

DESCRIPTION

Title of Invention:

SEAL MATERIAL HANDLING MONITORING DEVICE, HANDLING MONITORING
PROGRAM, HANDLING MONITORING METHOD, HANDLING MONITORING
5 SYSTEM AND HANDLING TRAINING SYSTEM

Technical Field

[0001] The present invention relates to technology for
handling seal materials such as gaskets used in a flange joint
10 of a pipe connection, and for handling monitoring.

Background Art

[0002] In handling to connect a pipe connection or
equipment such as a pump to a pipe, a seal material such as a
gasket is sandwiched in a flange joint, and the gasket is
15 tightened by means of bolts which are arranged in a plurality
of locations of the flange joint.

[0003] Where this handling is concerned, measuring the
tightening force or tightening state of flange tightening
connecting portions which have a gasket interposed
20 therebetween and monitoring leakage of fluid from the
tightening connecting portions is known (Patent Literature 1,
for example). With regard to the pressure in the vicinity of
the gasket interposed between the flange tightening connecting
portions, measuring this pressure using a pressure sensor and
25 determining the flange tightening force from the measurement
value is known (Patent Literature 2, for example).

[0004] As equipment and material for handling-related
training, detecting, by means of a load cell, the tightening
forces of the bolts which are tightened by means of a
30 tightening tool such as a torque wrench and displaying the
tightening forces on a display so that an operator is made to
confirm the flange surface pressure is known (Patent
Literature 3, for example).

[0005] In addition, for the sake of training for

tightening flange joint bolts, a flange tightening training system that provides visual recognition of bolt strain data is also known (Patent Literature 4, for example).

5 Citation List

Patent Literature

[0006] Patent Literature 1: Japanese Unexamined Patent Application Publication No. H9-329281

Patent Literature 2: Japanese Unexamined Patent Application
10 Publication No. 2007-292628

Patent Document 3: Japanese Unexamined Patent Application Publication No. 2009-191932

Patent Document 4: Japanese Unexamined Patent Application Publication No. 2015-141345

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Summary of Invention

Technical Problem

[0007] Incidentally, seal materials include various products with dissimilar characteristics, and there is a
20 degree of freedom in their selection. Even when a seal material with superior compatibility with the conditions is selected, there is a problem in that, if the handling state is imperfect, the functions of the seal material cannot be exhibited, and degradation of the seal function will induce
25 leakage and so forth. Although a higher axial force on the bolts tightening the seal material results in an increase in the tightening force, if the tightening force exceeds the threshold for the allowable force of the seal material, there is a risk of crushing the seal material, and if the tightening
30 force is inadequate, the required seal performance is not obtained. If the respective axial forces of the plurality of bolts are nonuniform, a distortion of the seal material is produced, and problems arise such as the expected seal performance not being obtained. For this reason, to secure the

security and reliability of the connecting portions of detachable pipes, handling of the seal material is very important and careful handling is needed.

[0008] Such seal material handling by proficient operators is desirable, and practice and experience are required to attain proficiency. However, even for experts, confirming and enhancing skills is of great importance in order to secure handling reliability.

[0009] Thus, in view of the foregoing problems, an object of the present invention is to facilitate confirmation of a seal material handling state and improve handling reliability and handling capabilities.

[0010] In addition, a further object of the present invention is not only to make the axial forces on the bolts that tighten a seal material uniform, but also, based on a finding by the present inventor that seal performance is also affected by parallelism between flanges, the tightening force on each seal material, and bolt tightening procedures, to monitor parallelism between flanges, the tightening force on each seal material, and the tightening procedure, thereby contributing to improving handling skills and further increasing seal handling reliability.

Summary

[0010a] According to an aspect, the present disclosure refers to a seal material handling monitoring device, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling monitoring device comprising: a plurality of first sensors that detect an axial force of each bolt; an information generation unit that generates distribution information of a target axial force by

means of the target axial force and position information for the axial force, and generates distribution information of the axial force by means of the axial force and position information; and a monitor that presents a first distribution map representing the target axial force and presents a second distribution map representing the axial force, via coordinates, and a second sensor that detects parallelism between flanges of the flange joint, wherein the information generation unit generates parallelism information by means of a sensor output from the second sensor, and the monitor presents a third distribution map representing parallelism between the flanges.

