

TUBE WALL THICKNESS MEASURING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

5 [0001]

The present invention relates to a tube wall thickness measuring apparatus.

Description of Related Art

[0002]

10 For example, boilers for garbage incineration require periodic measurement of boiler tube wall thickness to detect defects. As a general method for measuring a wall thickness of a boiler tube, a water immersion UT method and so on are known.

[0003]

For example, Patent Document 1 describes a technique of measuring a wall
15 thickness of a boiler tube without cutting the boiler tube. In the technique described in Patent Document 1, a guide tube which guides an ultrasonic probe (sensor) for measuring a wall thickness is used. The guide tube is introduced into a tube header from an inspection hole formed in the tube header, and a distal end thereof is introduced into the boiler tube.

20 [0004]

After that, the ultrasonic probe connected to a sensor cable is introduced into the guide tube from the inspection hole side, and the ultrasonic probe is moved forward. Therefore, the ultrasonic probe advances along the inside of the guide tube and is then introduced into the boiler tube by being guided by the guide tube.

25 [0005]

Further, Patent Document 2 describes a tube wall thickness measuring apparatus which has three telescopic arms and holds the ultrasonic probe at a center in a radial direction of the boiler tube by extending the three arms such that they come into contact with the inner circumferential surface of the boiler tube.

5 Each of the arms is a link mechanism which has a driven link extending parallel to an axis direction of the boiler tube and a pair of driving links supporting the driven link. A radial outer side of one driving link and the driven link are connected via a long hole. Accordingly, the driven link is movable and rotatable in the axis direction of the boiler tube with respect to this one driving link.

10 [Citation List]

[Patent Documents]

[0006]

[Patent Document 1] Japanese Patent No. 4056679

[Patent Document 2] Japanese Unexamined Patent Application, First

15 Publication No. 2015-169548

SUMMARY OF THE INVENTION

[0007]

20 However, in the tube wall thickness measuring apparatus disclosed in Patent Document 2, since the three arms are each driven by different driving sources, it is possible that the amount of expansion and contraction of each of the arms is not the same. Further, since an actuator is used for driving an arm, miniaturization is not easy, and for example, wheels may become caught when there is a protrusion formed by welding or an adhered object on the inner circumferential surface of the boiler tube, or the like.

25 [0008]

Therefore, it is an object of the present invention to provide a tube wall thickness measuring apparatus which is capable of centering a sensor with a simpler and smaller mechanism.

[0009]

5 According to a first aspect of the present invention, there is provided a tube wall thickness measuring apparatus which measures a wall thickness of a tube, including an apparatus main body, a sensor installed on the apparatus main body and configured to generate ultrasonic waves radially outward from a radial center of the tube, a pair of expansion/contraction mechanisms installed on the apparatus main body such that they
10 are expandable and contractible radially outwardly and radially inwardly and provided at regular intervals in a circumferential direction around an axis of the tube, a biasing member configured to bias the expansion/contraction mechanism such that it expands, wheels installed on each of the expansion/contraction mechanisms and configured to guide movement of the apparatus main body in an axis direction while being in contact
15 with an inner circumferential surface of the tube, and a transmission mechanism configured to convert a radial expansion of one of the expansion/contraction mechanisms into a radial expansion of the other expansion/contraction mechanism.

[0010]

 According to such a configuration, since the biasing member biases the
20 expansion/contraction mechanism to expand and the movement of the one expansion/contraction mechanism is transmitted to the other expansion/contraction mechanism by the transmission mechanism, it is possible to synchronously expand and contract the pair of expansion/contraction mechanisms without using a driving source such as an electric motor. Therefore, it is possible to center the sensor with a simpler
25 and smaller mechanism.

Further, since the expansion/contraction mechanism has only two positions in the circumferential direction, it is possible to facilitate the passage of the apparatus even when there is a protrusion formed by welding on an inner circumferential surface of a tube.

