

## DESCRIPTION

CLEARANCE MEASUREMENT METHOD, CLEARANCE MEASUREMENT DEVICE,  
METHOD OF MEASURING SCREW JOINT, SCREW JOINT MEASUREMENT  
5 SYSTEM, MEASUREMENT TERMINAL, SCREW JOINT MANUFACTURING  
METHOD, AND SCREW JOINT QUALITY CONTROL METHOD

## Field

[0001] The present invention relates to a clearance  
10 measurement method, a clearance measurement device, a  
method of measuring a screw joint, a screw joint  
measurement system, a measurement terminal, a screw joint  
manufacturing method, and a screw joint quality control  
method in a pipe joint structure for joining pipes.

## 15 Background

[0002] Conventionally, a foundation of a structure or a  
structure formed of pipes used for preventing landslides  
may have a required length of several tens of meters  
depending on construction conditions. In particular, a  
20 steel pipe made of a steel material has a remarkable  
tendency to have a long length. In transporting these  
structures formed of pipes to a construction site, long  
structures cannot be transported due to traffic  
restrictions. Thus, the workpieces each having a length of  
25 several meters, which is a conveyable length, are carried  
and are joined in the middle of construction (including  
placing) in the construction site.

[0003] A screw joint is used as a method of joining a  
structure formed of pipes at a construction site, and a  
30 screw joint as disclosed in Patent Literature 1 is used as  
an example. The screw joint is attached to each end of  
pipes to be joined, and the pipes are joined by being  
rotated and joined at a construction site to construct a

structure formed of pipes.

[0004] Normally, a male joint of a screw joint is attached to one pipe and a female joint is attached to another pipe in advance in a factory, and they are shipped to a site. There are several manufacturing procedures, but a male joint and a female joint are often manufactured as a set. After manufacture, the set of these joints may be attached to a tip of an elongated tube depending on the use application of these joints.

## 10 Citation List

### Patent Literature

[0005] Patent Literature 1: JP H10-311028 A

### Summary

### Technical Problem

15 [0006] In a screw joint, whether the screw joint can be joined or not is determined based on the screw shapes corresponding to each other of a male joint and a female joint that is paired with the male joint, and thus, joining check is usually performed before use. However, under the conditions of the screw joint, in particular, when the screw joint has a large diameter of 700 mm or more, the length of the pipe to which the screw joint is connected is 5 m or more and is long, or the material of the screw joint or the connected pipe is a heavy object made of a metal material such as steel, it is difficult to perform joining check. In this case, there are problems such as taking considerable time and effort for joining check, breakage of the joint itself, and concerns regarding ensuring safety.

[0007] In particular, in the case of a screw joint, there may be a part where a clearance (also referred to as allowance or a gap) between the screw of a male joint and the screw of a female joint is insufficient between a joining start position in a state where the male joint and

the female joint are disengaged (including a state immediately before the male joint is screwed into the female joint) and a joining completion position in a state where the joining between the male joint and the female joint is completed. When the clearance between the screw of the male joint and the screw of the female joint is insufficient, a connection step of the joint may be interrupted. Thus, in a screw joint, there has been a demand for a technique capable of more easily grasping whether the screw joint has a screw shape that can be joined before use on site regardless of the state of the screw joint or the connected pipe.

[0008] The present invention has been made in view of the above, and an object of the present invention is to provide a clearance measurement method, a clearance measurement device, a method of measuring a screw joint, a screw joint measurement system, a measurement terminal, a screw joint manufacturing method, and a screw joint quality control method capable of more easily performing joining check for a screw joint regardless of a state of the screw joint or a connected pipe.

#### Solution to Problem

[0009] (1) To solve the above-described problem and achieve the object, a clearance measurement method according to one aspect of the present invention measures a clearance between a screw of a male joint and a screw of a female joint corresponding to the male joint included in a set of screw joints, and includes: a joining completion state setting step of setting a joining completion state in which joining of the male joint and the female joint is completed based on data of screw shapes of the male joint and the female joint; a clearance measuring step of measuring a clearance between the screw of the male joint

and the screw of the female joint corresponding to the screw of the male joint in the joining completion state; and a rotational state setting step of setting a state in which the male joint and the female joint are rotated by a predetermined angle in a direction in which the joining of the male joint and the female joint is released when the joining is not released after the clearance measuring step, wherein the steps from the clearance measuring step to the rotational state setting step are repeated until the joining is released.

[0010] (2) In the above-described invention (1), the clearance measurement method according to one aspect of the present invention includes at least one of: a step of determining pass/fail of the set of screw joints based on the clearance measured in the clearance measuring step and a predetermined criterion; and an interference information assignment step of assigning information on an interference point to a point determined as the interference point based on the clearance measured in the clearance measuring step and the predetermined criterion.

[0011] (3) A method of measuring a screw joint according to one aspect of the present invention includes: a shape measurement step of measuring each of a screw shape of a male joint and a screw shape of a female joint corresponding to the male joint included in a set of screw joints; and a clearance measurement step of measuring a clearance for each set of the screw joints by the clearance measurement method according to the above-described invention based on data of the screw shapes measured in the shape measurement step.

[0012] (4) A screw joint manufacturing method according to one aspect of the present invention manufactures a set of screw joints including a male joint and a female joint

corresponding to the male joint, and includes: a joint manufacturing step of manufacturing the set of screw joint; and a joint measuring step of executing the method of measuring a screw joint according to the invention (3) on the set of screw joints including the male joint and the female joint manufactured by the joint manufacturing step.

[0013] (5) A screw joint quality control method according to one aspect of the present invention controls a quality of a set of screw joints including a male joint and a female joint corresponding to the male joint, and includes: a joint manufacturing step of manufacturing the set of screw joints; a joint measuring step of measuring a screw shape of the set of screw joints manufactured by the joint manufacturing step by the method of measuring a screw joint according to the invention (3); and a quality control step of controlling quality of the manufactured set of screw joint using a result obtained from the joint measuring step.

[0014] (6) A clearance measurement device according to one aspect of the present invention includes measures a clearance between a screw of a male joint and a screw of a female joint corresponding to the male joint included in a set of screw joints, and includes: a control unit configured to repeatedly execute, until the joining is released, a joining completion state setting step of setting a joining completion state in which joining between the male joint and the female joint is completed based on data of a screw shape of each of the male joint and the female joint and a rotational state setting step of setting, in a case where the joining is not released after the clearance between the screw of the male joint and the screw of the female joint corresponding to the screw of the male joint is measured in the joining completion state, a

state in which the male joint and the female joint are rotated by a predetermined angle in a direction in which the joining of the male joint and the female joint is released.

5 [0015] (7) In the invention (6), in the clearance measurement device according to one aspect of the present invention includes, the control unit is configured to execute, before the rotational state setting step, a clearance measuring step of measuring the clearance between  
10 the screw of the male joint and the screw of the female joint corresponding to the screw of the male joint in the joining completion state.

[0016] (8) In the invention (6), the clearance measurement device according to one aspect of the present  
15 invention includes a communication unit configured to execute, under control of the control unit, at least one of: a step of acquiring data of the screw shape of each of the male joint and the female joint; and a step of outputting information on the clearance obtained by the  
20 clearance measurement step.

[0017] (9) A screw joint measurement system according to one aspect of the present invention includes: a measurement unit configured to measure each of a screw shape of a male joint and a screw shape of a female joint corresponding to  
25 the male joint included in a set of screw joints; and the clearance measurement device according to the above-described invention configured to measure a clearance for each set of the screw joints based on data of the screw shapes measured by the measurement unit.

30 [0018] (10) A measurement terminal according to one aspect of the present invention is configured to measure a clearance between a screw of a male joint and a screw of a female joint corresponding to the male joint included in a

set of screw joints, and includes: a control unit configured to control the measurement terminal; a measurement unit configured to measure each of a screw shape of the male joint and a screw shape of the female joint under control of the control unit; a communication unit configured to execute at least one of: an output step of outputting the measured screw shapes as data to the clearance measurement device according to the above-described invention; and an acquisition step of acquiring information on the clearance for each set of the joints from the clearance measurement device under control of the control unit; and an output unit configured to output the acquired information in a predetermined format under control of the control unit.

15 [0019] (11) In the invention (10), in the measurement terminal according to one aspect of the present invention, the control unit is configured to execute at least either one of: a step of determining pass/fail for the set of screw joints based on the acquired information on the clearance and a predetermined criterion; and an interference information assignment step of assigning information on an interference point to a point determined as the interference point based on the acquired information on the clearance and the predetermined criterion.

20 [0020] (12) A screw joint measurement system according to one aspect of the present invention includes: the measurement terminal according to the above-described invention; and the clearance measurement device according to the above-described invention configured to measure a clearance for each set of the screw joints based on data of screw shapes measured by the measurement terminal.

25 [0021] (13) A screw joint quality control method according to one aspect of the present invention controls a

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quality of a set of screw joints including a male joint and a female joint corresponding to the male joint, and includes controlling quality of the set of screw joints by using information on the clearance obtained from the  
5 clearance measuring step executed by the control unit of the clearance measurement device according to the above-described invention.

#### Advantageous Effects of Invention

[0022] According to the clearance measurement method,  
10 the clearance measurement device, the method of measuring a screw joint, the screw joint measurement system, the measurement terminal, the screw joint manufacturing method, and the screw joint quality control method according to the present invention, it is possible to more easily perform  
15 joining check on the screw joint regardless of the state of the screw joint or the connected pipe.

#### Brief Description of Drawings

[0023] FIG. 1 is a diagram illustrating a joining start state of a screw joint to be measured in a screw joint  
20 measurement system according to an embodiment of the present invention.

FIG. 2 is a diagram illustrating a joining completion state of a screw joint to be measured in the screw joint measurement system according to the embodiment of the  
25 present invention.

FIG. 3 is a block diagram illustrating a screw joint measurement system according to a first example of the embodiment of the present invention.

FIG. 4 is a block diagram illustrating a screw joint  
30 measurement system according to a second example of the embodiment of the present invention.