[0010b] According to another aspect, the present disclosure refers to a seal material handling monitoring program for causing a computer to implement functions to: receive a sensor output from a plurality of first sensors that detect an axial force of each bolt, generate distribution information of a target axial force by means of the target axial force and position information for the axial force, and generate distribution information of the axial force by means of the axial force and position information; and present a first distribution map representing the target axial force and present a second distribution map representing the axial force, via coordinates; receive a sensor output from a second sensor that detects parallelism between flanges of a flange joint, generate parallelism information by means of the sensor output from the second sensor, and present a third distribution map representing the parallelism between the flanges.

[0010c] According to another aspect, the present disclosure refers to a seal material handling monitoring method, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling monitoring method comprising: a step of detecting an axial force of each bolt; a step of generating distribution information of a

target axial force by means of the target axial force and position information for the axial force, and generating distribution information of the axial force by means of the axial force and position information; a step of presenting a
5 first distribution map representing the target axial force and presenting a second distribution map representing the axial force, via coordinates; a step of detecting parallelism between flanges of the flange joint; a step of generating parallelism information by means of the parallelism; and a
10 step of presenting a third distribution map representing the parallelism between the flanges.

[0010d] According to another aspect, the present disclosure refers to a seal material handling monitoring system, sealing being performed by sandwiching a seal material
15 in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling monitoring system comprising: a seal handling unit including a sensor that detects parallelism between flanges of the flange joint; an information generation unit which is connected to the
20 sensor by means of a wired or wireless connection, and which generates parallelism information by means of the parallelism; and a monitor which is connected to the information generation unit by means of a wired or wireless connection, and which presents a distribution map representing the parallelism.

25 [0010e] According to another aspect, the present disclosure refers to a seal material handling training system, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling training system
30 comprising: a seal handling unit including a sensor that detects parallelism between flanges of the flange joint; an information generation unit which is connected to the sensor by means of a wired or wireless connection, and which generates parallelism information by means of the parallelism;

and a monitor which is connected to the information generation unit by means of a wired or wireless connection, and which presents a distribution map representing the parallelism.

[0011] To achieve the foregoing object, one example of the
5 present disclosure is a seal material handling monitoring device, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling monitoring device including graphical information generation means which
10 generates a plurality of coordinates that extend radially from a center point, displays target axial forces of the bolts or detected axial forces of the bolts, via each of the

coordinates, as the distance from the center point, and
generates a first distribution map from the target axial
forces or a second distribution map from the detected axial
forces, at the coordinates, by linking between the target
5 axial forces or the detected axial forces at adjacent
coordinates.

In the seal material handling monitoring device, the graphical
information generation means displays the first distribution map and
the second distribution map such that the first and second
10 distribution maps are superposed via common coordinates.

To achieve the foregoing object, one example of the
present disclosure is a seal material handling monitoring
device, sealing being performed by sandwiching a seal material
in a flange joint and tightening the seal material by means of
15 a plurality of bolts, the seal material handling monitoring
device including a plurality of first sensors that detect an
axial force of each bolt; an information generation unit that
generates distribution information of a target axial force by
means of the target axial force and position information for
20 the axial force, and generates distribution information of the
axial force by means of the axial force and position
information; and a monitor that presents a first distribution
map representing the target axial force and presents a second
distribution map representing the axial force, via coordinates.

25 [0012] The seal material handling monitoring device
further includes a second sensor that detects parallelism
between flanges of the flange joint, wherein the information
generation unit generates parallelism information by means of
a sensor output from the second sensor, and wherein the
30 monitor presents a third distribution map representing
parallelism between the flanges.

[0013] In the seal material handling monitoring device,

the information generation unit also refers to a tightening torque which is calculated by means of dimension information for the flanges of the flange joint and the bolts, determines, for each bolt, whether a tightening force for the seal

5 material has reached a target tightening force configured for each seal material, and presents determination results to the monitor.