5 [0011]

In the tube wall thickness measuring apparatus, each of the expansion/contraction mechanisms may be a parallel link mechanism with one degree of freedom which includes a first link and a second link rotatably installed on the apparatus main body parallel to each other, and a parallel link configured to connect a distal end
10 side of the first link and a distal end side of the second link and to move in a radial direction while being maintained parallel to the axis and on which the wheels are installed, and the transmission mechanism may include a first gear configured to rotate along with rotation of the first link of one of the expansion/contraction mechanisms, and a second gear fixed to the second link of the other expansion/contraction mechanism and
15 engaged with the first gear.

[0012]

According to such a configuration, since the parallel link is always kept parallel due to the expansion/contraction mechanism which is the parallel link mechanism having one degree of freedom and the transmission mechanism which is the gear, it is possible to
20 stabilize a position and posture of the sensor.

[0013]

In the tube wall thickness measuring apparatus, each of the expansion/contraction mechanisms may have a pair of the parallel link mechanisms configured to expand and contract within a pair of planes which are parallel to a plane
25 including the axis and disposed at regular intervals from the axis.

[0014]

According to such a configuration, a pair of parallel link mechanisms are disposed with an interval therebetween in a direction orthogonal to a flat surface on which the parallel link mechanism is disposed. Therefore, the stability of the sensor can be improved.

[0015]

According to the present invention, it is possible to expand and retract a pair of expansion/contraction mechanisms synchronously without using a driving source such as an electric motor. Therefore, it is possible to center a sensor with a simpler and smaller mechanism.

Further, since the expansion/contraction mechanism has only two positions in the circumferential direction, it is possible to facilitate the passage of the device even when there is a protrusion formed due to welding on an inner circumferential surface of a tube.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is an overall schematic view of a tube wall thickness measuring apparatus and a boiler according to an embodiment of the present invention.

FIG. 2 is a front view of a sensor probe of the tube wall thickness measuring apparatus according to the embodiment of the present invention, which illustrates a state in which an expansion/contraction mechanism is expanded.

FIG. 3 is a top view of the sensor probe according to the embodiment of the present invention.

FIG. 4 is a view for explaining an operation of the sensor probe according to the

embodiment of the present invention, which illustrates a state in which the expansion/contraction mechanism is expanded.

FIG. 5 is a view for explaining the operation of the sensor probe according to the embodiment of the present invention, which illustrates a state in which the expansion/contraction mechanism is contracted.

FIG. 6 is a front view of the sensor probe of the tube wall thickness measuring apparatus according to the embodiment of the present invention, which illustrates a state in which the expansion/contraction mechanism is contracted.

DETAILED DESCRIPTION OF THE INVENTION

[0017]

Hereinafter, an embodiment of a tube wall thickness measuring apparatus 1 of the present invention will be described in detail with reference to the drawings.

As illustrated in FIG. 1, the tube wall thickness measuring apparatus 1 according to the present embodiment is used for measuring a wall thickness of a boiler tube 52 in a boiler 50. For example, the tube wall thickness measuring apparatus 1 may measure the wall thickness of the boiler tube 52 using a sensor such as an ultrasonic probe.

[0018]

The boiler 50 includes a tube header 51 and a plurality of boiler tubes 52. The boiler tubes 52 are a plurality of rigid tubes serving as flow paths for water vapor and arranged in an extension direction of the tube header 51, and one ends thereof are connected to the tube header 51. Each of the boiler tubes 52 communicates with the tube header 51 and extends to be orthogonal to the tube header 51.

[0019]

A plurality of inspection holes 53 which are holes for inspection are formed in

the tube header 51 by being spaced apart from each other in the extension direction of the tube header 51. The inspection holes 53 and the boiler tube 52 are disposed such that they have a relative positional relationship of being twisted with respect to each other.

An inner diameter of the boiler tube 52 may be, for example, 68 mm.

5 The ultrasonic probe is introduced into the boiler tube 52 via the inspection holes 53 and the tube header 51.

[0020]

Next, a tube wall thickness measuring apparatus 1 for measuring a wall thickness of the boiler tube 52 to be inspected will be described.

