DESCRIPTION

TITLE OF INVENTION:

Evaluation Device and Evaluation Method

TECHNICAL FIELD

[0001] The present disclosure relates to an evaluation device and an evaluation method.

BACKGROUND ART

[0002] Conventionally, a technique for measuring strain of a flange using a portable non-contact three-dimensional coordinate measuring device has been known. For example, Japanese Patent Laying-Open No. 2017-227459 (PTL 1) discloses a technique for measuring not only waviness data but also inclination data of a flange surface in measuring strain of the flange surface, without requiring much space for measurement and without degrading the measurement accuracy even at a site where vibration occurs.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Patent Laying-Open No. 2017-227459

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] One of the causes of fluid leakage from a flange portion is considered to be deterioration, damage or the like of a gasket used at a joint of piping, and thus, an operator periodically replaces the gasket. At this time, the operator visually or tactilely checks a state of a flange surface of a flange, and when determining that repair of the flange surface is necessary, performs an appropriate operation (for example, polishing or the like). For example, in a ring-joint-type flange in which a ring joint gasket is used, checking a state of a flange surface having a ring joint groove formed therein and determining necessity of repair depend on technical knowledge and experience of the operator, and vary from person to person. Further, even if an operator with poor knowledge or experience checks the flange surface (ring joint

groove), the operator cannot determine the necessity of repair in many cases.

[0005] An object of an aspect of the present disclosure is to provide an evaluation device and an evaluation method capable of determining necessity of repair of a ring joint groove formed in a flange surface based on a state of the ring joint groove.

SOLUTION TO PROBLEM

[0006] An evaluation device according to an embodiment includes: an acquisition unit that acquires first three-dimensional shape data of a ring-joint-type flange; and an evaluation unit that evaluates a state of a ring joint groove formed in a flange surface of the flange based on the first three-dimensional shape data. The evaluation unit includes: a shape measurement unit that measures a plurality of first shape parameters relating to a shape of the ring joint groove; a detection unit that detects a flaw generated in a target region of the ring joint groove; a strain amount measurement unit that measures a first strain amount of a first contact surface of the ring joint groove with which a ring joint gasket comes into contact; and a determination unit that determines necessity of repair of the ring joint groove based on at least one of the flaw, the first strain amount, and the plurality of first shape parameters.

[0007] Preferably, when at least one of the plurality of first shape parameters is out of a reference range, when a length of the flaw is equal to or greater than a first length, when the first strain amount is equal to or greater than a first threshold value, or when the length of the flaw is less than the first length and a depth of the flaw is equal to or greater than a first depth, the determination unit determines that the ring joint groove is in a state requiring repair.

[0008] Preferably, the plurality of first shape parameters include an angle formed by a center line indicating a center of the ring joint groove and the first contact surface, and a width and a depth of the ring joint groove.

[0009] Preferably, the evaluation device further includes an output control unit that outputs advice information to a user based on a determination result of the determination unit. Based on a determination result indicating that the ring joint groove is in a state requiring repair, the output control unit outputs, as the advice

information, information that recommends cutting or polishing of the ring joint groove.

[0010] Preferably, when detecting a first flaw and a second flaw that are close to each other in the target region, the detection unit integrates the first flaw and the second flaw as one flaw.

[0011] Preferably, the strain amount measurement unit measures the first strain amount in a radial direction and a circumferential direction of the flange.

[0012] Preferably, the target region is a predetermined region in the first contact surface of the ring joint groove, or an entire region of the first contact surface.

[0013] Preferably, the acquisition unit further acquires second three-dimensional shape data of the ring joint gasket. The evaluation unit further evaluates a state of the ring joint gasket based on the second three-dimensional shape data. The shape measurement unit further measures a plurality of second shape parameters relating to a shape of the ring joint gasket. The detection unit further detects a flaw of a second contact surface of the ring joint gasket with which the ring joint groove comes into contact. The strain amount measurement unit further measures a second strain amount of the second contact surface. The determination unit further determines necessity of replacement of the ring joint gasket based on at least one of the flaw of the second contact surface, the second strain amount, and the plurality of second shape parameters.

[0014] Preferably, when at least one of the plurality of second shape parameters is out of a reference range, when a length of the flaw of the second contact surface is equal to or greater than a second length, when the second strain amount is equal to or greater than a second threshold value, or when the length of the flaw of the second contact surface is less than the second length and a depth of the flaw of the second contact surface is equal to or greater than a second depth, the determination unit determines that replacement of the ring joint gasket is necessary.

[0015] Preferably, the plurality of second shape parameters include a center diameter, a height, and a width of the ring joint gasket.

[0016] Preferably, the strain amount measurement unit calculates, based on the first strain amount and the second strain amount, a third strain amount in a region where the

ring joint gasket is fitted into the ring joint groove. When the third strain amount is equal to or greater than a third threshold value, the determination unit determines that at least one of repair of the ring joint groove and replacement of the ring joint gasket is necessary.

[0017] Preferably, the acquisition unit further acquires third three-dimensional shape data of a fastened flange assembly in which the flange and another flange are fastened via the ring joint gasket. The evaluation unit further includes a gap measurement unit that measures a gap between the flange and the other flange in the fastened flange assembly based on the third three-dimensional shape data. When the gap is equal to or greater than a predetermined value, the determination unit determines that an abnormality has occurred in at least one of the ring joint groove of each of the flange and the other flange, and the ring joint gasket.

[0018] An evaluation method according to another embodiment includes: acquiring first three-dimensional shape data of a ring-joint-type flange; and evaluating a state of a ring joint groove formed in a flange surface of the flange based on the first three-dimensional shape data. The evaluating includes: measuring a plurality of first shape parameters relating to a shape of the ring joint groove; detecting a flaw generated in a target region of the ring joint groove; measuring a first strain amount of a first contact surface of the ring joint groove with which a ring joint gasket comes into contact; and determining necessity of repair of the ring joint groove based on at least one of the flaw, the first strain amount, and the plurality of first shape parameters.

ADVANTAGEOUS EFFECTS OF INVENTION

[0019] According to the present disclosure, necessity of repair of a ring joint groove formed in a flange surface can be determined based on a state of the ring joint groove.

BRIEF DESCRIPTION OF DRAWINGS

[0020] Fig. 1 is a diagram for illustrating an overall configuration of an evaluation system.

Fig. 2 is a block diagram showing an example of a hardware configuration of an evaluation device.

Fig. 3 is a flowchart for illustrating an example of an operation overview of the evaluation system.

Fig. 4 is a diagram showing a fastened flange assembly.

Fig. 5 is a diagram for illustrating a measurement scheme for shape parameters of a ring joint groove of a flange.

Fig. 6 is a diagram for illustrating a calculation scheme for a length of a flaw of the ring joint groove.

Fig. 7 is a diagram for illustrating an integration scheme for a plurality of flaws.

Fig. 8 is a diagram for illustrating a calculation scheme for a depth of the flaw of the ring joint groove.

Fig. 9 is a diagram for illustrating a measurement scheme for a strain amount of the ring joint groove in a radial direction.

Fig. 10 is a diagram for illustrating a measurement scheme for a strain amount of the ring joint groove in a circumferential direction.

Fig. 11 is a diagram for illustrating a measurement scheme for shape parameters of a gasket.

Fig. 12 is a diagram for illustrating a setting scheme for a target region of the gasket.

Fig. 13 is a diagram for illustrating a calculation scheme for a length of a flaw of the gasket.

Fig. 14 is a diagram for illustrating a calculation scheme for a depth of the flaw of the gasket.

Fig. 15 is a diagram for illustrating a measurement scheme for a strain amount of the gasket in the radial direction.

Fig. 16 is a diagram for illustrating a measurement scheme for a strain amount of the gasket in the circumferential direction.

Fig. 17 is a diagram for illustrating a measurement scheme for a strain amount of a fastened portion.

Fig. 18 is a diagram for illustrating another example of the measurement

scheme for the strain amount of the fastened portion.

Fig. 19 is a block diagram showing an example of a functional configuration of the evaluation device.

DESCRIPTION OF EMBODIMENTS

[0021] The present embodiment will be described below with reference to the drawings. In the description below, the same components have the same reference characters allotted, and their names and functions are also the same. Therefore, detailed description thereof will not be repeated.

[0022] <System Configuration>

Fig. 1 is a diagram for illustrating an overall configuration of an evaluation system. Referring to Fig. 1, an evaluation system 1000 is a system for evaluating a state of a flange surface (flange seating surface) of a flange 30. The flange 30 is a ring-joint-type flange having a ring joint seating surface as the flange seating surface. Accordingly, the flange 30 is configured such that a ring joint gasket can be fitted therein.