FIG. 5 is a flowchart for explaining a method of measuring a screw joint according to a first embodiment of

the present invention.

FIG. 6 is a flowchart for explaining a clearance measurement step according to the first embodiment of the present invention.

5        FIG. 7A is a diagram for explaining coordinates of a screw joint in a clearance measurement method according to an embodiment of the present invention.

FIG. 7B is a diagram for explaining coordinates of a screw joint in the clearance measurement method according  
10 to the embodiment of the present invention.

FIG. 7C is a diagram for explaining coordinates of a screw joint in the clearance measurement method according to the embodiment of the present invention.

FIG. 8 is an enlarged sectional view illustrating a  
15 joint portion of a screw joint according to an embodiment of the present invention.

FIG. 9 is an enlarged sectional view illustrating an interference portion of the joint portion of the screw joint according to the embodiment of the present invention.

20        FIG. 10 is a flowchart for explaining a first modification of the clearance measurement step in the clearance measurement method according to the first embodiment of the present invention.

FIG. 11 is a flowchart for explaining a second  
25 modification of the clearance measurement step in the clearance measurement method according to the first embodiment of the present invention.

FIG. 12 is a flowchart for explaining a method of measuring a screw joint according to a second embodiment of  
30 the present invention.

FIG. 13 is a flowchart for explaining a method of measuring a screw joint according to a third embodiment of the present invention.

## Description of Embodiments

[0024] Hereinafter, embodiments of the present invention will be described with reference to the drawings. In all the drawings of the following embodiments, the same or  
5 corresponding parts are denoted by the same reference numerals. The present invention is not limited by the embodiments described below.

[0025] First, a screw joint to be measured by a screw joint measurement system according to an embodiment of the  
10 present invention will be described. FIGS. 1 and 2 are diagrams illustrating a joining start state and a joining completion state of a screw joint to be measured (measurement target) in the clearance measurement system of the present embodiment, respectively.

15 [0026] (Male Joint and Female Joint to be Measured)

As illustrated in FIG. 1, a screw joint 10 according to the present embodiment includes a male joint 11 serving as an inner joint and a female joint 12 serving as an outer joint. A male screw 13 is formed on a distal end side  
20 which is a side of the male joint 11 to be inserted and fitted. A female screw 14 is formed on a distal end side where the male joint is to be inserted and fitted in the female joint 12. The female screw 14 formed in the female joint 12 is formed in a screw shape corresponding to the  
25 male screw 13 formed in the male joint 11. With this configuration, the male joint 11 and the female joint 12 correspond to each other, and the male joint 11 can be inserted into the female joint 12 by screwing. A known screw shape or an unknown screw shape may be used. The  
30 screw shape may be a single thread or multiple threads, and in the present embodiment, for example, multiple threads are used. As the screw shape, a tapered screw or a parallel screw may be used, and in the present embodiment,

for example, a parallel screw is used. The material is not particularly limited. Examples of the material includes steel, metal materials other than steel, concrete, resin, and combinations of a plurality of materials. The material  
5 of the screw joint is selected according to a purpose of use or a condition of a pipe or the like to be described later. The present invention is particularly effective in the case of a screw joint with which it is difficult to perform joining check before shipment from the factory due  
10 to a large diameter or a heavy object (long).

[0027] Each of pipes 15 and 16 constitutes a structure. The pipe 15 constitutes an upper structure. The pipe 16 constitutes a lower structure. As the structure, various structurers can be adopted such as a structure having a  
15 predetermined function in a state of being embedded in the ground or the like, a structure used as a part of a structure on the ground, or a structure that transports gas or liquid by utilizing an internal space of the pipes 15 and 16. Examples of those having a predetermined function  
20 in a state of being embedded in the ground include a pile, a soil pile, a landslide prevention pile, a pipe sheet pile, a sheet pile wall, and a tunnel. Examples of those used as a part of a structure on the ground include a column and a beam. Examples of those that transport gas or  
25 liquid utilizing the internal spaces of the pipes 15 and 16 include an oil well pipe, a water pipe, and a gas pipe. Examples of the pipes 15 and 16 include a steel pipe, a concrete pipe, a resin pipe, and a pipe obtained by combining a plurality of materials. In the present  
30 invention, since the pipes 15 and 16 have a large diameter, a long length, or they are heavy objects, it is particularly effective in the case of a steel pipe with a screw joint with which it is difficult to perform joining

check before shipment from a factory.

[0028] In the present embodiment, the male joint 11 having the male screw 13 is fixed to the upper pipe 15. The female joint 12 having the female screw 14 is fixed to the lower pipe 16. Contrary to the above, the male joint 11 may be fixed to the lower pipe 16, and the female joint 12 may be fixed to the upper pipe 15. In addition, the male joint 11 and the female joint 12 may be used as measurement targets without being connected to the pipes 15 and 16.

[0029] (First Example of Embodiment)

Next, a screw joint measurement system according to a first example of an embodiment of the present invention will be described. FIG. 3 is a block diagram illustrating a screw joint measurement system according to a first embodiment.

[0030] As illustrated in FIG. 3, a screw joint measurement system 1 includes a clearance measurement device 20 and a measurement unit 35. Further, the clearance measurement device 20 is connected to a screw processing device 40. The screw joint measurement system 1 may adopt a configuration including the clearance measurement device 20, the measurement unit 35, and the screw processing device 40. In the screw joint measurement system 1 according to the first embodiment, it is assumed that the clearance measurement device 20 is fixed and used, but the measurement unit 35 and the clearance measurement device 20 may be in a close state or a in a state of being distanced.

[0031] (Clearance Measurement Device)

The clearance measurement device 20, the clearance measurement device 20 includes a control unit 21, a storage unit 22, and an input/output unit 23. The input/output

unit 23 does not have to be provided. As the clearance measurement device 20, a known computer, a server, a notebook computer, a mobile terminal, a tablet, a smartphone, a virtual device on a network such as a cloud, or the like may be used.

[0032] Specifically, a control unit 31 as a control unit includes a processor such as a central processing unit (CPU), a digital signal processor (DSP), or a field-programmable gate array (FPGA) having hardware, and a main storage unit such as a random access memory (RAM) or a read only memory (ROM) (none of which is illustrated).

[0033] The storage unit 22 is physically formed of a storage medium selected from a volatile memory such as a RAM, a nonvolatile memory such as a ROM, an erasable programmable ROM (EPROM), a hard disk drive (HDD), a solid state drive (SSD), a removable medium, and the like. The removable medium is, for example, a universal serial bus (USB) memory, or a disk recording medium such as a compact disc (CD), a digital versatile disc (DVD), or a Blu-ray (registered trademark) disc (BD). The storage unit 22 may be configured using a computer-readable recording medium such as a memory card that can be attached from the outside. The storage unit 22 can store an operating system (OS), various programs, various tables, various databases, and the like for executing the operation of the clearance measurement device 20. The various programs include a learning model and a neural network. These various programs can be widely distributed by being recorded in a computer-readable recording medium such as a hard disk, a flash memory, a CD-ROM, a DVD-ROM, or a flexible disk.

[0034] The storage unit 22 stores a clearance database 221 and a pipe type database 222. In the pipe type database 222, various types of information (pipe type

information) related to the male joint 11 and the female joint 12 constituting the screw joint 10 are stored as basic information in a searchable manner. The pipe type information includes information such as an identification ID of the screw joint 10, dimensions (diameter, screw dimensions, screw pitch, screw height, length, etc.) of the male joint 11 and the female joint 12, specifications, and the like. The clearance database 221 stores information related to a clearance between the male screw 13 and the female screw 14 based on pipe type information, and information of a measurement result related to a clearance between the male screw 13 and the female screw 14 measured by the measurement unit 35 described later in a searchable manner (hereinafter, clearance information). The clearance information includes, in addition to the information of the measurement result of the clearance, various types of information related to the clearance, such as information of a flag as information of an interference point defining an interference point, and information of pass/fail with respect to a set of the screw joint 10.

[0035] A clearance calculation unit 211 of the control unit 21 is configured to be able to store the screw shapes of the male screw 13 and the female screw 14 measured by the measurement unit 35 in the clearance database 221 of the storage unit 22 as digital data. The storage unit 22 may be provided in a housing different from the control unit 21, and a virtual storage device such as an external storage device or a cloud on a network may be used.

[0036] In the present embodiment, the control unit 21 loads the program stored in the storage unit 22 into the work area of the main storage unit and executes the program, and controls each unit and the like through the execution of the program, whereby a function matching a

predetermined purpose can be realized. Specifically, the control unit 21 can realize the functions of the clearance calculation unit 211 and a determination unit 212 by executing a program.

5 [0037] The input/output unit 23 includes, for example, a touch panel display, a speaker microphone, a button, a switch, and a jog dial. The input/output unit 23 as an output unit is configured to notify the outside of predetermined information by displaying characters,  
10 figures, and the like on a screen of a display such as a liquid crystal display, an organic EL display, or a plasma display, or outputting sound from a speaker, under the control of the control unit 21. The input/output unit 23 includes a printer that prints and outputs predetermined  
15 information on printing paper or the like. Various types of information stored in the storage unit 22 can be checked by, for example, a display of the input/output unit 23 installed in a predetermined office or the like.

[0038] The input/output unit 23 as an input unit is  
20 selected from, for example, a keyboard, a touch panel keyboard incorporated in the input/output unit 23 to detect a touch operation on a display panel, a voice input device that enables a call with the outside, a switch, a jog dial, or the like. The input/output unit 23 as an input unit can  
25 input a measurement value of the clearance from the input/output unit 23 when the clearance of a screw section of the male screw 13 or the female screw 14 is visually measured using the input/output unit 23 as an output unit. In addition, as will be described in detail later, in the  
30 joining of the male screw 13 and the female screw 14, it is also possible to set up or turn down a flag based on the presence or absence of interference from the input/output unit 23. Specifically, "0" may be input from the

input/output unit 23 when there is an interference between the male screw 13 and the female screw 14, and "1" may be input from the input/output unit 23 when there is no interference.