10 The tube wall thickness measuring apparatus 1 includes a data collection device 31, a data analysis device 32 which analyzes data collected by the data collection device 31, a cable winding device 33 connected to the data collection device 31, a cable 30 which is a flexible tube discharged from the cable winding device 33, a sensor probe 2 which is a sensor installed on a distal end of the cable 30, and a guide tube 34 which is a
15 guide device for the sensor probe 2.

[0021]

The data collection device 31 is a device in which thickness data of the boiler tube 52 measured by the sensor probe 2 is input via the cable 30. That is, the data collection device 31 serves to collect the thickness data of the boiler tube 52.

20 The data analysis device 32 is a computer used for analyzing the thickness data of the boiler tube 52 collected by the data collection device 31.

[0022]

The cable 30 is, for example, an elongated flexible tube formed of metal, vinyl or the like and is formed such that it is able to bend over an entire length thereof. An
25 outer diameter of the cable 30 is, for example, 12 mm.

The sensor probe 2 is provided on the distal end portion of the cable 30 and obtains measurement data for the wall thickness of the boiler tube 52 by emitting ultrasonic waves. A water supply hose is connected to the sensor probe 2 together with the cable 30.

5 [0023]

The cable winding device 33 is connected to a rear end of the cable 30 and is used for winding the cable 30 inserted into the boiler tube 52.

[0024]

The guide tube 34 is a tube for guiding the cable 30 and the sensor probe 2 to be
10 introduced into the boiler tube 52 and is disposed in the tube header 51 prior to measurement of the wall thickness of the boiler tube 52. The guide tube 34 is disposed such that it connects the inspection hole 53 and the boiler tube 52 which are in a twisted relationship with respect to each other.

[0025]

15 The guide tube 34 is formed of a bellows-shaped flexible hose. Therefore, the guide tube 34 is formed to be telescopic and bendable. The guide tube 34 may maintain a bent state as long as an external force is not applied while the guide tube 34 is bent. The guide tube 34 is inserted from the inside of the inspection hole 53 into the tube header 51 and extends while bending in the tube header 51, and a distal end thereof is
20 connected to the boiler tube 52.

[0026]

As illustrated in FIGS. 2 and 3, the sensor probe 2 of the tube wall thickness measuring apparatus 1 of the embodiment includes a main body 3 (apparatus main body), a pair of expansion/contraction mechanisms 4 which supports the main body 3, a
25 plurality of biasing members 5 which biases each of the expansion/contraction

mechanisms 4 such that they expand (extend radially outward about an axis A of the boiler tube 52), a wheel 6 installed on each of the expansion/contraction mechanisms 4, a transmission mechanism 7 which converts radial movement of one expansion/contraction mechanism 4a into radial movement of the other expansion/contraction mechanism 4b, and a sensor main body 8 installed at the main body 3.

[0027]

The main body 3 is a member elongated in an axis direction Da of the boiler tube 52 and disposed such that a longitudinal direction of the main body 3 is aligned with the axis of the boiler tube 52. Hereinafter, an axis A of the main body 3 disposed coaxially with the axis A of the boiler tube 52 is referred to as a center axis C.

The expansion/contraction mechanism 4 is expandable and contractible with respect to the main body 3 radially outward and radially inward about the center axis C. Hereinafter, a plane which includes the center axis C and expands in an expanding/contracting direction of the expansion/contraction mechanism 4 is referred to as a center surface F (refer to FIG. 3).

[0028]

The sensor probe 2 of the embodiment is formed symmetrically with respect to the center surface F. Each of the expansion/contraction mechanisms 4 of the embodiment has two parallel link mechanisms 15 which are symmetrical with respect to the center surface F.

The biasing member 5 is a tension coil spring. The biasing member 5 is not limited to a tension coil spring, and for example, may have a configuration using rubber or a torsion spring.

[0029]

The sensor main body 8 is installed at one end of the main body 3. The sensor

main body 8 oscillates ultrasonic waves to the inner circumferential surface of the boiler tube 52 radially outward from the center in the radial direction of the boiler tube 52 and receives reflected waves from the ultrasonic waves. Further, the sensor main body 8 is installed such that it is located at a center position within the boiler tube 52 in a state in which the center axis C of the main body 3 substantially coincides with the axis A of the boiler tube 52.