[0023] The evaluation system 1000 includes an evaluation device 10 and a 3D scanner 20. In the present embodiment, a case is assumed in which an operator as a user of the evaluation device 10 evaluates the state of the flange surface of the flange 30 using the 3D scanner 20, for example, when replacing a used sealing member that has been used for fastening of the flanges 30 with a new unused sealing member. The sealing member according to the present embodiment is a ring joint gasket 40 (hereinafter, also simply referred to as "gasket 40").

[0024] The gasket 40 is sandwiched in a portion where a pair of flanges 30 are joined to each other, and is fixed by tightening bolts of the flanges 30, thereby preventing a fluid from leaking from a gap between the flanges 30. The gasket 40 is a sealing member capable of sealing a gap in a portion where the gasket 40 is installed and providing sealing performance to the portion.

[0025] The 3D scanner 20 is, for example, a portable non-contact 3D scanner, and acquires three-dimensional shape data of an object (in the present embodiment, the

flange 30, the gasket 40) and outputs the acquired three-dimensional shape data. The 3D scanner 20 may use a known scheme such as a laser beam scheme or a pattern light projection scheme.

[0026] The flange 30 has a ring joint groove configured to receive the gasket 40 to be used. The gasket 40 fills and seals the ring joint grooves of the pair of flanges 30. When a fastener is tightened, the gasket 40 is pushed into the ring joint grooves and deformed to seal a joint portion between one flange 30 and the other flange 30. The gasket 40 is, for example, an octagonal ring joint gasket having an octagonal cross-sectional shape, an oval ring joint gasket having an elliptical cross-sectional shape, or the like.

[0027] The evaluation device 10 acquires the three-dimensional shape data from the 3D scanner 20 (that is, receives an input of the three-dimensional shape data). Typically, the evaluation device 10 is configured to be capable of communicating with the 3D scanner 20. In the present embodiment, based on the three-dimensional shape data of the flange 30 to be evaluated, the evaluation device 10 evaluates a state of the ring joint groove based on a flaw, strain or the like generated in the ring joint groove formed in the flange surface of the flange 30. Specifically, the evaluation device 10 determines necessity of repair of the ring joint groove, and outputs advice information about a coping method.

[0028] Further, based on the three-dimensional shape data of the gasket 40 to be evaluated, the evaluation device 10 determines necessity of replacement of the gasket 40 based on a flaw, strain or the like generated in the gasket 40, and outputs advice information about a coping method. Furthermore, the evaluation device 10 determines an abnormality of the flange 30 and the gasket 40 by utilizing the three-dimensional shape data of both the flange 30 and the gasket 40, three-dimensional shape data of a fastened assembly of the pair of flanges 30 and the gasket 40, or the like, and outputs advice information about a coping method.

[0029] The evaluation device 10 typically has a structure conforming to a general-purpose computer architecture, and causes a processor to execute a pre-installed

program to perform various processes described below. The evaluation device 10 is, for example, a laptop personal computer (PC). However, the evaluation device 10 may be any device as long as it can perform the functions and processes described below, and may be another device (for example, a desktop PC or a tablet terminal device).

[0030] <Hardware Configuration>

Fig. 2 is a block diagram showing an example of a hardware configuration of the evaluation device. Referring to Fig. 2, the evaluation device 10 includes a processor 101, a memory 103, a display 105, an input device 107, an input/output interface (I/F) 109, and a communication interface (I/F) 111. These components are connected to be capable of data communication with each other.

[0031] The processor 101 is typically an arithmetic processing unit such as a central processing unit (CPU) or a multi processing unit (MPU). The processor 101 reads and executes a program stored in the memory 103 to control the operation of each component of the evaluation device 10. Specifically, the processor 101 executes the program to implement each function of the evaluation device 10.

[0032] The memory 103 is implemented by a random access memory (RAM), a read-only memory (ROM), a hard disk, a solid state drive (SSD), or the like. The memory 103 stores the program executed by the processor 101, the three-dimensional shape data acquired by the 3D scanner 20, and the like.

[0033] The display 105 is, for example, a liquid crystal display, an organic electro luminescence (EL) display, or the like. The display 105 may be configured integrally with the evaluation device 10, or may be configured separately from the evaluation device 10.

[0034] The input device 107 receives an operation input to the evaluation device 10. The input device 107 is implemented by, for example, a keyboard, a button, a mouse, or the like. The input device 107 may be implemented as a touch panel.

[0035] The input/output interface 109 mediates data transmission between the processor 101 and the 3D scanner 20. The input/output interface 109 is connected to,

for example, the 3D scanner 20. Via the input/output interface 109, the processor 101 acquires the three-dimensional shape data measured by the 3D scanner 20.

[0036] The communication interface 111 mediates data transmission between the processor 101 and an external device. A wireless communication scheme such as Bluetooth (registered trademark) or a wireless local area network (LAN) is, for example, used as a communication scheme. A wired communication scheme such as a universal serial bus (USB) may be used as the communication scheme. The processor 101 may communicate with the 3D scanner 20 via the communication interface 111.

[0037] <Operation Overview>

Fig. 3 is a flowchart for illustrating an example of an operation overview of the evaluation system. Referring to Fig. 3, the 3D scanner 20 performs a 3D scan on the pair of flanges 30 and the gasket 40 to generate three-dimensional shape data thereof (step S10). Specifically, the 3D scanner 20 generates three-dimensional shape data of each flange 30, three-dimensional shape data of the gasket 40, and three-dimensional shape data of an assembly of the pair of flanges 30 fastened via the gasket 40 (hereinafter, also referred to as "fastened flange assembly").

[0038] The evaluation device 10 (for example, the processor 101) acquires each three-dimensional shape data from the 3D scanner 20 and stores each three-dimensional shape data in an internal memory (for example, the memory 103) (step S12).

[0039] The processor 101 measures a gap of the fastened flange assembly based on the three-dimensional shape data of the fastened flange assembly (step S14). Specifically, the processor 101 measures a gap between one flange 30 and the other flange 30 in the fastened flange assembly.

[0040] The processor 101 measures various data about the flange 30 based on the three-dimensional shape data of the flange 30 (step S16). Specifically, the processor 101 measures a shape of the ring joint groove formed in the flange surface of the flange 30, a length and a depth of a flaw generated in the ring joint groove, a strain amount of the ring joint groove, and the like.

[0041] The processor 101 measures various data about the gasket 40 based on the three-dimensional shape data of the gasket 40 (step S18). Specifically, the processor 101 measures a shape of the gasket 40, a length and a depth of a flaw generated in the gasket 40, a strain amount of the gasket 40, and the like. Furthermore, the processor 101 measures a strain amount of a region where the gasket 40 is fitted into the ring joint groove (step S20).

[0042] The processor 101 determines necessity of repair of the ring joint groove and replacement of the gasket 40 based on the respective measurement results in steps S14 to S20 (step S22). The processor 101 displays advice information to the user on the display 105 based on the determination result (step S24).

[0043] According to the evaluation system 1000, the shapes, the flaws, the strain amounts, and the like of the ring joint groove and the gasket 40 are measured using the three-dimensional shape data of the flange 30 and the gasket 40. Further, the gap of the fastened flange assembly and the strain amount when the gasket 40 is fitted into the ring joint groove are also measured. Then, the necessity of repair of the ring joint groove and replacement of the gasket 40 is determined based on the respective measurement results, and the advice information corresponding to the determination results is presented. Therefore, the operator can quickly grasp the necessity of repair and replacement, and can efficiently perform an action based on the advice information.

[0044] <Measurement of Gap of Fastened Flange Assembly>

Specific processing details of step S14 in Fig. 3 will now be described.

[0045] Fig. 4 is a diagram showing the fastened flange assembly. Fig. 4(a) shows a state in which an oval ring joint gasket 40 is fitted into a ring joint groove 310. Fig. 4(b) shows a state in which an octagonal ring joint gasket 40 is fitted into the ring joint groove.

[0046] Fig. 4(a) shows a fastened flange assembly in which the pair of flanges 30 (that is, an upper flange and a lower flange) are fastened via the oval gasket 40. Fig. 4(b) shows a fastened flange assembly in which the pair of flanges 30 are fastened via the octagonal gasket 40. Specifically, the oval (or octagonal) gasket 40 is fitted into the

ring joint groove 310 formed in the flange surface 300 of each flange 30. The ring joint groove 310 has a side surface 311 and a bottom surface 312. Typically, the oval (or octagonal) gasket 40 comes into contact with the side surface 311 of the ring joint groove 310.

[0047] As shown in Fig. 4, a gap Cg between one flange 30 (for example, the upper flange) and the other flange 30 (for example, the lower flange) is formed. The evaluation device 10 measures the gap Cg based on the three-dimensional shape data of the fastened flange assembly. A configuration may be adopted in which the operator measures the gap Cg with calipers and inputs the measurement value to the evaluation device 10. Typically, the evaluation device 10 measures the gap Cg at a plurality of locations (for example, four or more locations).