5 [0039] (Measurement Unit)

The measurement unit 35 is formed of at least one handheld 3D scanner, for example. As the 3D scanner, for example, a laser irradiation device, an infrared irradiation device, or the like may be adopted. Since the  
10 handheld 3D scanner needs to be operated while maintaining a focal length (for example, 20 cm to 40 cm) according to the model, it is desirable to secure a space of 50 cm or more around the scan target.

[0040] From the viewpoint of determining whether the  
15 male joint 11 and the female joint 12 can be joined, the measurement unit 35 preferably sets the measurement accuracy to about half or less of a desired clearance, specifically, for example, about  $0.375 (= 0.75/2)$  mm or less in a case where the clearance is 0.75 mm. The  
20 measurement accuracy is variously set according to the size of the screw joint 10, the screw shapes of the male screw 13 and the female screw 14, and the like, and is not limited to these numerical values. In particular, since the screw joint 10 has a three-dimensional shape, a blind  
25 spot is easily generated because of its uneven portion, and thus, for example, a handheld 3D scanner, which is a handy-type measuring instrument, is desirable from the viewpoint of operability. Normally, in a high-accuracy type handheld 3D scanner, it is necessary to attach a marker for shape  
30 measurement to an object every about 10 cm. When the screw joint 10 is large, it is desirable to use a marker-less type handheld 3D scanner which does not require attachment of a marker for shape measurement from the viewpoint of

efficiency.

[0041] Specifically, the sensor constituting the measurement unit 35 can measure the distance from the installation position to the target, for example, to the screw surface of the male screw 13 or the female screw 14 by irradiation and reflection of predetermined light such as laser light. The measurement unit 35 can execute so-called sensing to measure the distance from the measurement position to the surface of the target in association with two-dimensional position information. The sensing includes various measurements performed by the measurement unit 35. As the two-dimensional position information, coordinates (x, y) on an xy plane, coordinates (r,  $\theta$ ) at a distance r and a rotation angle  $\theta$ , and the like may be used. The screw shapes of the surfaces of the male screw 13 and the female screw 14 can be three-dimensionally measured based on the information of the distance corresponding to the two-dimensional position information.

[0042] It is more preferable to select the equipment of the measurement unit 35 having a higher resolution. In this case, the resolution may be any resolution as long as the shape of the screw that affects the clearance used to determine whether the male joint 11 and the female joint 12 can be joined can be accurately reproduced. In the present embodiment, since local unevenness may be less likely to occur in the shapes of the screws of the male screw 13 and the female screw 14, the resolution may be about 1 mm or less, but is not limited to this numerical value. Since the male joint 11 and the female joint 12 are combined on the scanned data to determine whether joining is possible, in the case of a target whose direction is not fixed in one direction, it is desirable to ensure directionality by providing a marker or a mark with a shape that can be

recognized by scanning.

[0043] The measurement unit 35 executes output processing of outputting a measurement value of the screw shape measured by sensing to the clearance measurement device 20. The clearance calculation unit 211 in the control unit 21 of the clearance measurement device 20 stores the acquired measurement value in the clearance database 221 of the storage unit 22.

[0044] (Screw Processing Device)

10 The screw processing device 40 is a device for an adjustment step for the male screw 13 and the female screw 14 of the screw joint 10. The screw processing device 40 includes a control unit 41, a storage unit 42, an input/output unit 43, and a screw processing unit 45. The control unit 41, the storage unit 42, and the input/output unit 43 are functionally and physically formed in the same manner as the control unit 21, the storage unit 22, and the input/output unit 23, respectively. The screw processing device 40 is connected to the clearance measurement device 20.

[0045] The control unit 41 loads the program stored in the storage unit 42 into the work area of the main storage unit and executes the program, and controls each unit and the like through the execution of the program, whereby a function matching a predetermined purpose can be realized. Specifically, the control unit 41 can realize the function of a processing control unit 411 by executing a program. The processing control unit 411 is configured to be able to control the screw processing unit 45.

30 [0046] The clearance calculation unit 211 of the clearance measurement device 20 reads the clearance information from the clearance database 221 stored in the storage unit 22 and outputs the clearance information to

the screw processing device 40. The screw processing device 40 that has acquired the clearance information at least temporarily stores the acquired clearance information in the storage unit 42. When an instruction to correct an interference part between the male screw 13 and the female screw 14 is input from an operator or the like through the input/output unit 43, the processing control unit 411 of the control unit 41 controls the screw processing unit 45 to execute processing of correcting the interference part based on the acquired clearance information. The screw processing device 40 may be integrated with the clearance measurement device 20. The screw joint 10 may be manufactured by the screw processing device 40. The screw joint measurement system 1 according to the first example of the embodiment is thus configured.

[0047] (Second Example of Embodiment)

Next, a screw joint measurement system according to a second embodiment of the present invention will be described. FIG. 4 is a block diagram illustrating a screw joint measurement system according to the second embodiment. As illustrated in FIG. 4, a screw joint measurement system 1A includes the clearance measurement device 20 and a measurement terminal 30A that can communicate with each other via a network 2.

[0048] The network 2 is, for example, a public communication network such as the Internet, and includes, for example, one or a combination of a local area network (LAN), a wide area network (WAN), a telephone communication network such as a mobile phone, a public line, a virtual private network (VPN), a dedicated line, and the like. In the network 2, wired communication and wireless communication are appropriately combined.

[0049] The screw joint measurement system 1A may be

further connected to the screw processing device 40 capable of communicating with at least the clearance measurement device 20 via the network 2. The screw joint measurement system 1A may adopt a configuration including the clearance measurement device 20, the measurement terminal 30A, and the screw processing device 40.

[0050] (Clearance Measurement Device)

A clearance measurement device 20A includes the control unit 21, the storage unit 22, the input/output unit 23, and a communication unit 24. The communication unit 24 as a communication unit is, for example, a local area network (LAN) interface board, a wireless communication circuit for wireless communication, or the like. The LAN interface board or the wireless communication circuit is connected to the network 2. The communication unit 24 is connected to the network 2 and communicates with the measurement terminal 30A and the screw processing device 40 A. Other configurations are the same as those of the clearance measurement device 20 in the first embodiment.

[0051] (Measurement Terminal)

The measurement terminal 30A includes the control unit 31, a storage unit 32, an input/output unit 33, a communication unit 34, and a measurement unit 35. The control unit 31, the storage unit 32, the input/output unit 33, and the communication unit 34 have physically and functionally the same configurations as those of the control unit 21, the storage unit 22, the input/output unit 23, and the communication unit 24 described above.

[0052] Further, the measurement unit 35 in the measurement terminal 30A according to the second embodiment is configured in the same manner as the measurement unit 35 in the first embodiment. The control unit 31 loads the program stored in the storage unit 32 into the work area of

the main storage unit and executes the program, thereby a function matching a predetermined purpose can be realized. Specifically, the control unit 31 can realize the function of a measurement control unit 311 by executing the program.

- 5 The measurement control unit 311 is configured to be able to control the measurement unit 35.

[0053] (Screw Processing Device)

- A screw processing device 40A includes the control unit 41, the storage unit 42, the input/output unit 43, a communication unit 44, and the screw processing unit 45. The communication unit 44 as a communication unit is physically and functionally formed in the same manner as the communication unit 24 described above, and is connected to the network 2. The communication unit 44 is connected to the network 2 and communicates with at least the clearance measurement device 20A. Other configurations are the same as those of the screw processing device 40 in the first embodiment. The screw joint measurement system 1A according to the second example of the embodiment is thus configured.
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[0054] (First Embodiment)

(Method of Measuring Screw Joint)

- Next, a method of measuring the screw joint 10 using the screw joint measurement system 1 according to the first example of the embodiment configured as described above or the screw joint measurement system 1A according to the second example will be described. FIG. 5 is a flowchart for explaining a method of measuring the screw joint 10 according to the first embodiment.
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- 30 [0055] (Manufacturing Step of Screw Joint)

As illustrated in FIG. 5, first, in Step ST1, a joint manufacturing step is executed by the screw processing device 40. In Step ST1, first, a forged ring is

manufactured by heat treatment. Next, while the casting ring is rotated by rotary cutting, the cutting blade is brought into contact with the casting ring and cut the ring to process the joint. The movement of the cutting blade  
5 can be automatically controlled by the control of the processing control unit 411 according to a predetermined program. Here, as an example, in a case where the screw shape of the joint is a multi-thread screw, one portion, that is, the same place is cut little by little until one  
10 thread is completed. When one thread is completed, the cutting blade is moved to the next thread. After the screw in the joint is completed, a trial joining is actually performed, and an arrival line is marked with an eye-mark in a joining completion state that satisfies structural  
15 performance. Thereafter, the joining is released and an arrow is marked on the starting line on the outer peripheral surface (a part with no screw is selected) of each joint, and an arrow is marked on the male joint 11 corresponding to the eye-mark of the female joint 12 at the  
20 time of release. A forged ring is not necessarily used, and a steel pipe or the like having a cuttable plate thickness may be used.

[0056] (Pipe Connecting Step)

Next, the procedure proceeds to Step ST2, and a pipe  
25 connecting step is executed. In Step ST2, first, the joining of the screw joint performed in Step ST1 is released. Next, either one of the male joint 11 and the female joint 12, here, for example, the female joint 12 is attached to a horizontal steel pipe. Next, the single body  
30 of the male joint 11 is experimentally joined to the steel pipe with the female joint in the horizontal placement state. After it is checked whether the joining reaches the arrival line by this trial joining, the joining is

released. Subsequently, the other of the male joint 11 and the female joint 12, here, for example, the male joint 11, is attached to the horizontal steel pipe.

[0057] Here, in the case of a combination of a steel screw joint and a steel pipe, it is checked whether the screw joint can be joined up to the joining completion position while allowing the influence of thermal deformation due to welding in this trial joining. In a case of a combination of a steel screw joint and a steel pipe sheet pile as a pipe, as an example, a steel coupling joint laterally connecting steel pipes is welded, and then the screw joint is welded to the steel pipes. Step ST2 does not have to be executed.