[0014] In the seal material handling monitoring device, by changing the position or angle of a seal handling unit that
10 includes the flange joint or by changing the position or angle of the flange joint, the work environment can also be simulated.

[0015] To achieve the foregoing object, one example of the present disclosure is a seal material handling monitoring
15 program for causing a computer to implement a function to generate a plurality of coordinates that extend radially from a center point, display target axial forces of the bolts or detected axial forces of the bolts, via each of the coordinates, as the distance from the center point, and
20 generate a first distribution map from the target axial forces or a second distribution map from the detected axial forces, at the coordinates, by linking between the target axial forces or the detected axial forces at adjacent coordinates.

In the seal material handling monitoring program, further, the
25 computer implements a function to display the first distribution map and the second distribution map such that the first and second distribution maps are superposed via common coordinates.

To achieve the foregoing object, one example of the present disclosure is a seal material handling monitoring
30 program for causing a computer to implement a function to receive a sensor output from a plurality of first sensors that detect an axial force

of each bolt, generate distribution information of a target axial force by means of the target axial force and position information for the axial force, and generate distribution information of the axial force by means of the axial force and position information, and present a first distribution map representing the target axial force and present a second distribution map representing the axial force, via coordinates.

5 [0016] In the seal material handling monitoring program, further, the computer implements a function to receive a sensor output from a second sensor that detects parallelism between flanges of a flange joint, generate parallelism information by means of the sensor output, and present a third distribution map representing the parallelism between the flanges.

[0017] In the seal material handling monitoring program, further, the computer implements a function to configure a target tightening force for each seal material, determine, for each bolt, whether a tightening force for the seal material has reached the target tightening force, and present the determination results via the monitor.

15 [0018] In the seal material handling monitoring program, further, the computer implements a function to determine a tightening procedure for each bolt, and present the determination results to the monitor.

[0019] To achieve the foregoing object, one example of the present disclosure is a seal material handling monitoring method, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts,

the seal material handling monitoring method including a step of generating, by graphical information generation means, a plurality of coordinates that extend radially from a center point, displays target axial forces of the bolts or detected

axial forces of the bolts, via each of the coordinates, as the distance from the center point, and generates a first distribution map from the target axial forces or a second distribution map from the detected axial forces, at the coordinates, by linking between the target axial forces or the detected axial forces at adjacent coordinates.

To achieve the foregoing object, one example of the present disclosure is a seal material handling monitoring method, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling monitoring method including a step of detecting an axial force of each bolt; a step of generating distribution information of a target axial force by means of the target axial force and position information for the axial force, and generating distribution information of the axial force by means of the axial force and position information; and a step of presenting a first distribution map representing the target axial force and presenting a second distribution map representing the axial force, via coordinates.

[0020] The seal material handling monitoring method further includes a step of detecting parallelism between flanges of the flange joint; a step of generating parallelism information by means of the parallelism; and a step of presenting a third distribution map representing the parallelism between the flanges.

[0021] To achieve the foregoing object, one example of the present disclosure is a seal material handling monitoring system, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling monitoring system including a seal handling unit including a first sensor that detects axial forces of a plurality of bolts which

tighten a seal sandwiched in a flange joint, or a second sensor that detects parallelism between flanges of the flange joint; and graphical information generation means which generates a plurality of coordinates that extend radially from a center point, displays
5 target axial forces of the bolts or detected axial forces of the bolts, via each of the coordinates, as the distance from the center point, and generates a first distribution map from the target axial forces or a second distribution map from the detected axial forces, at the coordinates, by linking between the target axial forces or
10 the detected axial forces at adjacent coordinates.