[0048] <Measurement of Various Data About Flange>

Specific processing details of step S16 in Fig. 3 will now be described.

[0049] (Measurement of Shape Parameters)

Fig. 5 is a diagram for illustrating a measurement scheme for shape parameters of the ring joint groove of the flange. Referring to Fig. 5(a) and Fig. 5(b), the evaluation device 10 measures a plurality of shape parameters P1 relating to the shape of the ring joint groove 310 based on the three-dimensional shape data of the flange 30.

[0050] The plurality of shape parameters P1 include an angle θr formed by a center line indicating a center of the ring joint groove 310 and the side surface 311, and a width F and a depth d of the ring joint groove 310. The side surface 311 corresponds to a contact surface of the ring joint groove 310 with which the gasket 40 comes into contact. The depth d corresponds to a distance between the flange surface 300 and the bottom surface 312 of the ring joint groove 310. The shape parameters P1 may include a corner radius of the ring joint groove 310 (not shown).

[0051] (Measurement of Length and Depth of Flaw)

The evaluation device 10 detects a flaw generated in a target region Nf of the ring joint groove 310 based on the three-dimensional shape data of the flange 30. The flaw of the ring joint groove 310 may be detected using a known technique. For

example, the evaluation device 10 detects the flaw of the ring joint groove 310 by comparing a feature amount of the flaw stored in advance in the memory 103 with a feature amount of an image created based on the three-dimensional shape data. Typically, the target region Nf is set to a region that comes into contact with the gasket 40 on each of the side surfaces 311 on an inner diameter side and on an outer diameter side of the ring joint groove 310.

[0052] Referring to Fig. 5(a), when the oval ring joint gasket is adopted, a width W of the target region Nf is set to, for example, "d/2". A center position of the target region Nf is set to, for example, a center position of the side surface 311 (a center position between the flange surface 300 and the bottom surface 312).

[0053] Referring to Fig. 5(b), when the octagonal ring joint gasket is adopted, the width W of the target region Nf is set to a width "w*" or "w* × (4/3)" of an inclined side portion of the ring joint gasket. The evaluation device 10 may measure an actual measurement value of a width of an actual contact region between the ring joint groove 310 and the gasket 40 based on the three-dimensional shape data, and use the actual measurement value as the width W.

[0054] Fig. 6 is a diagram for illustrating a calculation scheme for the length of the flaw of the ring joint groove. Referring to Fig. 6(a) and Fig. 6(b), the evaluation device 10 measures (calculates) a length L of a flaw 50 generated in the target region Nf of the side surface 311 based on the three-dimensional shape data. For example, perpendicular lines 351 to 353 are drawn from the center line to the side surface 311. The perpendicular line 351 intersects the flange surface 300, the perpendicular line 352 intersects one end of the flaw 50 generated in the side surface 311, and the perpendicular line 353 intersects the other end of the flaw 50. Accordingly, lengths L1 and L2 are calculated, and thus, the length L of the flaw 50 is calculated based on these lengths L1 and L2, the angle θr included in the shape parameter P1, an angle θ (= 90° – θr), and the like.

[0055] Fig. 7 is a diagram for illustrating an integration scheme for a plurality of flaws. Fig. 7(a) shows an example of the integration scheme for a plurality of flaws. Fig.

7(b) shows another example of the integration scheme for a plurality of flaws. Fig. 7(c) shows the length of the flaw after a plurality of flaws are integrated.

[0056] When a plurality of flaws are located at a close distance to each other, the evaluation device 10 integrates the plurality of flaws as one flaw. Referring to Fig. 7(a), the evaluation device 10 detects flaws A1 to A3. Subsequently, the evaluation device 10 calculates a plurality of integration regions B1 to B3 corresponding to the plurality of flaws A1 to A3, respectively. The integration region is a region set in order to determine whether or not the plurality of flaws can be integrated as one flaw. For example, the integration region B1 is a region defined by a distance of a region width K from each position of the flaw A1. Similarly, the integration regions B2 and B3 are regions defined by a distance of the region width K from each position of the flaws A2 and A3, respectively.

[0057] For the plurality of integration regions B1 to B3, the evaluation device 10 determines whether or not each of the integration regions B1 to B3 overlaps with other integration regions. In the example in Fig. 7(a), the integration regions B1 to B3 overlap with each other, and thus, the evaluation device 10 integrates the plurality of flaws A1 to A3 as one flaw.

[0058] Referring to Fig. 7(b), the evaluation device 10 detects the flaws A1 and A2, and calculates a plurality of integration regions B1 and B2 corresponding to the plurality of flaws A1 and A2, respectively. A calculation scheme for the integration region B1 will be described. A reference line indicating a maximum length of the flaw A1 is drawn, and line segments C1 and C2 located at a distance of the region width K from two ends of the flaw A1 on the reference line are obtained. Subsequently, in a left-right direction orthogonal to the reference line, ends of the flaw A1 located farthest from the reference line are identified. Line segments C3 and C4 located at a distance of the region width K from the specified ends in the respective directions are obtained. The integration region B1 is a region enclosed by the line segments C1 to C4. The integration region B2 is also obtained by the same calculation scheme.

[0059] The evaluation device 10 determines whether or not the integration region B1 overlaps with the integration region B2. In the example in Fig. 7(b), the integration regions B1 and B2 overlap with each other, and thus, the evaluation device 10 integrates the plurality of flaws A1 and A2 as one flaw.

[0060] Referring to Fig. 7(c), it is assumed that the evaluation device 10 integrates the flaws A1 to A3 using the above-described integration scheme and considers the flaws A1 to A3 as one flaw. In this case, the maximum length of the integrated flaw is defined by a distance between a point R1 closest to the flange surface 300 among respective positions of the flaws A1 to A3 and a point R2 closest to the bottom surface 312 (or farthest from the flange surface 300) among the respective positions of the flaws A1 to A3. Therefore, in accordance with the method described with reference to Fig. 6, the length L of the integrated flaw is calculated using a length of a line segment R1R2.

[0061] Fig. 8 is a diagram for illustrating a calculation scheme for a depth of the flaw of the ring joint groove. Referring to Fig. 8(a), as an example, a perpendicular line is drawn from the side surface 311 (an inclined side of the ring joint groove 310) to the deepest position of the flaw 50, and a length of the perpendicular line is measured (calculated) as a depth D of the flaw 50. Referring to Fig. 8(b), as another example, a perpendicular line is drawn from the center line to the deepest position of the flaw 50. A distance between an intersection point of the perpendicular line and the side surface 311 (the inclined side of the ring joint groove 310) and the deepest position is calculated as the depth D of the flaw 50. Referring to Fig. 8(c), as still another example, an imaginary surface 361 surrounding a peripheral portion of the flaw 50 is defined. A distance from the imaginary surface 361 to the deepest position of the flaw 50 is calculated as the depth D.

[0062] (Measurement of Strain Amount)

Based on the three-dimensional shape data of the flange 30, the evaluation device 10 measures a strain amount of a contact surface (that is, the side surface 311) of the ring joint groove 310 with which the gasket 40 comes into contact. Specifically,

the evaluation device 10 measures the strain amount of the side surface 311 in a radial direction and a circumferential direction of the flange 30.

[0063] Fig. 9 is a diagram for illustrating a measurement scheme for the strain amount of the ring joint groove in the radial direction. Fig. 9(a) is a top view of the flange surface 300. Fig. 9(b) and Fig. 9(c) are cross-sectional views of the ring joint groove 310.

[0064] Referring to Fig. 9(a), a plurality of check lines are drawn from a center O of the flange toward the radial direction. Typically, the check lines are drawn at equal intervals (for example, at intervals of 45 degrees) in the circumferential direction of the flange. The strain amount is measured for the side surfaces 311 on the inner diameter side and the outer diameter side intersecting the check lines.

[0065] Referring to Fig. 9(b), an average surface of the side surface 311 (the inclined side of the ring joint groove 310) in which strain is generated is defined as a reference surface (a conical side surface). A perpendicular line is drawn from the reference surface to the side surface 311, and a length of the perpendicular line is measured (calculated) as a strain amount Sr in the radial direction. Referring to Fig. 9(c), as another example, a perpendicular line is drawn from the center line to the reference surface. A distance between an intersection point of the perpendicular line and the side surface 311 (the inclined side of the ring joint groove 310) and an intersection point of the perpendicular line and the reference surface is calculated as the strain amount Sr in the radial direction.

[0066] Fig. 10 is a diagram for illustrating a measurement scheme for the strain amount of the ring joint groove in the circumferential direction. Fig. 10(a) and Fig. 10(b) are cross-sectional views of the ring joint groove 310. Fig. 10(c) is a diagram showing a trajectory of an intersection point of the side surface 311 of the ring joint groove 310 and a measurement surface in the circumferential direction.

