration beads or the like of the heat transfer tube 2 while the
40 tube thickness measuring system 100 retrieves the tube thickness measuring device 1 by winding the cable 3, the force of winding and pulling the cable 3 is transmitted to the movable portion 16 via the fixed portion 15, the second link

22, and the third link 23 due to the difficulty in movement of those parallel legs 20 and acts in a direction in which the movable portion 16 moves away from the fixed portion 15. Accordingly, the parallel legs 20 being caught move toward the center axis of the heat transfer tube 2 when viewed from the axial direction Da, the parallel legs 20 being caught can get over a barrier such as a penetration bead.

Thus, the tube thickness measuring system 100 can surely retrieve the tube thickness measuring device 1.

[0030]

The embodiments of the present disclosure have been described above in detail, but the technical scope of the present disclosure is not limited to those embodiments, and design changes and the like that do not depart from the scope of the present disclosure are also included.

Industrial Applicability

[0031]

In the tube thickness measuring device according to the present disclosure, the at least three expansion and contraction mechanisms expand by an identical distance in a radial direction as the movable portion moves. Thus, the ultrasonic probe can be appropriately arranged on the center axis of the heat transfer tube so as to accurately perform the water immersion UT.

Further, each of the expansion and contraction mechanisms contracts with the expansion of the biasing member connecting the fixed portion and the movable portion and expands with the contraction of the biasing member. Thus, the tube thickness measuring device can be downsized in a length direction of a center axis of a heat transfer tube. This makes it possible to increase the number of heat transfer tubes that can be subjected to the water immersion UT.

Accordingly, the present disclosure can provide and a tube thickness measuring system using the tube thickness measuring device, and the tube thickness measuring device can appropriately arrange an ultrasonic probe on a center axis of a heat transfer tube so as to accurately perform the water immersion UT and can be downsized in a length direction of the center axis of the heat transfer tube so as to increase the number of heat transfer tubes that can be subjected to the water immersion UT.

Reference Signs List

[0032]

1 Tube thickness measuring device

- 5 2 Heat transfer tube
- 3 Cable
- 4 Analysis device
- 5 Display device
- 6 Header
- 10 7 Corridor
- 8 Tube stub
- 9 Cable winding device
- 10 Guide tube
- 11 Wire manipulation device
- 15 12 Work stand
- 13 Sensor unit
- 14 Cylindrical portion
- 15 Fixed portion (15a First fixed portion, 15b Second fixed portion)
- 16 Movable portion
- 20 17 Expansion and contraction mechanism
- 18 Biasing member
- 19 Wheel
- 20 Parallel leg
- 21 First link
- 25 22 Second link
- 23 Third link
- 24 (24a, 24b) Through-hole
- 25 Housing groove
- 26 Chamfered portion
- 30 27 (27a, 27b) Locking section
- 28 Screw hole (second screw hole)
- 29 Screw (second screw)
- 30 Screw hole (first screw hole)
- 31 Screw (first screw)
- 35 100 Tube thickness measuring system
- Da Axial direction (a direction of a center axis of a heat transfer tube 2)
- Dc Circumferential direction (a direction around a center axis of a heat transfer tube 2 in a cross section perpendicular to the center axis)
- Dr Radial direction (a direction perpendicular to a center axis of a heat transfer
- 40 tube 2)

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Claims

[Claim 1]

A tube thickness measuring device configured to measure a wall thickness of a heat transfer tube, the tube thickness measuring device

10 comprising:

an ultrasonic probe comprising a sensor unit and a cylindrical portion, the sensor unit being configured to emit an ultrasonic wave toward a tube wall of the heat transfer tube and receive an ultrasonic wave reflected by the tube wall, the cylindrical portion being configured to fix the sensor unit;

15 a fixed portion configured to fix the cylindrical portion in such a manner that the cylindrical portion is inserted through the fixed portion;

a movable portion configured to be movable with respect to the fixed portion in such a manner that the cylindrical portion is inserted through the movable portion;

20 at least three expansion and contraction mechanisms disposed at equal intervals in a circumferential direction of the cylindrical portion, each of the at least three expansion and contraction mechanisms being connected to the fixed portion and the movable portion; and

a biasing member disposed between two of the expansion and contraction mechanisms adjacent to each other in the circumferential direction, the biasing members connecting the fixed portion and the movable portion,

25 wherein each of the at least three expansion and contraction mechanisms comprises,

a plurality of parallel legs each having a rod shape and comprising a wheel on both ends of the parallel leg,

30 a first link and a second link each having a rod shape and being rotatable, the first link and the second link respectively connecting the parallel leg and the fixed portion at different positions, and

a third link having a rod shape and being rotatable, the third link connecting the second link and the movable portion, and

35 when the biasing member expands to cause the movable portion to move away from the fixed portion, all of the plurality of parallel legs move parallel to each other by an identical distance in a radial direction of the cylindrical portion to come close to the cylindrical portion, and

40 when the biasing member contracts to cause the movable portion to come close to the fixed portion, all the parallel legs move parallel to each other

5 by an identical distance in the radial direction to move away from the cylindrical portion.

[Claim 2]

10 The tube thickness measuring device according to claim 1, further comprising a first screw, wherein the movable portion comprises a first screw hole penetrating the movable portion in an insertion direction of the cylindrical portion and being screwed with the first screw, and in such a manner that a tip of the first screw is protruded from the first screw hole to a position between the movable portion and the fixed portion, when the biasing member contracts to cause the movable portion to come close to the fixed portion, the movable portion stops at the tip, and a range in which the plurality of parallel legs move away from the cylindrical portion is narrowed.

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[Claim 3]

The tube thickness measuring device according to claim 2, further comprising a second screw, wherein the fixed portion comprises a second screw hole into which the second screw is screwed from a surface opposite to a surface facing the movable portion in the insertion direction of the cylindrical portion, and a head of the second screw catches a part of the cylindrical portion.

25

[Claim 4]

30 The tube thickness measuring device according to any one of claims 1 to 3, wherein the biasing member is a spring or rubber and biases the movable portion and the fixed portion toward each other.

[Claim 5]

35 The tube thickness measuring device according to claim 4, wherein the fixed portion further comprises a plurality of housing grooves corresponding to respective positions of all of the plurality of parallel legs, each of the plurality of housing grooves being recessed toward the radial direction, and when the biasing member expands to cause the movable portion to move away from the fixed portion, all of the plurality of parallel legs are housed in the corresponding housing grooves.

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[Claim 6]

A tube thickness measuring system configured to measure a wall thickness of a heat transfer tube, the tube thickness measuring system comprising:

10 the tube thickness measuring device according to any one of claims 1 to 5;

a cable having one end connected to the cylindrical portion;

an analysis device connected to another end of the cable; and

a display device configured to display a result of a calculation

15 performed by the analysis device,

wherein the analysis device performs the calculation in accordance with an ultrasonic wave received by the sensor unit and causes the display device to display information about the wall thickness of the heat transfer tube as the result of the calculation.