To achieve the foregoing object, one example of the present disclosure is a seal material handling monitoring system, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of
15 a plurality of bolts, the seal material handling monitoring system including a seal handling unit including a first sensor that detects axial forces of a plurality of bolts which tighten a seal material sandwiched in a flange joint, or a second sensor that detects parallelism between flanges of the
20 flange joint; an information generation unit which is connected to the first sensor or the second sensor by means of a wired or wireless connection, and which generates distribution information of a target axial force by means of the target axial force and position information for the axial
25 force, generates distribution information of the axial force by means of the axial force and position information, or generates parallelism information by means of the parallelism; and a monitor which is connected to the information generation unit by means of a wired or wireless connection, and which
30 presents a first distribution map representing the target axial force, presents a second distribution map representing the axial force, via

coordinates, or presents a third distribution map representing the parallelism.

[0022] To achieve the foregoing object, one example of the present disclosure is a seal material handling training system, sealing
5 being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling training system including: a seal handling unit including a first sensor that detects axial forces of a plurality of bolts which tighten a seal material sandwiched in a
10 flange joint, or a second sensor that detects parallelism between flanges of the flange joint; and graphical information generation means which generates a plurality of coordinates that extend radially from a center point, displays target axial forces of the bolts or detected axial forces of the bolts, via each of the
15 coordinates, as the distance from the center point, and generates a first distribution map from the target axial forces or a second distribution map from the detected axial forces, at the coordinates, by linking between the target axial forces or the detected axial forces at adjacent coordinates.

20 To achieve the foregoing object, one example of the present disclosure is a seal material handling training system, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling training system
25 including a seal handling unit including a first sensor that detects axial forces of a plurality of bolts which tighten a seal material sandwiched in a flange joint, or a second sensor that detects parallelism between flanges of the flange joint; an information generation unit which is connected to the first
30 sensor or the second sensor by means of a wired or wireless connection, and which generates distribution information of a

target axial force by means of the target axial force and position information for the axial force, generates distribution information of the axial force by means of the axial force and position information, or generates parallelism information by means of the parallelism; and a monitor which is connected to the information generation unit by means of a wired or wireless connection, and which presents a first distribution map representing the target axial force, presents a second distribution map representing the axial force, via coordinates, or presents a third distribution map representing the parallelism.

Advantageous Effects of Invention

[0023] According to the present invention, any of the following effects is obtained.

[0024] (1) A distribution map representing a seal tightening state can be presented in real time via coordinates, and a seal material tightening state can easily be recognized visually from the state of the shape of the distribution map and the distance from the center.

[0025] (2) When an axial force has been increased or decreased, slack due to elastic interaction, which is peculiar to flange tightening, can be easily recognized from a variation in the shape of the axial force distribution map, and based on this recognition, bolt tightening to match a target tightening force can be performed, and suitable sealing using the optimal tightening force can be realized.

[0026] (3) Because the relationship between the torque applied to the bolts and the axial force distribution can be easily ascertained, for a skilled operator, it is possible to correct habits and enhance skills, thereby enabling seal handling reliability to be improved.

[0027] (4) The present invention can be adopted as a seal material training support tool and can contribute to

expediting skills enhancement.

[0028] (5) If parallelism between flanges of a flange joint is monitored in real time, not only are suitable tightening forces attained, but the effect of a tightening procedure and bolt tightening forces on flange parallelism can be easily confirmed.

Brief Description of Drawings

[0029] Fig. 1 is a diagram illustrating a seal material handling monitoring device according to a first embodiment.

Fig. 2 is a flowchart illustrating a handling monitoring processing procedure.

Fig. 3 is a diagram illustrating a distribution map of target axial forces via coordinates, and illustrating axial forces that vary due to elastic interaction.

Fig. 4 is a diagram illustrating a seal material handling monitoring device according to an Example 1.

Fig. 5 is a flowchart illustrating a handling monitoring processing procedure.

Fig. 6 is a diagram illustrating a distribution map of flange parallelism.

Fig. 7 is a diagram illustrating a seal material handling monitoring system according to an Example 2.

Fig. 8 is a diagram illustrating a bolt which includes a strain gauge.

Fig. 9 is a diagram illustrating a configuration of a handling monitoring system.

Fig. 10 is a flowchart illustrating a seal handling procedure.