[0067] Referring to Fig. 10(a), an angle θm formed by a central axis of an inner diameter of the flange 30 and the flange surface 300 is defined. Based on the angle θm, a plurality of measurement surfaces X1 and X2 parallel to the flange surface 300

are created. An intersection point of the measurement surface X1 and the side surface 311 on the outer diameter side is defined as a point Od1, and an intersection point of the measurement surface X1 and the side surface 311 on the inner diameter side is defined as a point Id1. An intersection point of the measurement surface X2 and the side surface 311 on the outer diameter side is defined as a point Od2, and an intersection point of the measurement surface X2 and the side surface 311 on the inner diameter side is defined as a point Id2. As another example, referring to Fig. 10(b), the plurality of measurement surfaces X1 and X2 may be created by drawing a perpendicular line from the central axis to the ring joint groove 310.

[0068] Referring to Fig. 10(c), a trajectory of the point Od1 on an entire circumference of the ring joint groove 310 is shown. An average of the trajectory is defined as a reference circle, and a distance between the reference circle and the trajectory is measured (calculated) as a strain amount Sc in the circumferential direction. Then, an area within a predetermined distance (for example, $\pm$ 0.15 mm) from the reference circle is set as an allowable region. In the example in Fig. 10(c), the trajectory of the point Od1 is included in the allowable region (that is, the strain amount Sc is less than the predetermined distance), and thus, the strain amount Sr at the point Od1 of the side surface 311 is allowable. The strain amounts at the points Od2, Id1, and Id2 are also calculated in the same manner.

[0069] <Measurement of Various Data About Gasket>

Specific processing details of step S18 in Fig. 3 will now be described.

[0070] (Measurement of Shape Parameters)

Fig. 11 is a diagram for illustrating a measurement scheme for shape parameters of the gasket. Referring to Fig. 11(a) and Fig. 11(b), the evaluation device 10 measures a plurality of shape parameters P2 relating to a shape of the gasket 40 based on the three-dimensional shape data of the gasket 40.

[0071] Referring to Fig. 11(a), when the gasket 40 is an oval ring joint gasket, the plurality of shape parameters P2 include a center diameter (that is, a distance between an inner diameter center line and a cross-sectional center line of the gasket 40), a height

Hov, a width Aov, and a length of an R portion of the gasket 40. Referring to Fig. 11(b), when the gasket 40 is an octagonal ring joint gasket, the plurality of shape parameters P2 include the center diameter, a height Hoc, a width Aoc, a flat surface width Coc of a head portion, and a taper angle θoc of the head portion of the gasket 40.

[0072] (Measurement of Length and Depth of Flaw)

The evaluation device 10 detects a flaw generated in a target region Ng of the gasket 40 based on the three-dimensional shape data of the gasket 40. The flaw of the gasket 40 may be detected using a known technique. For example, the evaluation device 10 detects the flaw of the gasket 40 by comparing a feature amount of the flaw stored in advance in the memory 103 with a feature amount of an image created based on the three-dimensional shape data. Typically, the target region Ng is set to contact surfaces of the gasket 40 with which the respective side surfaces 311 on the inner diameter side and the outer diameter side of the ring joint groove 310 come into contact.

[0073] Fig. 12 is a diagram for illustrating a setting scheme for the target region of the gasket. Referring to Fig. 12(a), when an oval ring joint gasket is adopted, a tangent line 401 is drawn to the gasket 40 such that an angle formed with a cross-sectional center line of the gasket 40 becomes an angle θr. Centered at a contact point between the tangent line 401 and the gasket 40, a width of "d/2" is defined, and two perpendicular lines are drawn to the gasket 40. An intersection point of one perpendicular line and the gasket 40 is defined as a point Y1, and an intersection point of the other perpendicular line and the gasket 40 is defined as a point Y2.

[0074] The target region Ng when the gasket 40 is an oval ring joint gasket is set to a side surface region of the gasket 40 from the point Y1 to the point Y2. The target region Ng shown in Fig. 12(a) includes the contact surface of the gasket 40 with which the side surface 311 on the outer diameter side of the ring joint groove 310 comes into contact.

[0075] Referring to Fig. 12(b), when an octagonal ring joint gasket is adopted, a width of "w* × (4/3)" is defined centered at the center of the inclined side portion, and two

perpendicular lines are drawn to the gasket 40. An intersection point of one perpendicular line and the gasket 40 is defined as a point Y3, and an intersection point of the other perpendicular line and the gasket 40 is defined as a point Y4.

[0076] The target region Ng when the gasket 40 is an octagonal ring joint gasket is set to a side surface region of the gasket 40 from the point Y3 to the point Y4. The target region Ng shown in Fig. 12(b) includes the contact surface of the gasket 40 with which the side surface 311 on the outer diameter side of the ring joint groove 310 comes into contact. A configuration may be adopted in which a side surface region defined by a width of "w*" centered at the center of the inclined side portion is set as the target region Ng.

[0077] Fig. 13 is a diagram for illustrating a calculation scheme for a length of the flaw of the gasket. Referring to Fig. 13(a) and Fig. 13(b), the evaluation device 10 measures (calculates) a length Lg of a flaw 60 generated in the target region Ng of the gasket 40 based on the three-dimensional shape data. For example, perpendicular lines 451 to 453 are drawn from the cross-sectional center line to a contact surface 411 of the gasket 40 (that is, a surface where the gasket 40 and the ring joint groove 310 come into contact). The perpendicular line 451 intersects an end of the contact surface 411, the perpendicular line 452 intersects one end of the flaw 60 generated in the target region Ng, and the perpendicular line 453 intersects the other end of the flaw 60. Accordingly, lengths L1g and L2g are calculated, and thus, the length Lg of the flaw 60 is calculated based on these lengths L1g and L2g, an angle θr included in the shape parameter P2, an angle θ ($= 90° - \theta r$), and the like.

[0078] An integration scheme for a plurality of flaws generated in the gasket 40 is the same as the above-described integration scheme for the plurality of flaws generated in the ring joint groove.

[0079] Fig. 14 is a diagram for illustrating a calculation scheme for a depth of the flaw of the gasket. Referring to Fig. 14(a), a perpendicular line is drawn from the contact surface 411 of the gasket 40 to the deepest position of the flaw 60, and a length of the perpendicular line is measured (calculated) as a depth Dg of the flaw 60. Referring to

Fig. 14(b), as another example, a perpendicular line is drawn from the cross-sectional center line to the deepest position of the flaw 60. A distance between an intersection point of the perpendicular line and the contact surface 411 of the gasket 40 and the deepest position is calculated as the depth Dg of the flaw 60. Referring to Fig. 14(c), as still another example, an imaginary surface 461 surrounding a peripheral portion of the flaw 60 is defined. A distance from the imaginary surface 461 to the deepest position of the flaw 60 is calculated as the depth Dg.

[0080] (Measurement of Strain Amount)

Based on the three-dimensional shape data of the gasket 40, the evaluation device 10 measures a strain amount of the contact surface 411 of the gasket 40 with which the side surface 311 of the ring joint groove 310 comes into contact. Specifically, the evaluation device 10 measures the strain amount of the contact surface 411 in the radial direction and the circumferential direction of the gasket 40. The contact surface 411 of the oval gasket 40 is a surface including the R portion of the gasket 40. The contact surface 411 of the octagonal gasket 40 is a surface including the inclined side portion of the gasket 40.

[0081] Fig. 15 is a diagram for illustrating a measurement scheme for the strain amount of the gasket in the radial direction. Fig. 15(a) is a top view of the gasket 40. Fig. 15(b) and Fig. 15(c) are cross-sectional views of the gasket 40.

[0082] Referring to Fig. 15(a), a plurality of check lines are drawn from a center Og of an inner diameter of the gasket 40 toward the radial direction. Typically, the check lines are drawn at equal intervals (for example, at intervals of 45 degrees) in the circumferential direction of the gasket 40. The strain amount is measured for the contact surfaces 411 on the inner diameter side and the outer diameter side intersecting the check lines.

[0083] Referring to Fig. 15(b), an average surface of the contact surface 411 in which strain is generated is defined as a reference surface. A perpendicular line is drawn from the reference surface to the contact surface 411, and a length of the perpendicular line is measured (calculated) as a strain amount Srg in the radial direction. Referring

to Fig. 15(c), as another example, a perpendicular line is drawn from the center line to the reference surface. A distance between an intersection point of the perpendicular line and the contact surface 411 and an intersection point of the perpendicular line and the reference surface is calculated as the strain amount Srg in the radial direction.

[0084] Fig. 16 is a diagram for illustrating a measurement scheme for the strain amount of the gasket in the circumferential direction. Fig. 16(a) and Fig. 16(b) are cross-sectional views of the gasket 40. Fig. 16(c) is a diagram showing a trajectory in the circumferential direction of an intersection point of the contact surface 411 of the gasket 40 and a measurement surface.