[0058] (Method of Measuring Screw Joint)

15 Here, a method of measuring a screw joint according to the present embodiment will be described. The present embodiment includes a shape measurement step of measuring the shape of a screw joint after machining, and a clearance measurement step with respect to a set of screw joints based on the measured shape of the screw joint. These shape measurement step and clearance measurement steps are performed before the screw joint 10 is actually used.

[0059] (Shape Measurement Step)

25 That is, after Step ST1 or Step ST2 is executed, the procedure proceeds to Step ST3 to execute the shape measurement step. In the shape measurement step, first, the measurement unit 35 measures the screw shapes of the male screw 13 of the male joint 11 and the female screw 14 of the female joint 12 with respect to one set of the screw joints 10 manufactured in Step ST1. The measurement unit 35 outputs or transmits (hereinafter, referred to as transmit) measurement data of the measured screw shape to the clearance measurement device 20. Here, in the shape

measuring shape for the screw joint 10, the measurement of the screw shapes using the measurement unit 35 is performed, for example, by measuring the distance from the measurement unit 35 to the surface of the screw joints  
5 (male joint 11 and female joint 12).

[0060] In the step of measuring the shape of the screw joint 10, the screw shapes may also be measured by imaging the screw joints (male joint 11 and female joint 12) from a plurality of viewpoints to acquire a plurality of image  
10 data, and by photogrammetry using the plurality of acquired images. Specifically, after point cloud data is acquired by the handheld 3D scanner constituting the measurement unit 35, the acquired point cloud data is converted into polygons (STL, meshing), and shape measurement and virtual  
15 arrangement are executed by CAD software that three-dimensionally measures the screw joint 10 as a target.

[0061] Here, to realize the virtual arrangement, for example, in a case where the shape is grasped in detail, it is preferable to use a vertex of the screw as a data point.  
20 That is, to measure the shape of the screw, it is preferable that the vertex of the screw is included in the data points of the point cloud data, and more specifically, it is preferable to set the resolution to a value equal to or less than the radius of curvature of the vertex of the  
25 screw, for example, about 0.5 mm or less.

[0062] However, local unevenness may be less likely to occur as the shape of the screw, and the resolution may be set to about 1 mm in consideration of the fact that the contact that affects the joinability is a surface contact  
30 of the screw surface. As an example, by setting the accuracy of the data point to half or less of the clearance as an indication of the accuracy of the data point, specifically, for example, in a case where the clearance is

0.75 mm, by setting the indication of the accuracy of the data point to 0.375 mm or less, determination can be performed with practically sufficient accuracy. The male joint 11 and the female joint 12 are regarded as rigid  
5 bodies and the joint determination is performed by using CAD-based software that performs three-dimensional measurement, and thus, there is no problem in the pass determination when there is a clearance. On the other hand, even when there is an interference generated to some  
10 extent, fitting may be possible as long as the interference is within the range of the deformability of the joint as an elastic body.

[0063] In this manner, the determination can be performed with high accuracy by setting the determination  
15 criterion value in consideration of the measurement accuracy, the neglect of local contact, the frictional resistance, the elastic deformation amount, and the use conditions (directionality at the time of joining such as vertical, horizontal, and oblique, and outside  
20 temperature). The determination criterion value does not need to be based on 0, and it is also possible to determine whether fitting is possible, for example, based on a digital clearance of -0.2 mm (virtual interference amount of 0.2 mm). Depending on the measurement accuracy,  
25 interference may occur even when the clearance has a positive value, and it is desirable to set an appropriate determination criterion. Since the positive and negative of the clearance depends on the method of organizing, it may be determined that having a negative represents a state  
30 in which a clearance is present.

[0064] In the screw joint 10, the entire screw joint is not necessarily measured as long as the measurement unit 35 measures the outer surface side of the male joint 11 and

the inner surface side of the female joint 12. In this case, it is possible to shorten the measurement time and reduce the capacity of the measurement data. In addition, when the acquired point cloud data is converted into a polygon (STL, meshing), points within a predetermined surface error range (for example, 0.01 mm) can be omitted, and the data capacity can be reduced.

[0065] (Clearance Measurement Step)

Next, the procedure proceeds to Step ST4, and the clearance measurement step as a clearance measurement method will be described. FIG. 6 is a flowchart for explaining a clearance measurement method according to the first embodiment. The flowchart illustrated in FIG. 6 is executed by the clearance measurement device 20.

[0066] (Acquisition Step)

As illustrated in FIG. 6, in the clearance measurement method according to the first embodiment, first, in Step ST411 as an acquisition step of performing an acquisition processing, the control unit 21 of the clearance measurement device 20 acquires measurement data from the measurement unit 35. The measurement data is measurement data regarding the screw shape of the male screw 13 of the male joint 11 and the screw shape of the female screw 14 of the female joint 12 measured by the measurement unit 35 in Step ST3.

[0067] (Joining Completion State Setting Step)

Next, the process proceeds to Step ST412 as a joining completion state setting step of executing the joining completion state setting processing, and the clearance calculation unit 211 of the control unit 21 sets the joining completion state in which the male joint 11 is joined to the inner side of the female joint 12 based on the acquired measurement data of the screw shapes of the

male screw 13 and the female screw 14.

[0068] In the present invention, the "joining completion state" indicates a state in which the entire length of the screw portion of the male joint 11 with respect to the pipe axis direction is substantially accommodated inside the female joint 12 and the joining is completed as illustrated in FIG. 2. In other words, it is a state the male joint 11 screwed into the female joint 12 hardly turns any more in the direction in which the screw advances. As illustrated in FIG. 2, ideally, the unthreaded portion of the male joint 11 and the distal end portion of the female joint 12 are in contact with each other (referred to as a shoulder touch).

[0069] In the present invention, the biggest feature is that the joining completion state is set as the initial position, and the measurement of the clearance is started from the joining completion state.

[0070] Normally, in the case of performing joining check with a real joint, the position where the male screw and the female screw are assembled (which is also the start position of the screw with respect to the circumferential direction of the joint) is specified while moving the joins. Here, in the case of a single thread screw, there is only one start position of the screw with respect to the circumferential direction of the joint, and it is very difficult to specify the start position depending on the conditions of the screw joint as described above. A multi-thread screw has a plurality of start positions of the screw with respect to the circumferential direction of the joint, but when the multi-thread screw is assumed to be used at a specific start position, it is also difficult to specify the start position. In particular, when virtual joining is simulated using a computer or the like, there

are a plurality of conditions in the circumferential direction and the axial direction for setting the position at which the male screw and the female screw are assembled, and it is more difficult to start screwing in the first place.

[0071] However, the joining completion position where the male screw and the female screw are completely joined can be easily set in any environment including a virtual case. Thus, in the present invention, by measuring the clearance while setting the joining completion position as the initial position and releasing the joining, the clearance measurement step is simplified, and the clearance can be measured more easily regardless of the state of the screw joint or the connected pipe.

[0072] (Clearance Measuring Step)

Next, the processing proceeds to Step ST413 as a clearance measuring step, and the clearance calculation unit 211 of the control unit 21 derives the clearance between the male screw 13 and the female screw 14 based on the measurement data of the male screw 13 and the female screw 14 in the joining completion state. The derivation of the clearance by the clearance calculation unit 211 is executed at a preset point. In the present specification, the clearance is also referred to as gap, allowance, or the like.

[0073] Here, FIGS. 7A, 7B, and 7C illustrate a method of creating a coordinate system of a measurement position. That is, as illustrated in FIG. 7A, a plane for creating a section of the male screw 13 of the male joint 11 and a section along the radial direction of the female screw 14 of the female joint 12 is manufactured, and a sectional line L illustrated in FIG. 7B is manufactured. Next, two straight lines l are manufactured from the sectional line

to create an intersection point C. Next, as illustrated in FIG. 7C, a circle (hereinafter, fitting circle) in which an error from a point (designated point) to which a curve is designated is minimized is manufactured. A coordinate  
5 system is manufactured by the center point of the fit circle and the plurality of intersection points C. The method of creating a coordinate system described with reference to FIGS. 7A to 7C is merely an example, and the creation and setting of the coordinate system may be  
10 performed by any method.

[0074] The description returns to FIG. 6. Based on the coordinate system manufactured in this manner, it is possible to select, as preset points, four points shifted by, for example,  $90^\circ$  in a circumferential manner with  
15 respect to the center of a circle in a section (a plane perpendicular to the vertical direction in FIGS. 1 and 2) of the male joint 11 and the female joint 12. The preset points may be, for example, eight points shifted by  $45^\circ$  on the circumference with respect to the center of the circle,  
20 and are not necessarily limited to predetermined positions or the numbers.

[0075] In Step ST413, as described above, the clearance calculation unit 211 generates a sectional view of the screws from the data of the screw shapes at the preset four  
25 or eight positions, and derives the clearance c between the male screw 13 and the female screw 14. In this manner, by setting the method of obtaining the measurement point as illustrated in FIGS. 7A to 7C, the clearance calculation unit 211 can automatically calculate the determined part by  
30 a predetermined method. The input/output unit 23 of the clearance measurement device 20 may be caused to output the sectional view of the screws generated by the clearance calculation unit 211, and the operator may visually

determine the presence or absence of the clearance and input the presence or absence of the clearance from the input/output unit 23.

[0076] FIGS. 8 and 9 illustrate an example of a section  
5 of the screw joint 10, which is generated by the clearance calculation unit 211 of the clearance measurement device 20 according to the first embodiment and converted into data. FIG. 8 is an enlarged sectional view illustrating a part of a state where the male screw 13 and the female screw 14 of  
10 the data-converted screw joint 10 do not interfere with each other and are joined. FIG. 9 is an enlarged sectional view illustrating a part of a state where the male screw 13 and the female screw 14 of the data-converted screw joint 10 partially interfere with each other and are not properly  
15 joined.