[0030]

The main body 3 is supported by the pair of expansion/contraction mechanisms 4 so that the center axis C is arranged coaxially with the axis A of the boiler tube 52.

Each of the expansion/contraction mechanisms 4 is a link mechanism which expands and contracts in the radially outward direction and the radially inward direction about the center axis C. The expansion/contraction mechanisms 4 are respectively provided at regular intervals in a circumferential direction about the center axis C. In other words, the expansion/contraction mechanisms 4 are respectively installed so that a pitch in the circumferential direction becomes 180°.

[0031]

One expansion/contraction mechanism 4a is expandable and contractible from the main body 3 in one direction orthogonal to the center axis C, and the other expansion/contraction mechanism 4b is expandable and contractible from the main body 3 in the other direction orthogonal to the center axis C.

The main body 3 is centered by the pair of expansion/contraction mechanisms 4 expanding and the wheels 6 being supported against an inner circumferential surface of the boiler tube 52.

[0032]

The main body 3 includes a body portion 9, a first expansion/contraction

restricting portion 11 and a second expansion/contraction restricting portion 12 which restrict expansion and contraction of the expansion/contraction mechanisms 4, a first rotating shaft 13, and a second rotating shaft 14.

5 The body portion 9 is formed to have a cylindrical shape and has a through-hole 10 formed coaxially with the center axis C. A cable 30 is inserted into the through-hole 10.

The body portion 9 has a flat surface portion 16 which is a flat surface parallel to the center surface F. The flat surface portion 16 is a flat surface on which the expansion/contraction mechanism 4 is installed via the rotating shafts 13 and 14.

10 [0033]

The first rotating shaft 13 is a shaft which extends in a direction orthogonal to the flat surface portion 16. The first rotating shaft 13 may be formed by a shaft portion of a fastening member such as a bolt.

15 The second rotating shaft 14 is a shaft which extends in a direction orthogonal to the flat surface portion 16. The second rotating shaft 14 may be formed by a shaft portion of a fastening member such as a bolt. The first rotating shaft 13 and the second rotating shaft 14 are separated from each other in the axis direction Da.

[0034]

20 The expansion/contraction mechanism 4 is a so-called link mechanism and includes a first link 17 which is a link rotatably installed at the first rotating shaft 13, a second link 18 which is a link rotatably installed at the second rotating shaft 14, and a parallel link 19 which is a link rotatably installed at the distal end side of the first link 17 and the second link 18 opposite to the rotating shafts 13 and 14. The first link 17 and the second link 18 are rotatably installed at the main body 3 such that they are parallel to
25 each other.

[0035]

The first link 17 and the body portion 9 are connected to be rotatable in a plane parallel to the center surface F via the first rotating shaft 13. Similarly, the second link 18 and the body portion 9 are connected to be rotatable in a plane parallel to the center surface F via the second rotating shaft 14. The first rotating shaft 13 and the second rotating shaft 14 are pin joints capable of rotating with one degree of freedom.

[0036]

The first link 17 and the parallel link 19 are connected to be rotatable in a plane parallel to the center surface F via a joint 20. Similarly, the second link 18 and the parallel link 19 are connected to be rotatable in a plane parallel to the center surface F via the joint 20. The joint 20 is a pin joint capable of rotating with one degree of freedom.

Due to the first link 17, the second link 18 and the parallel link 19, the expansion/contraction mechanism 4 forms a parallel link mechanism 15 having one degree of freedom. A length of the first link 17 and a length of the second link 18 are set such that the parallel link 19 is always kept parallel to the center axis C (axis A).

[0037]

The wheels 6 are installed at both ends of the parallel link 19. The wheels 6 are installed to be movable along the inner circumferential surface of the boiler tube 52 in the axis direction Da.

The biasing member 5 is installed to connect a center portion of the parallel link 19 and the body portion 9. The biasing member 5 biases the parallel link 19 so that the parallel link 19 moves radially outward. Therefore, the expansion/contraction mechanism 4 is maintained in an expanding state as illustrated in FIG. 2.