[0085] Referring to Fig. 16(a), an angle θmg formed by a central axis of the inner diameter of the gasket 40 and a bottom surface 412 (or a top surface) of the gasket 40 is defined. Based on the angle θmg, a plurality of measurement surfaces X1g and X2g parallel to the contact surface 411 of the gasket 40 are created. An intersection point of the measurement surface X1g and the contact surface 411 on the outer diameter side is defined as a point Oe1, and an intersection point of the measurement surface X1g and the contact surface 411 on the inner diameter side is defined as a point Ie1. Further, an intersection point of the measurement surface X2g and the contact surface 411 on the outer diameter side is defined as a point Oe2, and an intersection point of the measurement surface X2g and the contact surface 411 on the inner diameter side is defined as a point Ie2. As another example, referring to Fig. 16(b), the plurality of measurement surfaces X1g and X2g may be created by drawing a perpendicular line from the central axis to the gasket 40.

[0086] Referring to Fig. 16(c), a trajectory of the point Oe1 on an entire circumference of the gasket 40 is shown. An average of the trajectory is defined as a reference circle, and a distance between the reference circle and the trajectory is measured (calculated) as a strain amount Scg in the circumferential direction. Then, an area within a predetermined distance (for example, ± 0.15 mm) from the reference circle is set as an allowable region. In the example in Fig. 16(c), the trajectory of the point Oe1 is included in the allowable region (that is, the strain amount Scg is less than the

predetermined distance), and thus, the strain amount Srg at the point Oe1 of the contact surface 411 is allowable. The strain amounts at the points Oe2, Ie1, and Ie2 are also calculated in the same manner.

[0087] <Measurement of Strain Amount When Gasket Is Fitted>

Specific processing details of step S20 in Fig. 3 will now be described.

[0088] The strain amount of the side surface 311 of the ring joint groove 310 can be measured by the schemes described with reference to Fig. 9 and Fig. 10. Further, the strain amount of the contact surface 411 of the gasket 40 can be measured by the schemes described with reference to Fig. 15 and Fig. 16. However, in practice, since these are used in a state where the gasket 40 is fitted into the ring joint groove 310, it is preferable to measure how much strain is generated in this state. A measurement scheme for a strain amount of a fastened portion in which the gasket 40 is fitted into the ring joint groove 310 will now be described.

[0089] Fig. 17 is a diagram for illustrating a measurement scheme for the strain amount of the fastened portion. Fig. 17(a) is a diagram for illustrating the strain amounts of the contact surface of the gasket and the side surface of the ring joint groove. Fig. 17(b) is a diagram for illustrating the strain amount of the fastened portion.

[0090] Referring to Fig. 17(a), both the strain amount of the contact surface 411 of the gasket 40 and the strain amount of the side surface 311 of the ring joint groove are less than a reference strain amount Thx. Therefore, the evaluation device 10 determines that the respective strain amounts of the contact surface 411 and the side surface 311 are allowable strain amounts.

[0091] Referring to Fig. 17(b), the evaluation device 10 calculates the strain amount of the fastened portion in which the gasket 40 is fitted into the ring joint groove 310, based on the respective strain amounts of the contact surface 411 and the side surface 311. Specifically, a total value of the strain amount at each position of the contact surface 411 and the strain amount at each position of the side surface 311 facing each position of the contact surface 411 when the gasket 40 is fitted into the ring joint groove 310 is calculated as the strain amount of the fastened portion.

[0092] For example, referring to Fig. 17(a), in a region 501, the contact surface 411 is strained upward (in a +Th direction), and the side surface 311 is also strained upward. Therefore, the strain amount of the fastened portion is not large, and is less than the reference strain amount Thx.

[0093] On the other hand, in a region 502, although the contact surface 411 is strained upward, the side surface 311 is strained downward (in a −Th direction). Therefore, the strain amount of the fastened portion is large, and is equal to or greater than the reference strain amount Thx.

[0094] The evaluation device 10 extracts a maximum value of the strain amount of the fastened portion and compares the maximum value with the reference strain amount Thx to determine whether or not the strain amount of the fastened portion is allowable.

[0095] Fig. 18 is a diagram for illustrating another example of the measurement scheme for the strain amount of the fastened portion. Fig. 18(a) is a diagram for illustrating the strain amounts of the contact surface of the gasket and the side surface of the ring joint groove. Fig. 18(b) is a diagram for illustrating the strain amount of the fastened portion.

[0096] In the example in Fig. 18(a), a flaw or an adhering substance is present on the side surface 311 of the ring joint groove 310. When a flaw or an adhering substance is present on the side surface 311 (or the contact surface 411) as described above, a configuration may be adopted in which the strain amount is calculated in consideration thereof. Referring to Fig. 18(b), it can be seen that the strain amount of the fastened portion is equal to or greater than the reference strain amount Thx in a region where a flaw or an adhering substance is present on the side surface 311.

[0097] <Determination of Necessity of Repair and Replacement>

Specific processing details of step S22 in Fig. 3 will now be described.

[0098] Based on the respective evaluation results described above, the evaluation device 10 determines the necessity of repair of the ring joint groove 310 and replacement of the gasket 40. Specifically, the necessity of repair and replacement is determined using the following conditions.

[0099] (Condition Z1: Gap of Fastened Flange Assembly)

A condition Z1 is a condition based on the gap Cg of the fastened flange assembly. Specifically, the evaluation device 10 determines whether or not the condition Z1 that at least one of the respective gaps Cg measured at the plurality of locations is equal to or greater than a reference value Cx (for example, 1.5 mm) is satisfied. When the condition Z1 is satisfied, the evaluation device 10 determines that an abnormality has occurred in at least one of the ring joint groove 310 of each of the one flange 30 and the other flange 30, and the gasket 40.

[0100] The evaluation device 10 evaluates a severity of the flange 30 and the gasket 40. The severity is evaluated on an 11-point scale of "0 to 10". It is assumed that the larger the severity value is, the more severe the state of the flange 30 and the gasket 40 is (that is, the worse the state of the flange 30 and the gasket 40 is). When the condition Z1 is satisfied, the evaluation device 10 evaluates the severity as "2".

[0101] (Condition Z2: Shape of Ring Joint Groove)

A condition Z2 is a condition based on the shape parameter P1 of the ring joint groove 310 of the flange 30. The evaluation device 10 determines whether or not each shape parameter P1 satisfies a corresponding reference.

[0102] Specifically, the evaluation device 10 determines whether or not a condition Z2a that the angle θr is outside a reference angle range θx (for example, a range of 23 ± 0.5 degrees) is satisfied. The evaluation device 10 determines whether or not a condition Z2b that the width F of the ring joint groove 310 is outside a reference range Fx (for example, a range of a specified width $\pm$ 0.2 mm) is satisfied. The evaluation device 10 determines whether or not a condition Z2c that the depth d of the ring joint groove 310 is outside a reference range dx (for example, a range of "specified depth" to "specified depth + 0.4 mm") is satisfied.

[0103] Then, when at least one of the condition Z2a to the condition Z2c is met (that is, when the condition Z2 is satisfied), the evaluation device 10 determines that the ring joint groove 310 is in a state requiring repair. When the condition Z2 is satisfied, the evaluation device 10 evaluates the severity of the ring joint groove 310 as "10".

[0104] (Condition Z3: Flaw and Strain Amount of Ring Joint Groove)

A condition Z3 is a condition based on a maximum length Lmax of the flaw generated in the target region Nf of the ring joint groove 310 and the strain amount of the side surface 311. The maximum length Lmax is a maximum value of lengths L of a plurality of detected flaws.

[0105] The evaluation device 10 determines whether or not a condition Z3a that the maximum length Lmax of the flaw is equal to or greater than a reference value Lx1 is satisfied. The reference value Lx1 is set to, for example, "W × (1/2)" using the width W of the target region Nf. As described above, when an oval ring joint gasket is adopted, "W = d/2", and when an octagonal ring joint gasket is adopted, "W = w* × (4/3)" or "W = w*". When the maximum length Lmax is equal to or greater than the reference value Lx1 (that is, when the condition Z3a is satisfied), the evaluation device 10 determines that the ring joint groove 310 is in a state requiring repair.

[0106] Further, the evaluation device 10 determines whether or not the strain amount of the side surface 311 is equal to or greater than a reference strain amount Th1 (for example, 0.15 mm). Specifically, the evaluation device 10 determines whether or not a condition Z3b that both a maximum strain amount J1 of the side surface 311 in the radial direction and a maximum strain amount J2 of the side surface 311 in the circumferential direction are equal to or greater than the reference strain amount Th1 is satisfied. When both the maximum strain amount J1 and the maximum strain amount J2 are equal to or greater than the reference strain amount Th1 (that is, when the condition Z3b is satisfied), the evaluation device 10 determines that the ring joint groove 310 is in a state requiring repair.