[0077] As illustrated in FIG. 8, when no interference occurs between screw crests 13a and 14a and screw bottoms 13b and 14b, respectively, the male joint 11 and the female joint 12 are joined. Here, for example, the height  $h$  of  
20 the screw crest 13a of the male screw 13 to be appropriately joined is, for example, 5.0 mm. The center of each of the screw crests 13a and 14a is assumed to be the closest point at half the distance between a corner and a corner of the male screw 13. The white point  $p$  is a  
25 measurement point that can ensure sufficient resolution with respect to the male screw 13 of the male joint 11 and the female screw 14 of the female joint 12. As the number of white points  $p$  increases, the determination accuracy of the center positions of the male screw 13 and the female  
30 screw 14 can improve.

[0078] The height  $h$  of each of the screw crests 13a and 14a is a distance between the center of each of the screw crests 13a and 14a and the bottom on the stabbing side.

The radial clearance  $c$  between the screw crest 13a of the male screw 13 and the screw bottom 14b of the female screw 14 is, for example, 0.75 mm. The clearance  $c$  is a radial component of the rotation axis of the male joint 11 in a line connecting the center of the screw crest 13a and the center of the screw bottom 14b. That is, the clearance  $c$  can be derived as  $c = r_2 - r_1$  from the distance  $r_1$  from the center of the diameter of the male joint 11 to the surface of the male joint 11 in contact with the screw crest 13a in the circumferential direction and the distance  $r_2$  from the center of the diameter of the male joint 11 to the screw bottom 14b of the female joint 12.

[0079] The clearance  $c$  is not necessarily limited to the above definition, and various definitions depending on whether the screw joint 10 can be joined can be set. For example, as another example of the definition of the clearance  $c$ , it is also possible to adopt a method of determining the position in consideration of the vertices of the screw crests 13a and 14a. That is, when the vertexes to be measured are determined in advance and are obliquely connected, a distance corresponding to the radial direction or the axial direction between the connected vertexes can be measured to obtain the clearance  $c$ . In addition, the distance may be measured in the normal direction for each point or line connecting a point and a point in the male joint 11, that is, for each mesh, and the distance at the time of contact with the female joint 12 in the joined state, that is, the shortest distance may be set as the clearance  $c$ . The distance may be conversely measured in a direction from the female joint 12 toward the male joint 11.

[0080] As illustrated in FIG. 9, from the positional relationship between the male joint 11 and the female joint

12, when interference (interference portion E) occurs at least partially between the screw crests 13a and 14a and the screw bottoms 13b and 14b, the male joint 11 and the female joint 12 cannot be joined. Here, for example, the height  $h$  of the screw crest 13a of the male screw 13 in a state where the joints are not appropriately joined is, for example, 5.0 mm. The radial clearance  $c$  between the female screw 14 and the screw bottom 14b will interfere, for example, by -1 mm, that is, 1 mm in the radial direction.

10 [0081] In the examples of FIGS. 8 and 9 described above, the screw pitch  $P$  is, for example, 12.5 mm, but is not limited to this value. The screw pitch  $P$  is an axial distance from an end of the screw bottom 13b of the male screw 13 in one thread to a starting position of the screw bottom 13b of the male screw 13 in the next thread.

15 Alternatively, the screw pitch  $P$  is an axial distance from an end of the screw crest 14a of the female screw 14 with one thread to a starting position of the next screw crest 14a with one thread. In the case of a single thread screw, the screw pitch  $P$  means the distance traveled by the screw when one rotation is made. In the case of a multi-thread screw, the screw pitch  $P$  is difficult to define as a constant distance because the distance traveled when one rotation is made varies depending on the number of threads.

20 Thus, the screw pitch  $P$  is defined as described above in the present specification, but is not necessarily limited to the definition described above.

25 [0082] The clearance calculation unit 211 stores, in the clearance database 221, a result of the clearance  $c$  derived at a plurality of places, for example, four places or eight places set in advance as clearance information. In the male joint 11 and the female joint 12, the clearances  $c$  are derived for all the screw crests 13a and 14a and the screw

30

bottoms 13b and 14b of the joint portions at a plurality of preset points. Then, a minimum clearance  $c$  along the radial direction with respect to the rotation axis is derived. Specifically, the clearance calculation unit 211  
5 extracts, with predetermined measurement software, a value at which the clearance  $c$  between the male screw 13 of the male joint 11 and the female screw 14 of the female joint 12 in each longitudinal section (see FIG. 7B) is minimum in the rotation radius direction. The derived information of  
10 the clearance  $c$  may be stored in the storage unit 22 in association with the screw joint identification ID of the pipe type information stored in the pipe type database 222.  
[0083] (Clearance Determination Step)

Next, the processing proceeds to Step ST414 as a  
15 clearance determination step, and the determination unit 212 of the control unit 21 reads the clearance information from the clearance database 221 of the storage unit 22 and determines whether joining can be performed according to a predetermined criterion. That is, the determination unit  
20 212 determines whether the clearance  $c$  between the male screw 13 of the male joint 11 and the female screw 14 of the female joint 12 is equal to or less than a predetermined value as a predetermined reference, for example. The predetermined value may be set to any value,  
25 and in the present embodiment, the predetermined value is set to 0, for example.

[0084] In Step ST414, when the determination unit 212 determines that the clearance  $c$  between the male screw 13 of the male joint 11 and the female screw 14 of the female  
30 joint 12 is equal to or less than a predetermined value, specifically, for example, equal to or less than 0 ( $c \leq 0$ ) (Step ST414: Yes), the process proceeds to Step ST418. In Step ST418, the determination unit 212 outputs information

indicating that the screw joint 10 to be measured is fail, and stores information on fail as clearance information in the clearance database 221. The clearance measurement step then ends.

5 [0085] In Step ST414, when the determination unit 212 determines that the clearance  $c$  between the male screw 13 of the male joint 11 and the female screw 14 of the female joint 12 is larger than a predetermined value, specifically, for example, larger than 0 ( $c > 0$ ) (Step  
10 ST414: No), the process proceeds to Step ST415. That is, when the clearance  $c$  in the portion joined at a plurality of preset points is larger than a predetermined value, it is determined that the male joint 11 and the female joint 12 can be joined without causing interference. Here, in a  
15 case where the predetermined value is set to 0, the determination unit 212 can determine that interference does not occur and the male joint 11 and the female joint 12 can be joined when the clearance  $c$  is always in a positive state ( $c = r_2 - r_1 > 0$ ). Since the interference part E may  
20 be manufactured not only in the radial direction of the screw portion but also in the pipe axis direction of the screw portion and a part other than the screw portion, determination may be made in a similar manner. However, since the screw joint 10 is most likely to deform in the  
25 radial direction of the screw portion, the determination unit 212 can determine that the screw portion can be joined when the clearance in the radial direction of the screw portion satisfies the above-described condition ( $c >$   
predetermined value). This time, as a static examination,  
30 a method using measurement software or CAD on the assumption that the shape of the entire joint is rigid that does not deform has been adopted. However, as a dynamic examination, a method with consideration that the shape of

the joint elastically deforms due to partial minute interference, frictional resistance, and the like can also be adopted. As the dynamic examination, dynamic analysis is performed by FEM, mechanism analysis, or the like, and  
5 interference is determined based on variations in load, torque, contact, friction, or the like.

[0086] (Joining Determination Step)

In Step ST415 as a joining determination step, the determination unit 212 determines whether the male joint 11  
10 and the female joint 12 of the screw joint 10 are not screwed and the joining is released. When the determination unit 212 determines that the male joint 11 and the female joint 12 are not screwed and the joining is released (Step ST415: Yes), the process proceeds to Step  
15 ST417.

[0087] In Step ST417, the determination unit 212 outputs information indicating that the screw joint 10 to be measured is pass, and stores information on pass as clearance information in the clearance database 221. The  
20 clearance calculation unit 211 can derive the clearance c with respect to the entire circumference of the male screw 13 and the female screw 14 until the joining of the male joint 11 and the female joint 12 is virtually released. The clearance measurement step then ends.

25 [0088] When the determination unit 212 determines in Step ST415 that the male joint 11 and the female joint 12 are not separated from each other and the joining is not released (Step ST415: No), the process proceeds to Step ST416.

30 [0089] (Rotation State Setting Step)

In Step ST416 as a rotational state setting step of performing the rotational state setting processing, the clearance calculation unit 211 sets a state in which the

male joint 11 and the female joint 12 joined to each other are rotated in the releasing direction by a predetermined rotation angle, specifically, for example, 90° or 45°.

Here, the rotation state setting step executed in Step  
5 ST416 will be described in detail.

[0090] That is, it is considered that the male joint 11 and the female joint 12, which are converted into data, are rotated (hereinafter, reverse rotation) in the direction opposite to the rotation direction at the time of joining  
10 from the joining completion state and are completely released. In a case where interference does not occur in the whole section in all the screw portions of the male screw 13 and the female screw 14 at the time of release virtually executed in this data, it can be determined that  
15 the male joint 11 and the female joint 12 can be joined.

When interference occurs at least partially, that is, when the clearance  $c$  is equal to or less than a predetermined value, it can be determined that joining is impossible.

[0091] It is preferable to perform determination by  
20 reverse rotation starting from the joining completion state between the male joint 11 and the female joint 12 in this manner, which is an important feature in the present embodiment. When the degree of interference is derived while the male joint 11 and the female joint 12 are rotated  
25 in the joining direction of the male screw 13 and the female screw 14 to be joined from the joining start state in which the male joint and the female joint are separated in the screw joint 10, it is not always possible to immediately start the rotational joining from the position  
30 where the male joint 11 and the female joint 12 are brought into contact with each other. In this case, it is necessary to repeat the change of the initial positions of the male joint 11 and the female joint 12 to search for the

initial position where the rotational joining can actually be started. On the other hand, as in the present embodiment, when the reverse rotation is performed from the joining completion state, the initial positions of the male joint 11 and the female joint 12 are determined to be one position, and thus, the search for the rotation start position can be omitted. Here, in a case where the joining check is performed in the actual screw joint 10 instead of converted data, it is possible to specify the initial position of the start of joining while moving the initial position. In a case where the joining check is performed on the digitized virtual, it is necessary to examine and search for a plurality of settings of the initial position of the joining start in the circumferential direction, the axial direction, and the like, and it is extremely difficult to rotationally join the male joint 11 and the female joint 12 in the virtual data. It is relatively easy to specify the joining completion position. Thus, the measurement processing of the screw joint 10 can be simplified and the efficiency can be improved by setting the joining completion position as the initial position and confirming the presence or absence of interference while releasing the joining by reverse rotation. Interference is more likely to occur at a position where the male screw 13 and the female screw 14 mesh with each other more, that is, near the joining completion position in the fitting. Thus, the interference position can be found earlier by reversely rotating from the joining completion position to derive the degree of interference.