[0038]

The transmission mechanism 7 is a mechanism which transmits movement of

the first link 17 of the one expansion/contraction mechanism 4a to the second link 18 of the other expansion/contraction mechanism 4b.

The transmission mechanism 7 includes a first gear 21 which rotates along with the rotation of the first link 17 of one expansion/contraction mechanism 4a, and a second gear 22 which is fixed to the second link 18 of the other expansion/contraction mechanism 4b and engaged with the first gear 21. Pitch circle diameters of the first gear 21 and the second gear 22 are the same. A rotation ratio between the first gear 21 and the second gear 22 is 1.

[0039]

The first gear 21 is a spur gear and is fixed to the first link 17 of the one expansion/contraction mechanism 4a so that a center of the first gear 21 coincides with a center of the first rotating shaft 13. A center of a pitch circle of the first gear 21 coincides with the center of the first rotating shaft 13. When the first link 17 rotates around the first rotating shaft 13, the first gear 21 fixed to the first link 17 with a bolt 26 also rotates around the first rotating shaft 13.

[0040]

The second gear 22 is a spur gear and is fixed to the second link 18 of the other expansion/contraction mechanism 4b so that a center of the second gear 22 coincides with a center of the second rotating shaft 14. A center of a pitch circle of the second gear 22 coincides with the center of the second rotating shaft 14. When the second gear 22 rotates around the second rotating shaft 14, the second link 18 fixed to the second gear 22 with a bolt 27 also rotates around the second rotating shaft 14.

[0041]

Further, part of the first gear 21 is cut off due to spatial limitation. The first gear 21 and the second gear 22 have the same shape except that part of the first gear 21 is

cut off. That is, the first gear 21 and the second gear 22 have the same pitch circle diameter and tooth profile.

The first gear 21 and the second gear 22 of the transmission mechanism 7 are engaged with each other so that one expansion/contraction mechanism 4a and the other expansion/contraction mechanism 4b are symmetrically synchronized with each other.
[0042]

As described above, the sensor probe 2 is formed symmetrically with respect to the center surface F. Each of the expansion/contraction mechanisms 4 has a pair of parallel link mechanisms 15 which are parallel to the center surface F and expand and contract within a pair of planes arranged at the same interval from the center surface F.
[0043]

As illustrated in FIG. 3, in the pair of parallel link mechanisms 15, the parallel link 19 is shared. In other words, the pair of parallel link mechanisms 15 are connected via the parallel link 19. The wheels 6 are respectively disposed at longitudinal ends of the parallel links 19 to be spaced apart from each other in a widthwise direction of the parallel link 19. In other words, the wheels 6 are disposed at four corners of the rectangular parallel link 19 as seen in the axis direction Da.
[0044]

The expansion/contraction restricting portions 11 and 12 are portions which restrict expansion and contraction of the expansion/contraction mechanisms 4.

The first expansion/contraction restricting portion 11 has a first contact surface 23 which restricts the rotation of the first link 17 of the expansion/contraction mechanism 4. The first contact surface 23 is formed to restrict the movement of the first link 17 such that the expansion/contraction mechanism 4 does not expand excessively.
Specifically, the first expansion/contraction restricting portion 11 is formed to restrict the

extension of the expansion/contraction mechanism 4 to a state in which the expansion/contraction mechanism 4 has slightly expanded from the state illustrated in FIG. 2.

[0045]

5 The second expansion/contraction restricting portion 12 has a second contact surface 24 which restricts the rotation of the second link 18 of the expansion/contraction mechanism 4. The second contact surface 24 is formed to restrict the movement of the second link 18 such that the expansion/contraction member does not contract more than in the state illustrated in FIG. 6.

10 The expansion/contraction restricting portions 11 and 12 do not need to be surfaces, and for example, a bolt which interferes with the links 17 and 18 may be installed at the flat surface portion 16 of the body portion 9.