[0107] In summary, when at least one of the condition Z3a and the condition Z3b is satisfied (that is, when the condition Z3 is satisfied), the evaluation device 10 determines that the ring joint groove 310 is in a state requiring repair. When the condition Z3 is satisfied, the evaluation device 10 evaluates the severity of the ring joint groove 310 as "8".

[0108] (Condition Z4: Flaw of Ring Joint Groove)

A condition Z4 is a condition based on the length L and the depth D of the flaw of the ring joint groove.

[0109] The evaluation device 10 determines whether or not a condition Z4a that a flaw having the length L which is less than the reference value Lx1 and equal to or greater than a reference value Lx2 and having the depth D which is equal to or greater than a reference value Dx1 (for example, 0.25 mm) is present is satisfied. For example, the reference value Lx2 is set to "W × (1/4)". Further, the evaluation device 10 determines whether or not a condition Z4b that a flaw having the length L which is less than the reference value Lx2 and having the depth D which is equal to or greater than a reference value Dx2 (for example, 0.75 mm) is present is satisfied.

[0110] When at least one of the condition Z4a and the condition Z4b is satisfied (that is, when the condition Z4 is satisfied), the evaluation device 10 determines that the ring joint groove 310 is in a state requiring repair. When the condition Z4 is satisfied, the evaluation device 10 evaluates the severity of the ring joint groove 310 as "6".

[0111] (Condition Z5: Shape of Gasket)

A condition Z5 is a condition based on the shape parameter P2 of the gasket 40. The evaluation device 10 determines whether or not each shape parameter P2 satisfies a corresponding reference.

[0112] Specifically, the evaluation device 10 determines whether or not a condition Z5a that the center diameter of the gasket 40 is outside a reference range Cdx (for example, a range of a specified value ± 0.18 mm) is satisfied. The evaluation device 10 determines whether or not a condition Z5b that the height H (for example, Hov, Hoc) of the gasket 40 is outside a reference range Hx (for example, a range of "specified value – 0.5 mm" to "specified value + 1.3 mm") is satisfied. The evaluation device 10 determines whether or not a condition Z5c that the width A (for example, Aov, Aoc) of the gasket 40 is outside a reference range Ax (for example, a range of a specified value ± 0.2 mm) is satisfied.

[0113] When the oval gasket 40 is adopted, the evaluation device 10 determines whether or not a condition Z5d that the length of the R portion of the gasket 40 is

outside a reference range (for example, a range of a specified value ± 0.2 mm) is satisfied.

[0114] When the octagonal gasket 40 is adopted, the evaluation device 10 determines whether or not a condition Z5e that the flat surface width Coc of the gasket 40 is outside a reference range (for example, a range of a specified value ± 0.2 mm) is satisfied. Furthermore, the evaluation device 10 determines whether or not a condition Z5f that the taper angle θoc of the head portion of the gasket 40 is outside a reference range (for example, a range of 23 ± 0.5 degrees) is satisfied.

[0115] When at least one of the condition Z5a to the condition Z5d is met (that is, when the condition Z5 is satisfied) for the oval gasket 40, the evaluation device 10 determines that the gasket 40 is in a state requiring replacement. Further, when at least one of the conditions Z5a to Z5c, Z5e, and Z5f is met (that is, when the condition Z5 is satisfied) for the octagonal gasket 40, the evaluation device 10 determines that the gasket 40 is in a state requiring replacement. When the condition Z5 is satisfied, the evaluation device 10 evaluates the severity of the gasket 40 as "10".

[0116] (Condition Z6: Flaw and Strain Amount of Gasket)

A condition Z6 is a condition based on a maximum length Lgmax of the flaw generated in the target region Ng of the gasket 40 and the strain amount of the contact surface 411. The maximum length Lgmax is a maximum value of lengths Lg of a plurality of detected flaws.

[0117] The evaluation device 10 determines whether or not a condition Z6a that the maximum length Lgmax of the flaw is equal to or greater than a reference value Lgx1 is satisfied. The reference value Lgx1 is set to, for example, "Wg × (1/2)" using the width Wg of the target region Ng. When the oval ring joint gasket is adopted, the width Wg is the width of the target region Ng in Fig. 12(a). When the octagonal ring joint gasket is adopted, the width Wg is the width of the target region Ng in Fig. 12(b). When the maximum length Lgmax is equal to or greater than the reference value Lgx1 (that is, when the condition Z6a is satisfied), the evaluation device 10 determines that the gasket 40 is in a state requiring replacement.

[0118] The evaluation device 10 determines whether or not the strain amount of the contact surface 411 is equal to or greater than a reference strain amount Th2 (for example, 0.15 mm). Specifically, the evaluation device 10 determines whether or not a condition Z6b that both a maximum strain amount Jg1 of the contact surface 411 in the radial direction and a maximum strain amount Jg2 of the contact surface 411 in the circumferential direction are equal to or greater than the reference strain amount Th2 is satisfied. When both the maximum strain amount J1 and the maximum strain amount J2 are equal to or greater than the reference strain amount Th2 (that is, when the condition Z6b is satisfied), the evaluation device 10 determines that the gasket 40 is in a state requiring replacement.

[0119] In summary, when at least one of the condition Z6a and the condition Z6b is satisfied (that is, when the condition Z6 is satisfied), the evaluation device 10 determines that the gasket 40 is in a state requiring replacement. When the condition Z6 is satisfied, the evaluation device 10 evaluates the severity of the gasket 40 as "8".

[0120] (Condition Z7: Flaw of Gasket)

A condition Z7 is a condition based on the length Lg and the depth Dg of the flaw of the gasket.

[0121] The evaluation device 10 determines whether or not a condition Z7a that a flaw having the length Lg which is less than a reference value Lgx1 and equal to or greater than a reference value Lgx2 and having the depth Dg which is equal to or greater than the reference value Dx1 (for example, 0.25 mm) is present is satisfied. For example, the reference value Lgx2 is set to "Wg × (1/4)". Further, the evaluation device 10 determines whether or not a condition Z7b that a flaw having the length Lg which is less than the reference value Lgx2 and having the depth Dg which is equal to or greater than the reference value Dx2 (for example, 0.75 mm) is present is satisfied.

[0122] When at least one of the condition Z7a and the condition Z7b is satisfied (that is, when the condition Z7 is satisfied), the evaluation device 10 determines that the gasket 40 is in a state requiring replacement. When the condition Z7 is satisfied, the evaluation device 10 evaluates the severity of the gasket 40 as "6".

[0123] (Condition Z8: Strain Amount of Fastened Portion)

A condition Z8 is a condition based on the strain amount of the fastened portion in which the gasket 40 is fitted into the ring joint groove 310.

[0124] The evaluation device 10 determines whether or not a condition Z8 that the maximum value of the strain amount of the fastened portion is equal to or greater than the reference strain amount Thx (for example, 0.05 mm) is satisfied. When the maximum value of the strain amount of the fastened portion is equal to or greater than the reference strain amount Thx (that is, when the condition Z8 is satisfied), the evaluation device 10 determines that the ring joint groove 310 is in a state requiring repair, or that the gasket 40 is in a state requiring replacement. When the condition Z8 is satisfied, the evaluation device 10 evaluates the severity of the fastened portion as "4".

[0125] (Condition Z9: Strain Amount and Flaw of Fastened Portion)

A condition Z9 is a condition based on the strain amount and the flaw depth (for example, depths D, Dg) of the fastened portion.

[0126] The evaluation device 10 determines whether or not a condition Z9 that a total value of the maximum value of the strain amount and the flaw depth of the fastened portion is equal to or greater than the reference value Thx (for example, 0.05 mm) is satisfied. When the total value is equal to or greater than the reference value Thx (that is, when the condition Z9 is satisfied), the evaluation device 10 determines that the ring joint groove 310 is in a state requiring repair, or that the gasket 40 is in a state requiring replacement. When the condition Z9 is satisfied, the evaluation device 10 evaluates the severity of the fastened portion as "4".

[0127] (Summary)

When the condition Z1 is satisfied, the evaluation device 10 determines that an abnormality has occurred in at least one of the flange 30 and the gasket 40. When any one of the conditions Z2 to Z4 is satisfied, the evaluation device 10 determines that the ring joint groove 310 is in a state requiring repair. When any one of the conditions Z5 to Z7 is satisfied, the evaluation device 10 determines that the gasket 40 is in a state

requiring replacement. When any one of the conditions Z8 and Z9 is satisfied, the evaluation device 10 determines that the ring joint groove 310 of the flange 30 is in a state requiring repair, or that the gasket 40 is in a state requiring replacement. Further, when any one of the conditions Z1 to Z9 is satisfied, the evaluation device 10 evaluates the severity in accordance with the satisfied condition.