[0092] As a specific procedure executed by the clearance calculation unit 211 in Step ST416, first, as illustrated in FIG. 2, the male joint 11 and the female joint 12 converted into data are virtually arranged at the joining

completion position. The rotation axes of the male joint 11 and the female joint 12 are extracted. Specifically, for example, the outer diameter of the distal end portion in the male joint 11 and the inner diameter of the distal end portion in the female joint 12 are selected at a plurality of points such as four points or eight points. Next, a fitting circle having the minimum deviation from the selection point is manufactured, and the center of the fitting circle is set to the rotation axis. The rotation axes of the male joint 11 and the female joint 12 are matched with each other, and a shoulder touch state is derived. Here, the position of the eye-mark is defined as the joining completion position. Any method can be adopted for the setting of the rotation shaft and the setting of the joining completion position, and various methods can be adopted other than the above-described methods.

[0093] Next, in a state where the male joint 11 and the female joint 12 have aligned rotation axes and are shoulder touched, a minimum clearance along the radial direction of the rotation axes is derived with respect to all the screw crests 13a and 14a in a longitudinal section (see FIGS. 7A to 7C) equal to or less than a predetermined angular interval such as  $45^\circ$  or  $90^\circ$ . Here, a portion where the clearance becomes negative is also measured. A value at which the clearance of the screw portions of the male joint 11 and the female joint 12 in each longitudinal section is minimum in the rotation radius direction is extracted by measurement software. More specifically, an overall minimum value is derived, or a minimum value is derived for each of a plurality of screw crests of the screw crests 13a and 14a. Further, it is also possible to perform visual observation, examination using representative points, and the like depending on the conditions. In addition, the

distance may be measured in the normal direction for a line connecting a point and a point in the male joint 11, that is, for each mesh, and the distance at the time of contact with the female joint 12 in the joined state, that is, the shortest distance may be set as the clearance c. The distance may be conversely measured in a direction from the female joint 12 toward the male joint 11.

[0094] Thereafter, reverse rotation is made in a direction opposite to the joining direction by a preset rotation angle. Here, the rotation angle is, for example, 45° intervals or 90° intervals, but is not limited to these values. The amount of movement in the axial direction according to the angle of reverse rotation is determined by the screw pitch P of the male screw 13 and the female screw 14. The reason of setting the section for deriving the clearance and the interval of the reverse rotation to 45° or less or 90° or less is that the screw joint 10 is continuous in the circumferential direction, local deformation hardly occurs, and the presence or absence of interference can be sufficiently detected even when the check is performed at an interval of about 45° to 90°.

[0095] When interference occurs in the reverse rotation, a state is set in which the rotation shaft of the male joint 11 is moved to the side where the clearance along the rotation radius direction is larger, and the presence or absence of interference is checked at that stage. When there is further interference, a state in which the male joint 11 and the female joint 12 are moved along the axial direction of the rotation axis is set, and a position where the male joint and the female joint do not interfere is searched for. When a position with which no interference occurs is specified, reverse rotation is started again from the specified position. The presence or absence of

interference may be determined without moving the rotation axis.

[0096] The above procedures are repeated to reversely rotate the male joint 11 and the female joint 12 until the joining is released. In these procedures, when all the clearances of the male screw 13 and the female screw 14 are larger than a predetermined value, for example, 0, it is determined that joining is possible, and when the clearances are equal to or less than the predetermined value, it is determined that joining is impossible.

[0097] After the rotation state setting step in Step ST416 is completed, the process proceeds to Step ST413, and a clearance  $c$  of a portion joined at a preset point is derived. The control unit 21 repeatedly executes Steps ST413 to ST416 until the clearance  $c$  becomes equal to or less than a predetermined value (Step ST414: Yes) or the joining of the male joint 11 and the female joint 12 is released (Step ST415: Yes). Thereafter, the determination unit 212 stores information indicating pass or fail of the measured screw joint 10 in the clearance database 221 as clearance information. The clearance measurement step then ends. According to the clearance measurement step of the first embodiment, since it is determined that the screw joint 10 is fail when the clearance  $c$  becomes equal to or less than a predetermined value, it is possible to shorten the time required for finding a failed product in the screw joint.

[0098] Thereafter, the procedure proceeds to Step ST5 illustrated in FIG. 5, and the control unit 21 outputs information indicating whether the measured screw joint 10 is pass or fail to the input/output unit 23. The screw joint 10 determined as fail may be marked on the actual screw joint 10. It is possible to appropriately select

whether to execute an adjustment step to be described later or discard the screw joint 10 determined as fail. The measurement processing of the screw joint is thus completed.

5 [0099] It is possible to manage the quality of the screw joint 10 based on the method of measuring a screw joint described above. That is, in the quality control method for the screw joint 10, first, in Step ST1, the screw joint 10 is manufactured in the joint manufacturing step. Next, 10 the screw shapes of the male screw 13 and the female screw 14 of the screw joint 10 are measured in the joint measuring step in Step ST3. Thereafter, in Step ST4, by measuring the clearance for each set of the male screw 13 and the female screw 14 using the measurement result 15 obtained by the joint measuring step, it is possible to control the quality of the screw joint 10 as the quality control step.

[0100] (First Modification)

Next, a first modification of the clearance 20 measurement step according to the first embodiment will be described. FIG. 10 is a flowchart for explaining the clearance measurement step according to the first modification. In the clearance measurement method according to the first embodiment, the clearance measuring 25 processing is completed when a position where the clearance is equal to or less than a predetermined value is found. In the clearance measurement step according to the first modification, unlike the clearance measurement step according to the first embodiment, it is assumed that the 30 entire circumferences of the male joint 11 and the female joint 12 of the screw joint 10 are measured as clearance measurement regardless of pass/fail.

[0101] That is, as illustrated in FIG. 10, Steps ST421

to ST423 are the same as Steps ST411 to ST413 according to the first embodiment described above, respectively. In the first modification, after execution of Step ST423, the process proceeds to Step ST424. In Step ST424, the  
5 clearance calculation unit 211 stores, in the clearance database 221, a result of the clearance  $c$  derived at a plurality of preset points, for example, four or eight points as clearance information. Thereafter, the process proceeds to Step ST425. Steps ST425 and ST426 are the same  
10 as Steps ST415 and ST416 according to the first embodiment, respectively. In the first modification, the processing of determining whether the clearance is equal to or less than the predetermined value is not executed. Other processing is the same as that of the first embodiment, and thus  
15 description thereof is omitted.

[0102] (Second Modification)

Next, a second modification of the clearance measurement step according to the first embodiment will be described. FIG. 11 is a flowchart for explaining the  
20 clearance measurement step according to the second modification. In the clearance measurement method according to the first embodiment, the clearance measuring processing is completed when a position where the clearance is equal to or less than a predetermined value is found.  
25 In the clearance measurement step according to the second modification, unlike the clearance measurement step according to the first embodiment, it is assumed that the determination based on the comparison with the predetermined value is collectively performed after  
30 measuring the entire circumference of the male joint 11 and the female joint 12 of the screw joint 10 as clearance measurement regardless of whether the clearance is equal to or less than a predetermined value.

[0103] That is, as illustrated in FIG. 11, Steps ST431 to ST434 are the same as Steps ST421 to ST424 according to the first modification described above, respectively. In the second modification, the process proceeds to Step ST435 after execution of Step ST434. In Step ST435, the clearance calculation unit 211 executes Step ST435, which is a rotational state setting step that is the same as Step ST416 according to the first embodiment. The process proceeds to Step ST436.

10 [0104] In Step ST436, the determination unit 212 determines whether the joining is released in the same manner as in Step ST415. When the determination unit 212 determines in Step ST436 that the joining of the screw joint 10 is not released (Step ST436: No), the process

15 proceeds to Step ST433, and Steps ST433 to ST436 are repeatedly executed. When the determination unit 212 determines in Step ST436 that the joining of the screw joint 10 is released (Step ST436: Yes), the process proceeds to Step ST437.

20 [0105] In Step ST437, the determination unit 212 determines whether the clearance  $c$  between the male joint 11 and the female joint 12 is equal to or less than a predetermined value, in the same manner as in Step ST414 according to the first embodiment. In Step ST437, when the

25 determination unit 212 determines that there is no portion where the clearance  $c$  between the male joint 11 and the female joint 12 is equal to or less than a predetermined value (Step ST437: No), the clearance measurement step is terminated. When the determination unit 212 determines in

30 Step ST437 that the clearance  $c$  between the male joint 11 and the female joint 12 is equal to or less than the predetermined value (Step ST437: Yes), the process proceeds to Step ST438 as an interference information assignment

step. In Step ST438 that is an interference information assignment step of performing an interference information assignment processing, the determination unit 212 sets a flag as an interference point at a part where the clearance  
5 c is equal to or less than a predetermined value. Next, the determination unit 212 stores a flag related to the interference point as clearance information in the clearance database 221 of the storage unit 22. The clearance measurement step then ends.

10 [0106] The clearance measurement steps according to the first modification and the second modification can be used when it is desired to set the clearance at the manufacturing site or when it is less necessary to obtain the determination result of the clearance in real time or  
15 in a short time. In particular, in the clearance measurement step according to the second modification, it is possible to provide a third party with clearance information such as a position where the clearance is equal to or less than the predetermined value and there is no  
20 portion where the clearance is equal to or less than the predetermined value. Thus, it is easy to cope with a case where the clearance measurement step is executed at a place different from the manufacturing site.