[0046]

 Next, an operation of the expansion/contraction mechanisms 4 of the sensor probe 2 of the embodiment will be described. Further, as illustrated in FIGS. 4 and 5, in the plurality of links 17 and 18, only the first link 17 of the one expansion/contraction mechanism 4a and the second link 18 of the other expansion/contraction mechanism 4b are illustrated by a solid line to make an operation of the transmission mechanism 7 easier to understand.

20 [0047]

 When the sensor probe 2 is disposed inside the boiler tube 52 having a large inner diameter, the expansion/contraction mechanisms 4 expand due to a tension of the biasing member 5 as illustrated in FIG. 4. That is, the expansion/contraction mechanisms 4 which are the parallel link mechanisms 15 expand, the parallel links 19 of the expansion/contraction mechanisms 4 move radially outward, and the first link 17 of

25

one expansion/contraction mechanism 4a rotates clockwise.

[0048]

Along with the rotation of the first link 17, the first gear 21 of the transmission mechanism 7 fixed to the first link 17 also rotates in a clockwise direction R1. As the first gear 21 rotates, the second gear 22 engaged with the first gear 21 rotates in a counterclockwise direction R2.

Therefore, the second link 18 of the other expansion/contraction mechanism 4b rotates in the counterclockwise direction R2. That is, the first link 17 and the second link 18 rotate synchronously. Since the other expansion/contraction mechanism 4b is also the parallel link mechanism 15, the parallel link 19 of the other expansion/contraction mechanism 4b is also moved radially outward by the rotation of the second link 18.

[0049]

When the sensor probe 2 is disposed inside the boiler tube 52 having a small inner diameter, the expansion/contraction mechanism 4 contracts in response to the tension of the biasing member 5 as illustrated in FIG. 5. That is, the expansion/contraction mechanism 4 as the parallel link mechanism 15 contracts and the parallel link 19 of the expansion/contraction mechanism 4 moves radially inward, and the first link 17 of the one expansion/contraction mechanism 4a rotates in the counterclockwise direction R2.

[0050]

Along with the rotation of the first link 17, the first gear 21 of the transmission mechanism 7 fixed to the first link 17 also rotates in the counterclockwise direction R2. As the first gear 21 rotates, the second gear 22 engaged with the first gear 21 rotates in the clockwise direction R1.

Therefore, the second link 18 of the other expansion/contraction mechanism 4b rotates in the clockwise direction R1. Due to the rotation of the second link 18, the parallel link 19 of the other expansion/contraction mechanism 4b also moves radially inward.

5 [0051]

As illustrated in FIG. 6, the boiler tube 52 has a small diameter portion 52a. The small diameter portion 52a is provided, for example, at a coupling portion between the tube header 51 (refer to FIG. 1) and the boiler tube 52.

The sensor probe 2 of the embodiment is drawn via the cable 30 (pulled upward
10 in FIG. 6), whereby the expansion/contraction mechanisms 4 contract. The sensor probe 2 of the embodiment is contracted by the expanding and contracting mechanism 4 when passing through the small diameter portion 52a and expands after passing through the small diameter portion 52a.

[0052]

15 A reduction ratio of the sensor probe 2 of the embodiment, that is, a ratio of a minimum width W2 (refer to FIG. 6) to a maximum width W1 (refer to FIG. 2) is 0.511. Specifically, the maximum width W1 is 70.1 mm and the minimum width W2 is 35.8 mm.

[0053]

20 According to the above-described embodiment, since the biasing member 5 biases the expansion/contraction mechanism 4 such that it expands and the movement of the one expansion/contraction mechanism 4a is transmitted to the other expansion/contraction mechanism 4b by the transmission mechanism 7, it is possible to synchronously expand and contract the pair of expansion/contraction mechanisms 4
25 without using a driving source such as an electric motor. Therefore, it is possible to

center the sensor main body 8 with a simpler and smaller mechanism.

Further, since the expansion/contraction mechanism 4 has only two positions in the circumferential direction, it is possible to facilitate the passage of the sensor probe 2 even when there is a protrusion formed by welding on the inner circumferential surface of the boiler tube 52.