[0128] On the other hand, when none of the conditions Z1 to Z9 is satisfied, it is considered that the states of the ring joint groove 310 and the gasket 40 are good. Therefore, in this case, the evaluation device 10 determines that repair of the ring joint groove 310 and replacement of the gasket 40 are unnecessary.

[0129] <Display of Advice Information>

Specific processing details of step S24 in Fig. 3 will now be described.

[0130] (When Condition Z1 Is Satisfied)

The gasket, the ring joint groove, and the like may be deformed. Therefore, the evaluation device 10 displays, on the display 105, advice information indicating that it is necessary to check these abnormalities when the flange is opened, and including the severity "2". Further, the advice information includes information that recommends repair of the ring joint groove and replacement of the gasket in accordance with the result of the abnormality checking. The information that recommends the repair of the ring joint groove includes, for example, information that recommends cutting or polishing by an amount equal to or greater than an added value obtained by adding a predetermined value (for example, 0.05 mm) to the maximum value of the flaw and the strain amount.

[0131] (When Conditions Z2 and Z3 Are Satisfied)

The ring joint groove is deformed, and repair is necessary. The evaluation device 10 displays, on the display 105, advice information indicating that repair of the ring joint groove is necessary. The advice information includes information that recommends lapping of the ring joint groove and the gasket, and checking of the abutment surface using red lead. When the condition Z2 is satisfied, the advice information further includes information indicating the severity "10". When the

condition Z3 is satisfied, the advice information further includes information indicating the severity "8".

[0132] (When Condition Z4 Is Satisfied)

The ring joint groove has an abnormality, and repair is necessary. The evaluation device 10 displays, on the display 105, advice information indicating that repair of the ring joint groove is necessary and including the severity "4". The advice information includes information that recommends lapping of the ring joint groove and the gasket, and checking of the abutment surface using red lead.

[0133] (When Conditions Z5 and Z6 Are Satisfied)

The gasket is deformed, and replacement is necessary. The evaluation device 10 displays, on the display 105, advice information indicating that replacement of the gasket is necessary. The advice information includes information that recommends lapping of the ring joint groove and the gasket, and checking of the abutment surface using red lead. When the condition Z5 is satisfied, the advice information further includes information indicating the severity "10". When the condition Z6 is satisfied, the advice information further includes information indicating the severity "8".

[0134] (When Condition Z7 Is Satisfied)

The gasket has an abnormality, and replacement is necessary. The evaluation device 10 displays, on the display 105, advice information indicating that replacement of the gasket is necessary and including the severity "6". The advice information includes information that recommends lapping of the ring joint groove and the gasket, and checking of the abutment surface using red lead.

[0135] (When Conditions Z8 and Z9 Are Satisfied)

There is a possibility of leakage due to deformation or the like of the gasket or the ring joint groove. The evaluation device 10 displays, on the display 105, advice information including information that recommends repair of the ring joint groove and replacement of the gasket, and including the severity "4".

[0136] <Functional Configuration>

Fig. 19 is a block diagram showing an example of a functional configuration of

the evaluation device. Referring to Fig. 19, the evaluation device 10 includes a data acquisition unit 601, an evaluation unit 603, and an output control unit 605 as main functional configurations. Each of these functions is implemented by, for example, the processor 101 of the evaluation device 10 executing a program stored in the memory 103. A part or all of these functions may be configured to be implemented by hardware.

[0137] The data acquisition unit 601 acquires the three-dimensional shape data of each of the flange 30 and the gasket 40. Further, the data acquisition unit 601 acquires the three-dimensional shape data of the fastened flange assembly in which the one flange 30 and the other flange 30 are fastened via the ring joint gasket 40. Specifically, the data acquisition unit 601 acquires the respective three-dimensional shape data from the 3D scanner 20 via the input/output interface 109 (or the communication interface 111).

[0138] The evaluation unit 603 evaluates the states of the ring joint groove 310, the gasket 40, and the fastened flange assembly based on the respective three-dimensional shape data. Specifically, the evaluation unit 603 includes a shape measurement unit 611, a gap measurement unit 612, a setting unit 613, a detection unit 615, a strain amount measurement unit 617, and a determination unit 619.

[0139] The shape measurement unit 611 measures the plurality of shape parameters P1 (for example, the angle θr, the width F, and the depth d) relating to the shape of the ring joint groove 310 based on the three-dimensional shape data of the flange 30. The shape measurement unit 611 measures the plurality of shape parameters P2 (for example, the center diameter, the height, and the width of the gasket) relating to the shape of the gasket 40 based on the three-dimensional shape data of the gasket 40.

[0140] The gap measurement unit 612 measures the gap between the one flange 30 and the other flange 30 in the fastened flange assembly based on the three-dimensional shape data of the fastened flange assembly.

[0141] The setting unit 613 sets the target region Nf of the ring joint groove 310 based on the three-dimensional shape data of the flange 30. Specifically, the setting unit 613 sets the target region Nf in accordance with the scheme described with reference to Fig.

5. The target region Nf is the predetermined region (for example, the region defined by the width W) in the contact surface (that is, the side surface 311) of the ring joint groove 310. The target region Nf may be the entire region of the side surface 311.

[0142] Further, the setting unit 613 sets the target region Ng of the gasket 40 based on the three-dimensional shape data of the gasket 40. Specifically, the setting unit 613 sets the target region Ng in accordance with the scheme described with reference to Fig. 12. The target region Ng is set to the contact surface 411 of the gasket 40 with which the side surface 311 of the ring joint groove 310 comes into contact.

[0143] The detection unit 615 detects a flaw generated in the target region Nf based on the three-dimensional shape data of the flange 30. In an aspect, when the detection unit 615 detects a first flaw (for example, the flaw A1 in Fig. 7) and a second flaw (for example, the flaw A2 in Fig. 7) that are close to each other in the target region Nf in accordance with the above-described integration scheme for a plurality of flaws, the detection unit 615 integrates the first flaw and the second flaw as one flaw. The detection unit 615 outputs a detection result of the flaw in the target region Nf to the determination unit 619. The detection result includes the length L, the depth D, and the like of the detected flaw.

[0144] Further, the detection unit 615 detects a flaw generated in the contact surface 411 (for example, the target region Ng) of the gasket 40 with which the ring joint groove 310 comes into contact, based on the three-dimensional shape data of the gasket 40. The detection unit 615 outputs a detection result of the flaw in the target region Ng to the determination unit 619. The detection result includes the length Lg, the depth Dg, and the like of the detected flaw.

[0145] The strain amount measurement unit 617 measures the strain amount of the contact surface (that is, the side surface 311) of the ring joint groove 310 based on the three-dimensional shape data of the flange 30. Specifically, the strain amount measurement unit 617 measures the strain amount of the side surface 311 in the radial direction in accordance with the measurement scheme described with reference to Fig. 9, and measures the strain amount of the side surface 311 in the circumferential

direction in accordance with the measurement scheme described with reference to Fig. 10.

[0146] In another aspect, the strain amount measurement unit 617 measures the strain amount of the contact surface 411 of the gasket 40 based on the three-dimensional shape data of the gasket 40. Specifically, the strain amount measurement unit 617 measures the strain amount of the contact surface 411 in the radial direction in accordance with the measurement scheme described with reference to Fig. 15, and measures the strain amount of the contact surface 411 in the circumferential direction in accordance with the measurement scheme described with reference to Fig. 16.

[0147] In still another aspect, the strain amount measurement unit 617 calculates the strain amount of the region (for example, the fastened portion) in which the gasket 40 is fitted into the ring joint groove 310, based on the strain amount of the side surface 311 and the strain amount of the contact surface 411. Specifically, the strain amount measurement unit 617 calculates the strain amount in accordance with the measurement schemes described with reference to Fig. 17 and Fig. 18.

[0148] The determination unit 619 determines necessity of repair of the ring joint groove 310 based on at least one of the flaw of the ring joint groove 310, the strain amount of the ring joint groove 310, and the plurality of shape parameters P1.

[0149] Specifically, when at least one of the plurality of shape parameters P1 is out of the reference range (for example, when the condition Z2 is satisfied), when the length L of the flaw in the target region Nf is equal to or greater than a first length (for example, the reference value Lx1) (for example, when the condition Z3a is satisfied), or when the strain amount of the side surface 311 is equal to or greater than a first threshold value (for example, the reference strain amount Th1) (for example, when the condition Z3b is satisfied), the determination unit 619 determines that the ring joint groove 310 is in a state requiring repair.

[0150] Further, when the length L of the flaw is less than the first length and the depth D of the flaw is equal to or greater than a first depth (for example, the reference value Dx1) (for example, when the condition Z4a is satisfied), the determination unit 619

determines that the ring joint groove 310 is in a state requiring repair.

[0151] In another aspect, the determination unit 619 determines necessity of replacement of the gasket 40 based on at least one of the flaw of the contact surface 411, the strain amount of the contact surface 411, and the plurality of shape parameters P2.