[0107] According to the measurement method of the screw  
25 joint 10 according to the first embodiment of the present invention described above, it is possible to check whether the screw joint 10 can be joined after the manufacture of the screw joint is completed or before the screw joint is implemented. In addition, conventionally, it has been  
30 determined whether the male joint 11 and the female joint 12 turn, but since interference between the screw crests 13a and 14a can be confirmed as a clearance between the screws by information based on a measurement result,

accuracy can be secured. Since the determination starts from the joining completion position of the screw joint 10, it is not necessary to search for the joining start position, and further, it is possible to detect an interference point early, thus, it is possible to efficiently start the measurement of the clearance of the screw joint 10. Further, it is possible to safely and easily perform joining check in advance at a site such as a factory regardless of a screw state such as a long length and a size. The place where the measurement method of the screw joint 10 according to the present embodiment is used is not limited to a factory or the like, and the method can also be used in a place of a construction site or the like. Specifically, for example, in a construction site, when deformation of the screw joint 10 is concerned as the screw joint is damaged due to attachment of welding of an additional member, transportation, or the like, or when direct sunlight is excessively received, it is possible to measure the shapes of the male joint 11 and the female joint 12 by the measurement unit 35 in a location of the construction site and to perform joining check before actual joining. Thus, it is possible to minimize stop of site work due to a trouble.

[0108] (Second Embodiment)

Next, a method of measuring a screw joint according to a second embodiment of the present invention will be described. FIG. 12 is a flowchart for explaining a method of measuring the screw joint 10 according to the second embodiment. In the method of measuring the screw joint 10 according to the second embodiment, after the clearance  $c$  is determined in the entire screw circumference of the screw crests 13a and 14a in the male joint 11 and the female joint 12, the pass/fail determination is executed

for each screw joint 10. In addition, unlike the first embodiment, Step ST414 (see FIG. 6) as a clearance determination step is separated as a pass/fail determination step from the clearance measurement step (Step ST4).

[0109] That is, as illustrated in FIG. 12, in the method of measuring the screw joint 10 according to the second embodiment, Steps ST1 to ST4 are executed as in the first embodiment. Thereafter, instead of Step ST5 according to the first embodiment, the pass/fail determination step is executed in Step ST6. In the second embodiment, it is preferable to adopt the clearance measurement step according to the first modification or the second modification as the clearance measurement step in Step ST4.

[0110] Specifically, in the pass/fail determination step in Step ST6, the clearance calculation unit 211 determines pass/fail of joining of the screw joint 10 by the determination unit 212 in Step ST4 based on the clearance information of the entire circumference of the male screw 13 and the female screw 14 derived by execution of Steps ST423 and ST433, for example. That is, the determination unit 212 reads and acquires the clearance information from the clearance database 221 of the storage unit 22, and determines pass/fail in the joining of the screw joint 10 based on the acquired clearance information. Various criteria may be adopted as criteria for determination of pass/fail by the determination unit 212. A method similar to that in Step ST414 (see FIG. 6) as the clearance determination step described above can be used. Specifically, for example, it is determined whether the clearance  $c$  is equal to or less than a predetermined value. Here, the predetermined value is, for example, 0. In this case, when a part having a predetermined value or less,

that is, a part having 0 or less or a part to have 0 or less, is set as an interference point, it is possible to determine that a case where the number of parts is equal to or more than the preset number of parts is determined as fail, and a case other than that is determined as pass. Alternatively, it is possible to determine that the joint is fail when there is at least one part where the number of points is 0 or less or where the interference point and the flagged point are present and it is pass when there is no such a part, and the like. That is, in the clearance measurement step according to the third modification, the pass/fail can be determined according to the number of parts where the clearance  $c$  is equal to or less than a predetermined value and the number of flags of the interference points.

[0111] In the pass/fail determination step, in the same manner as in Step ST438 according to the second modification, based on not only the pass/fail of the screw joint 10 but also the measured clearance  $c$  included in the clearance information, a part where the clearance  $c$  is equal to or less than a predetermined value set in advance may be flagged as an interference point. In this case, when the number of flags is equal to or more than a predetermined number set in advance, it can be determined as fail, and when the number of flags is less than the predetermined number, it can be determined as pass.

[0112] When it is determined as pass in the pass/fail determination step (Step ST6: Yes), the procedure proceeds to Step ST61, and it is possible to output the fact that the screw joint 10 is pass to the input/output unit 23 and the like or transmit the fact to the outside via the communication unit 24 and the network 2. Accordingly, the screw joint 10 determined as pass can be shipped. On the

other hand, the screw joint 10 determined as fail can be discarded or adjusted again. In this case, the clearance information of the target screw joint 10 can be transmitted to the screw processing devices 40 and 40A in association with the identification ID of the screw joint as necessary.

[0113] According to the second embodiment, the same effects as those of the first embodiment can be obtained. Further, according to the second embodiment, it is possible to determine pass/fail by an external processing device via the network 2 using the clearance information and to share information on an inspection result of the screw joint 10.

[0114] (Third Embodiment)

Next, a method for measuring a screw joint according to a third embodiment of the present invention will be described. FIG. 13 is a flowchart for explaining a method of measuring the screw joint 10 according to the third embodiment. The method of measuring the screw joint 10 according to the third embodiment is a method of executing the adjustment step after performing the clearance measurement step in Step ST4, which is different from the first embodiment.

[0115] That is, as illustrated in FIG. 13, in the measuring method of the screw joint 10 according to the third embodiment, Steps ST1 to ST4 are executed as in the first embodiment. Thereafter, instead of Step ST5 according to the first embodiment, an adjustment step is executed in Step ST7. In the third embodiment, as the clearance measurement step in Step ST4, the clearance measurement step according to the first embodiment, the first modification, or the second modification can be adopted.

[0116] (Adjustment Step)

Next, the adjustment step in Step ST7 will be

described. As illustrated in FIG. 13, the adjustment step is executed after the clearance measurement step for the screw joint 10 which is determined as fail based on the measured clearance  $c$  or in which an interference point is present. The adjustment step includes an adjusting step to be described later. For example, when there is no output of information indicating pass or fail in the clearance measurement step executed in the preceding stage, Step ST6 (pass/fail determination step) according to the second embodiment may be executed before each adjusting step described later in Step ST7.

[0117] (Adjusting Step)

In the adjustment step for the screw joint 10 in Step ST7, the shape measurement step, the clearance measurement step, and the adjustment step may be repeatedly executed until the set of screw joints 10 that needs to be adjusted is determined to be acceptable. Further, in the adjustment step, the pass/fail determination step may be executed before the adjusting step. As the adjusting step, for example, an appropriate method may be appropriately selected and adopted from four methods according to the specification and purpose of the screw joint 10.

[0118] That is, the first method in the adjusting step is a method in which, when there is a plurality of joining start positions of the screw joint 10 such as a multi-thread screw, the joining start position is virtually changed, and the determination unit 212 executes the pass/fail determination step to perform the pass/fail determination. Here, at the time when the joint is determined as pass in the pass/fail determination step, the completion and start positions are marked at positions corresponding to the actual joint.

[0119] Next, a second method in the adjusting step is a

method in which the pass/fail determination step is executed again for the screw joint 10 in which the screw shape is corrected in consideration of virtual cutting of a part of the screw joint 10 within a range satisfying the strength required for the male joint 11 and the female joint 12, and the pass/fail determination is performed. When the interference is small, it is possible to cut the actual joint with a grinder or the like at the time when the joint is virtually determined as pass in consideration of cutting within a range of a safety factor of about 1.2, for example. The first method and the second method described above are methods that do not require the measurement unit 35 to perform a 3D scan again.

[0120] Next, a third method in the adjusting step is a method in which a part of the actual screw joint is corrected by correction by thermal deformation, measurement is performed again by the measurement unit 35, the pass/fail determination step is performed again, and the pass/fail determination is performed. The correction by thermal deformation is performed by welding heat, burner heating, compression or applying tension using a jack as necessary, or the like.

[0121] Next, a fourth method in the adjustment step is a method in which the screw joint 10 is newly manufactured and measured again by the measurement unit 35, and then the pass/fail determination step is performed again to perform the pass/fail determination. The new manufacture of the screw joint 10 includes not only the new manufacture but also the case where the screw joint 10 is detached from the pipes 15 and 16 and attached again in the case of a steel pipe with a joint. When there is a plurality of the same screw joints 10, a screw joint that passes in the pass/fail determination step can be obtained by changing the

combination of the corresponding male joint and female joint.

[0122] According to the third embodiment, the same effects as those of the first embodiment can be obtained.

5 Further, the third embodiment, including the adjusting step, can newly adjust the screw joint 10 to a passed product with the adjusting step.

[0123] (Fourth Embodiment)

Next, a fourth embodiment will be described. In the  
10 fourth embodiment, the screw joint measurement system 1A according to the second example of the embodiment is adopted as the screw joint measurement system, and the clearance measurement step according to the first embodiment is adopted. In the fourth embodiment, the  
15 clearance measurement device 20A may be formed of a fixed information processing device or a server that can communicate with the measurement terminal 30A through the network 2. In this case, the measurement terminal 30A is configured as a terminal including an independent  
20 measurement unit 35 capable of communicating with the clearance measurement device 20A via the communication unit 34 and the network 2.

[0124] Here, the control unit 31 of the measurement terminal 30A can output the clearance information  
25 transmitted from the clearance measurement device 20A by displaying the clearance information on the input/output unit 33 or the like. As the clearance information to be displayed on the input/output unit 33, it is possible to output various types of information such as a result of the  
30 pass/fail of the screw joint 10 and an enlarged display of a sectional view of an interference portion of the male screw 13 of the male joint 11 and the female screw 14 of the female joint 12.

[0125] The control unit 31 can select various types of information received from the clearance measurement device 20A via the network 2 and output the selected information from the input/output unit 33. For example, even when the clearance information including both information of pass and fail is transmitted from the clearance measurement device 20A to the measurement terminal 30A, the control unit 31 can perform control so as to output the fact of fail from the input/output unit 33 only when information of fail is transmitted. Further, since the measurement terminal 30A can communicate with the screw processing device 40A via the communication unit 34 and the network 2, the screw processing device 40A can supply the clearance information from the measurement terminal 30A to the screw processing device 40A via the clearance measurement device 20A to correct the interference point.