[0054]

Further, since the parallel link 19 is always kept parallel due to the extension mechanism 4 which is the parallel link mechanism 15 having one degree of freedom and the transmission mechanism 7 which is the gear, it is possible to stabilize a position and posture of the sensor main body 8.

[0055]

Further, since the pair of parallel link mechanisms 15 are disposed at intervals in a direction orthogonal to the center surface F and thus the wheels 6 are disposed in a rectangular shape when seen in the axis direction Da, the stability of the sensor main body 8 can be improved.

[0056]

Further, since the links 17 and 18 forming each of the expansion/contraction mechanisms 4 are not connected to the parallel link 19 through a long hole, strength of the parallel link mechanism 15 can be improved.

[0057]

Although the embodiments of the present invention have been described in detail with reference to the drawings, a specific configuration is not limited to this embodiment, and design changes and the like within a scope not deviating from the gist of the present invention are included.

Further, in the above-described embodiment, the gear is used as the transmission

mechanism 7, but the present invention is not limited thereto, and a transmission mechanism 7 such as a chain sprocket or a belt can be adopted.

Further, there may be an intermediate gear between the first gear 21 and the second gear 22.

5

EXPLANATION OF REFERENCES

[0058]

- | | |
|----|---|
| | 1 Tube wall thickness measuring apparatus |
| | 2 Sensor probe |
| 10 | 3 Main body (apparatus main body) |
| | 4 Expansion/contraction mechanism |
| | 5 Biasing member |
| | 6 Wheel |
| | 7 Transmission mechanism |
| 15 | 8 Sensor main body (sensor) |
| | 9 Body portion |
| | 10 Through-hole |
| | 11 First expansion/contraction restricting portion |
| | 12 Second expansion/contraction restricting portion |
| 20 | 13 First rotating shaft |
| | 14 Second rotating shaft |
| | 15 Parallel link mechanism |
| | 16 Flat surface portion |
| | 17 First link |
| 25 | 18 Second link |

	19 Parallel link
	20 Joint
	21 First gear
	22 Second gear
5	23 First contact surface
	24 Second contact surface
	30 Cable
	31 Data collection device
	32 Data analysis device
10	33 Cable winding device
	34 Guide tube
	50 Boiler
	51 Tube header
	52 Boiler tube (tube)
15	53 Inspection hole
	A Axis
	C Center axis
	F Center surface

What is claimed is:

1. A tube wall thickness measuring apparatus which measures a wall thickness of a tube, comprising:

5 an apparatus main body,

a sensor installed on the apparatus main body and configured to generate ultrasonic waves radially outward from a radial center of the tube,

a pair of expansion/contraction mechanisms installed on the apparatus main body such that they are expandable and contractible radially outwardly and radially

10 inwardly and provided at regular intervals in a circumferential direction around an axis of the tube,

a biasing member configured to bias the expansion/contraction mechanism such that it expands,

wheels installed on each of the expansion/contraction mechanisms and

15 configured to guide movement of the apparatus main body in an axis direction while being in contact with an inner circumferential surface of the tube, and

a transmission mechanism configured to convert a radial expansion of one of the expansion/contraction mechanisms into a radial expansion of the other expansion/contraction mechanism.

20

2. The tube wall thickness measuring apparatus according to of claim 1, wherein each of the expansion/contraction mechanisms is a parallel link mechanism with one degree of freedom which comprises a first link and a second link rotatably installed on the

apparatus main body parallel to each other, and a parallel link configured to connect a

25 distal end side of the first link and a distal end side of the second link and to move in a

radial direction while being kept parallel to the axis and on which the wheels are installed,
and

the transmission mechanism comprises a first gear configured to rotate along
with rotation of the first link of one of the expansion/contraction mechanisms, and a
5 second gear fixed to the second link of the other expansion/contraction mechanism and
engaged with the first gear.

3. The tube wall thickness measuring apparatus according to of claim 2, wherein each
of the expansion/contraction mechanisms has a pair of the parallel link mechanisms
10 configured to expand and contract in a pair of planes which are parallel to a plane
including the axis and disposed at regular intervals from the axis.