Fig. 11 is a flowchart illustrating a handling monitoring processing procedure.

Fig. 12 is a diagram illustrating an example of an axial force table.

Fig. 13 is a diagram illustrating an example of a

parallelism table.

Fig. 14 is a diagram illustrating variations of an axial force distribution map.

Fig. 15 is a diagram illustrating variations of an axial
5 force distribution map.

Fig. 16 is a diagram to illustrate configuration of a target axial force for each gasket according to an Example 3.

Fig. 17 is a diagram to illustrate a display of a tightening procedure according to an Example 4.

10 Fig. 18 is a flowchart illustrating a processing procedure to determine acceptance/rejection of a tightening force, according to an Example 5.

Fig. 19 is a diagram illustrating a tightening force distribution map and evaluation table.

15 Fig. 20 is a flowchart illustrating a processing procedure to determine acceptance/rejection of a tightening sequence, according to an Example 6.

Fig. 21 is a diagram illustrating a seal handling unit according to an Example 7.

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Description of Embodiments

[0030] <Handling monitoring device>

[0031] Fig. 1 illustrates a seal material handling monitoring device according to one embodiment. The
25 configuration illustrated in Fig. 1 is an example, and the present invention is not limited to such a configuration.

[0032] The seal material handling monitoring device (hereinafter simply called "handling monitoring device") 2 is installed in a seal handling unit 4. The seal handling unit 4
30 is the monitoring target of the handling monitoring device 2 and is an example of a seal handling device. The seal handling unit 4 includes a flange joint 6 and provides sealing by sandwiching a gasket 8, which is an example of a seal material, in the flange joint 6.

[0033] The flange joint 6 is means for connecting pipes 10-1 and 10-2, and includes a pair of flanges 6-1 and 6-2. The flange 6-1 is formed integrally with an end portion of the pipe 10-1, and the flange 6-2 is formed integrally with an end
5 portion of the pipe 10-2.

[0034] The gasket 8 is fitted between the opposing surfaces of the flanges 6-1 and 6-2. The shape of the gasket 8 is circular, and is smaller in diameter than the flanges 6-1 and 6-2 and larger in diameter than the inside diameter of the
10 pipes 10-1 and 10-2. If only the pipes 10-1 and 10-2 are connected, the flange joint 6 is normally unnecessary but use of the flange joint 6 must be provided to allow the pipes 10-1 and 10-2, for example, to be detached and re-attached at regular intervals during maintenance and so forth, and lies in
15 realizing, through sealing, identical functions as seamless piping for the connected pipes 10-1 and 10-2.

[0035] A plurality of bolts 12-1, 12-2, ...12-8 are provided for each of the flanges 6-1 and 6-2. Each bolt 12-1, 12-2, ...12-8 is disposed at an angular distance of a fixed
20 angle θ in a peripheral position at a distance from a center O of the pipes 10-1 and 10-2. The angle θ is an example of axial force position information. The bolts 12-1, 12-2, ...12-8 each penetrate the respective flanges 6-1 and 6-2 in equal positions, and nuts 14 are attached with the flanges 6-1 and
25 6-2 sandwiched therebetween. Because the nuts 14 are tightened in alignment with the bolts 12-1, 12-2, ...12-8, uniform tightening forces can be applied to the gasket 8.

[0036] A suitable tightening tool 16 is required to apply a torque T to each of the nuts 14. Possible examples of the
30 tightening tool 16 are a ratchet torque wrench, digital torque wrench, bolt tensioner, ratchet wrench, spanner, ring wrench or impact wrench, or the like. If the tightening tool 16 is applied to the nuts 14 and exerts a torque T thereon, an axial force F is generated in an axial direction Z in the drawing in

each of the bolts 12-1, 12-2, ...12-8, and the axial force F becomes a tightening force for the gasket 8.