[0126] (Fifth Embodiment)

Next, a fifth embodiment will be described. In the fifth embodiment, the screw joint measurement system 1A according to the second example of the embodiment is adopted as a screw joint measurement system. In addition, as a method of measuring the screw joint 10, the method of measuring a screw joint according to the second embodiment illustrated in FIG. 12 is adopted. In this case, it is preferable to adopt the clearance measurement step according to the first modification or the second modification. In the fifth embodiment, the clearance measurement device 20 may be formed of a fixed information processing device, or may be formed of a server capable of communicating with the measurement terminal via the network 2. In this case, the measurement terminal 30A is formed of an independent terminal capable of communicating with the clearance measurement device 20 via the communication unit

34 and the network 2.

[0127] In the fifth embodiment, the control unit 31 of the measurement terminal 30A has a function similar to the determination unit 212 in the control unit 21 of the clearance measurement device 20A. Processing similar to that of the determination unit 212 of the clearance measurement device 20A may be configured to be executable by communication with the clearance measurement device 20A. In this case, the control unit 31 of the measurement terminal 30A can execute the joining determination step in Step ST6 illustrated in FIG. 12 based on the clearance information received from the clearance measurement device 20A.

[0128] In the fourth and fifth embodiments, since the measurement terminal 30A can be used independently, measurement and pass/fail determination of the screw joint 10 can be executed at various sites.

[0129] Although the embodiments of the present invention have been specifically described above, the present invention is not limited to the above-described embodiments, and various modifications based on the technical idea of the present invention are possible. For example, the numerical values and materials described in the embodiments are merely examples, and numerical values and materials different from those may be used as necessary.

[0130] For example, in each of the above-described embodiments and modifications, the determination unit 212 determines whether the clearance  $c$  between the male screw 13 of the male joint 11 and the female screw 14 of the female joint 12 is equal to or less than a predetermined value as a predetermined criterion, but the determination unit 212 is not limited to this configuration, and it may

determine whether the clearance  $c$  is less than a predetermined value as a predetermined criterion. As the predetermined criterion, "Yes" and "No" in Step ST414 or Step ST437 may be interchanged based on whether it is a  
5 predetermined value or more or exceeds a predetermined value. In these cases as well, the predetermined value can be set to a value of 0 or more.

[0131] For example, in the method of measuring a screw joint according to the embodiments described above, the  
10 measurement can be performed manually or automatically using shape measuring software applied to a handheld 3D scanner, high-end CAD, or the like. When the processing is automatically executed, the repetitive processing such as Steps ST413 to ST416 and Steps ST423 to ST426 described  
15 above can be executed using a software program by the control unit 21 of the clearance measurement device 20. This configuration can further improve the efficiency of the method of measuring a screw joint.

#### Industrial Applicability

20 [0132] The clearance measurement method, the clearance measurement device, the method of measuring a screw joint, the screw joint measurement system, the measurement terminal, the screw joint manufacturing method, and the screw joint quality control method according to the present  
25 invention are suitably applied to a joint structure of a steel pipe to which a steel pipe is joined.

#### Reference Signs List

[0133] 1, 1A SCREW JOINT MEASUREMENT SYSTEM  
2 NETWORK  
30 10 SCREW JOINT  
11 MALE JOINT  
12 FEMALE JOINT  
13 MALE SCREW

|    |            |                              |
|----|------------|------------------------------|
|    | 13a, 14a   | SCREW CREST                  |
|    | 13b, 14b   | SCREW BOTTOM                 |
|    | 14         | FEMALE SCREW                 |
|    | 15         | PIPE                         |
| 5  | 20, 20A    | CLEARANCE MEASUREMENT DEVICE |
|    | 21, 31, 41 | CONTROL UNIT                 |
|    | 22, 32, 42 | STORAGE UNIT                 |
|    | 23, 33, 43 | INPUT/OUTPUT UNIT            |
|    | 24, 34, 44 | COMMUNICATION UNIT           |
| 10 | 30A        | MEASUREMENT TERMINAL         |
|    | 35         | MEASUREMENT UNIT             |
|    | 40, 40A    | SCREW PROCESSING DEVICE      |
|    | 45         | SCREW PROCESSING UNIT        |
|    | 211        | CLEARANCE CALCULATION UNIT   |
| 15 | 212        | DETERMINATION UNIT           |
|    | 221        | CLEARANCE DATABASE           |
|    | 222        | PIPE TYPE DATABASE           |
|    | 311        | MEASUREMENT CONTROL UNIT     |
|    | 411        | PROCESSING CONTROL UNIT      |
| 20 |            |                              |

## CLAIMS

1. A clearance measurement method of measuring a clearance between a screw of a male joint and a screw of a female joint corresponding to the male joint included in a set of screw joints, the method comprising:

a joining completion state setting step of setting a joining completion state in which joining of the male joint and the female joint is completed based on data of screw shapes of the male joint and the female joint;

a clearance measuring step of measuring a clearance between the screw of the male joint and the screw of the female joint corresponding to the screw of the male joint in the joining completion state; and

a rotational state setting step of setting a state in which the male joint and the female joint are rotated by a predetermined angle in a direction in which the joining of the male joint and the female joint is released when the joining is not released after the clearance measuring step,

wherein the steps from the clearance measuring step to the rotational state setting step are repeated until the joining is released.

2. The clearance measurement method according to claim 1, the method comprising at least one of:

a step of determining pass/fail of the set of screw joints based on the clearance measured in the clearance measuring step and a predetermined criterion; and

an interference information assignment step of assigning information on an interference point to a point determined as the interference point based on the clearance measured in the clearance measuring step and the predetermined criterion.

3. A method of measuring a screw joint, the method comprising:

a shape measurement step of measuring each of a screw shape of a male joint and a screw shape of a female joint  
5 corresponding to the male joint included in a set of screw joints; and

a clearance measurement step of measuring a clearance for each set of the screw joints by the clearance measurement method according to claim 1 or 2 based on data  
10 of the screw shapes measured in the shape measurement step.

4. A screw joint manufacturing method of manufacturing a set of screw joints including a male joint and a female joint corresponding to the male joint, the method  
15 comprising:

a joint manufacturing step of manufacturing the set of screw joint; and

a joint measuring step of executing the method of measuring a screw joint according to claim 3 on the set of  
20 screw joints including the male joint and the female joint manufactured by the joint manufacturing step.

5. A screw joint quality control method of controlling a quality of a set of screw joints including a male joint and  
25 a female joint corresponding to the male joint, the method comprising:

a joint manufacturing step of manufacturing the set of screw joints;

a joint measuring step of measuring a screw shape of  
30 the set of screw joints manufactured by the joint manufacturing step by the method of measuring a screw joint according to claim 3; and

a quality control step of controlling quality of the

manufactured set of screw joint using a result obtained from the joint measuring step.

6. A clearance measurement device for measuring a  
5 clearance between a screw of a male joint and a screw of a female joint corresponding to the male joint included in a set of screw joints, the clearance measurement device comprising:

10 a control unit configured to repeatedly execute, until the joining is released,

a joining completion state setting step of setting a joining completion state in which joining between the male joint and the female joint is completed based on data of a screw shape of each of the male joint and the  
15 female joint and

a rotational state setting step of setting, in a case where the joining is not released after the clearance between the screw of the male joint and the screw of the female joint corresponding to the screw of the male joint  
20 is measured in the joining completion state, a state in which the male joint and the female joint are rotated by a predetermined angle in a direction in which the joining of the male joint and the female joint is released.

25 7. The clearance measurement device according to claim 6, wherein

the control unit is configured to execute, before the rotational state setting step, a clearance measuring step of measuring the clearance between the screw of the male  
30 joint and the screw of the female joint corresponding to the screw of the male joint in the joining completion state.

8. The clearance measurement device according to claim 6, further comprising a communication unit configured to execute, under control of the control unit, at least one of:

5 a step of acquiring data of the screw shape of each of the male joint and the female joint; and

a step of outputting information on the clearance obtained by the clearance measurement step.

10 9. A screw joint measurement system comprising:

a measurement unit configured to measure each of a screw shape of a male joint and a screw shape of a female joint corresponding to the male joint included in a set of screw joints; and

15 the clearance measurement device according to any one of claims 6 to 8 configured to measure a clearance for each set of the screw joints based on data of the screw shapes measured by the measurement unit.

20 10. A measurement terminal configured to measure a clearance between a screw of a male joint and a screw of a female joint corresponding to the male joint included in a set of screw joints, the measurement terminal comprising:

25 a control unit configured to control the measurement terminal;

a measurement unit configured to measure each of a screw shape of the male joint and a screw shape of the female joint under control of the control unit;

30 a communication unit configured to execute at least one of:

an output step of outputting the measured screw shapes as data to the clearance measurement device according to any one of claims 6 to 8; and

an acquisition step of acquiring information on the clearance for each set of the joints from the clearance measurement device under control of the control unit; and

an output unit configured to output the acquired  
5 information in a predetermined format under control of the control unit.

11. The measurement terminal according to claim 10,  
wherein the control unit is configured to execute at least  
10 either one of:

a step of determining pass/fail for the set of screw joints based on the acquired information on the clearance and a predetermined criterion; and

an interference information assignment step of  
15 assigning information on an interference point to a point determined as the interference point based on the acquired information on the clearance and the predetermined criterion.

20 12. A screw joint measurement system comprising:

the measurement terminal according to claim 10 or 11;  
and

the clearance measurement device according to any one of claims 6 to 8 configured to measure a clearance for each  
25 set of the screw joints based on data of screw shapes measured by the measurement terminal.

13. A screw joint quality control method of controlling a quality of a set of screw joints including a male joint and  
30 a female joint corresponding to the male joint, the method comprising

controlling quality of the set of screw joints by using information on the clearance obtained from the

clearance measuring step executed by the control unit of the clearance measurement device according to any one of claims 6 to 8.