[0152] Specifically, when at least one of the plurality of shape parameters P2 is out of the reference range (for example, when the condition Z5 is satisfied), when the length Lg of the flaw of the contact surface 411 is equal to or greater than a second length (for example, the reference value Lgx1) (for example, when the condition Z6a is satisfied), or when the strain amount is equal to or greater than a second threshold value (for example, the reference strain amount Th2) (for example, when the condition Z6b is satisfied), the determination unit 619 determines that replacement of the gasket 40 is necessary.

[0153] Further, when the length Lg of the flaw of the contact surface 411 is less than the second length and the depth Dg of the flaw is equal to or greater than a second depth (for example, the reference value Dx1) (for example, when the condition Z7a is satisfied), the determination unit 619 determines that replacement of the gasket 40 is necessary.

[0154] In still another aspect, when the strain amount of the region where the gasket 40 is fitted into the ring joint groove 310 is equal to or greater than a third threshold value (for example, the reference strain amount Thx) (for example, when the condition Z8 or the condition Z9 is satisfied), the determination unit 619 determines that at least one of repair of the ring joint groove 310 and replacement of the gasket 40 is necessary.

[0155] In a further aspect, when the gap Cg in the fastened flange assembly is equal to or greater than the reference value Cx (for example, when the condition Z1 is satisfied), the determination unit 619 determines that an abnormality has occurred in at least one of the ring joint groove 310 of each of the one flange 30 and the other flange 30, and the gasket 40.

[0156] The output control unit 605 outputs the advice information to the user based on

the determination result of the determination unit 619. Specifically, based on the determination result indicating that the ring joint groove 310 is in a state requiring repair, the output control unit 605 outputs, as the advice information, information that recommends cutting or polishing of the ring joint groove 310. Further, based on the determination result indicating that the gasket 40 is in a state requiring replacement, the output control unit 605 outputs, as the advice information, information that recommends replacement of the gasket 40. Typically, the output control unit 605 displays, on the display 105, the contents described in <Display of Advice Information> above.

[0157] <Advantages>

According to the present embodiment, regardless of technical knowledge and experience of the operator, the necessity of repair of the ring joint groove and the necessity of replacement of the gasket are appropriately determined in accordance with the states of the ring joint groove of the flange, the gasket, and the fastened flange assembly. Further, determination as to the necessity of repair and replacement does not vary from person to person. Further, the operator can efficiently perform an action on the flange and the gasket based on the advice information.

[0158] <Other Embodiments>

(1) In the above-described embodiment, a program that causes a computer to function and execute control as described in the flowchart above can also be provided. Such a program can also be provided as a program product by being recorded in a non-transitory computer-readable recording medium attached to a computer, such as a flexible disk, a secondary storage device, a main storage device, or a memory card. Alternatively, the program can also be provided by being recorded in a recording medium built into a computer, such as a hard disk. Further, the program can also be provided by being downloaded via a network.

[0159] (2) The configuration exemplified as the above-described embodiment is an example of the configuration of the present invention, and can be combined with another known technique, or can be modified, such as a part of the configuration being

omitting, without departing from the gist of the present invention. Further, in the above-described embodiment, the processes and configurations described in other embodiments may be appropriately adapted and implemented.

[0160] It should be understood that the embodiment disclosed herein is illustrative and non-restrictive in every respect. The scope of the present invention is defined by the terms of the claims, rather than the description above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0161] 10 evaluation device; 20 scanner; 30 flange; 40 ring joint gasket; 50, 60 flaw; 101 processor; 103 memory; 105 display; 107 input device; 109 input/output interface; 111 communication interface; 300 flange surface; 310 ring joint groove; 601 data acquisition unit; 603 evaluation unit; 605 output control unit; 611 shape measurement unit; 612 gap measurement unit; 613 setting unit; 615 detection unit; 617 strain amount measurement unit; 619 determination unit; 1000 evaluation system.

CLAIMS

[Claim 1] An evaluation device comprising:

an acquisition unit that acquires first three-dimensional shape data of a ring-joint-type flange; and

an evaluation unit that evaluates a state of a ring joint groove formed in a flange surface of the flange based on the first three-dimensional shape data, wherein

the evaluation unit includes:

a shape measurement unit that measures a plurality of first shape parameters relating to a shape of the ring joint groove;

a detection unit that detects a flaw generated in a target region of the ring joint groove;

a strain amount measurement unit that measures a first strain amount of a first contact surface of the ring joint groove with which a ring joint gasket comes into contact; and

a determination unit that determines necessity of repair of the ring joint groove based on at least one of the flaw, the first strain amount, and the plurality of first shape parameters.

[Claim 2] The evaluation device according to claim 1, wherein

when at least one of the plurality of first shape parameters is out of a reference range, when a length of the flaw is equal to or greater than a first length, when the first strain amount is equal to or greater than a first threshold value, or when the length of the flaw is less than the first length and a depth of the flaw is equal to or greater than a first depth, the determination unit determines that the ring joint groove is in a state requiring repair.

[Claim 3] The evaluation device according to claim 2, wherein

the plurality of first shape parameters include an angle formed by a center line

indicating a center of the ring joint groove and the first contact surface, and a width and a depth of the ring joint groove.

[Claim 4] The evaluation device according to claim 2 or 3, further comprising an output control unit that outputs advice information to a user based on a determination result of the determination unit, wherein

based on a determination result indicating that the ring joint groove is in a state requiring repair, the output control unit outputs, as the advice information, information that recommends cutting or polishing of the ring joint groove.

[Claim 5] The evaluation device according to any one of claims 1 to 3, wherein

when detecting a first flaw and a second flaw that are close to each other in the target region, the detection unit integrates the first flaw and the second flaw as one flaw.

[Claim 6] The evaluation device according to any one of claims 1 to 3, wherein

the strain amount measurement unit measures the first strain amount in a radial direction and a circumferential direction of the flange.

[Claim 7] The evaluation device according to any one of claims 1 to 3, wherein

the target region is a predetermined region in the first contact surface of the ring joint groove, or an entire region of the first contact surface.

[Claim 8] The evaluation device according to any one of claims 1 to 3, wherein

the acquisition unit further acquires second three-dimensional shape data of the

ring joint gasket,

the evaluation unit further evaluates a state of the ring joint gasket based on the second three-dimensional shape data,

the shape measurement unit further measures a plurality of second shape parameters relating to a shape of the ring joint gasket,

the detection unit further detects a flaw of a second contact surface of the ring joint gasket with which the ring joint groove comes into contact,

the strain amount measurement unit further measures a second strain amount of the second contact surface, and

the determination unit further determines necessity of replacement of the ring joint gasket based on at least one of the flaw of the second contact surface, the second strain amount, and the plurality of second shape parameters.

[Claim 9] The evaluation device according to claim 8, wherein

when at least one of the plurality of second shape parameters is out of a reference range, when a length of the flaw of the second contact surface is equal to or greater than a second length, when the second strain amount is equal to or greater than a second threshold value, or when the length of the flaw of the second contact surface is less than the second length and a depth of the flaw of the second contact surface is equal to or greater than a second depth, the determination unit determines that replacement of the ring joint gasket is necessary.

[Claim 10] The evaluation device according to claim 9, wherein

the plurality of second shape parameters include a center diameter, a height, and a width of the ring joint gasket.

[Claim 11] The evaluation device according to claim 9, wherein

the strain amount measurement unit calculates, based on the first strain amount and the second strain amount, a third strain amount in a region where the ring joint

gasket is fitted into the ring joint groove, and

when the third strain amount is equal to or greater than a third threshold value, the determination unit determines that at least one of repair of the ring joint groove and replacement of the ring joint gasket is necessary.

[Claim 12] The evaluation device according to any one of claims 1 to 3, wherein

the acquisition unit further acquires third three-dimensional shape data of a fastened flange assembly in which the flange and another flange are fastened via the ring joint gasket,

the evaluation unit further includes a gap measurement unit that measures a gap between the flange and the other flange in the fastened flange assembly based on the third three-dimensional shape data, and

when the gap is equal to or greater than a predetermined value, the determination unit determines that an abnormality has occurred in at least one of the ring joint groove of each of the flange and the other flange, and the ring joint gasket.

[Claim 13] An evaluation method comprising:

acquiring, by a processor, first three-dimensional shape data of a ring-joint-type flange; and

evaluating, by the processor, a state of a ring joint groove formed in a flange surface of the flange based on the first three-dimensional shape data, wherein

the evaluating includes:

measuring a plurality of first shape parameters relating to a shape of the ring joint groove;

detecting a flaw generated in a target region of the ring joint groove;

measuring a first strain amount of a first contact surface of the ring joint groove with which a ring joint gasket comes into contact; and

determining necessity of repair of the ring joint groove based on at least

one of the flaw, the first strain amount, and the plurality of first shape parameters.