[0037] A sensor group 18 which detects each axial force F is provided. The sensor group 18 corresponds to each of the
5 bolts 12-1, 12-2, ...12-8, and a plurality of sensors 18-1, 18-2, ...18-8 are provided. A sensor which outputs the axial force F via an electrical signal may be used for the sensors 18-1, 18-2, ...18-8, and the sensor may be a sensor that
10 directly detects a tightening force on the gasket 8, where any of a pressure sensor, a strain gauge, a displacement gauge, a load meter, or the like, may be used.

[0038] Each sensor output of the sensor group 18 is captured and accumulated by a data accumulation unit 20. Each detected axial force is an electrical signal and electrically
15 accumulated in the data accumulation unit 20. The data accumulation unit 20 may be configured from a computer and may use an existing data logger.

[0039] Each detected axial force is fed from the data accumulation unit 20 to the information generation unit 22
20 with predetermined timing. The information generation unit 22 is an example of graphical information generating means. A computer, for example, may be used as the information generation unit 22. The information generation unit 22 digitizes and captures the respective detected axial forces
25 and executes information processing to plot the tightening forces. The functions of the information generation unit 22 which executes the information processing include a function for generating a plurality of coordinate axes y that extend radially from center point 0, a function for displaying, at a
30 distance from center point 0, a target axial force F_{ref} of the bolts or a detected axial force F of the bolts, on each coordinate axis y , and a function for generating a first distribution map 26-1 from the target axial forces or a second distribution map 26-2 from the detected axial forces, on the

coordinate axes y. These functions are obtained by means of information processing.

[0040] The information processing includes processing such as:

5 a) The capture and storage of each detected axial force.

b) The generation of position information of each detected axial force and plot information representing a distribution of the detected axial forces.

10 c) The generation of coordinates for developing axial force distributions.

d) The generation of plot information representing a distribution of target axial forces by using the target axial forces and position information. The target axial forces are axial forces required for suitable tightening forces on the gasket 8.

15 [0041] The coordinate and plot information obtained in this information processing is provided to a monitor 24, and an axial force diagram is presented together with the coordinates on the screen of the monitor 24. The monitor 24 is an example of an information presentation unit that presents sealing states to an operator or administrator, or the like. The monitor 24 may be connected wirelessly or via a wired connection to the information generation unit 22, or a display of a personal computer (PC) may be used.

25 [0042] <Axial force monitoring>

[0043] Next, Fig. 2 illustrates a processing procedure for detected axial force monitoring. This processing procedure is an example of the handling monitoring program and handling monitoring method of the present invention.

30 [0044] This processing procedure is processing after performing pre-selection of the gasket 8 which is compatible with the handling conditions, and after temporary tightening of each of the bolts 12-1, 12-2, ...12-8.

[0045] It is determined whether to tighten the bolts 12-1,

12-2, ...12-8 (S101), and if tightening is to be performed (YES in S101), each sensor output is fed from the sensor group 18 to the data accumulation unit 20, and the detected axial forces are accumulated (S102). This accumulation corresponds to a) the capture and storage of each detected axial force of the foregoing information processing.

[0046] The processing to plot the detected axial forces and target axial forces is executed (S103). This processing includes the foregoing b) the generation of position information of each detected axial force and plot information representing a distribution of the detected axial forces, c) the generation of coordinates for developing axial force distributions, and d) the generation of plot information representing a target axial force distribution by using the target axial forces and position information.

[0047] After this plot processing, a distribution map of the detected axial forces and target axial forces via coordinates is displayed on the monitor 24 (S104).

[0048] In this display, variations in the detected axial forces are monitored and it is determined whether the tightening of the bolts 12-1, 12-2, ...12-8 is complete (S105). If prior to completion of the tightening of the bolts 12-1, 12-2, ...12-8 (NO in S105), the processing of S102 to S105 is continued. Accordingly, variations in the detected axial forces are reflected in the distribution map displayed on the monitor 24, and the detected axial forces are dynamically displayed as variations in the distribution map.

[0049] If the tightening of the bolts 12-1, 12-2, ...12-8 is complete (YES in S105), a distribution map of the target axial forces and detected axial forces via coordinates at the time the tightening is completed is displayed (S106), and the handling monitoring processing is completed. Accordingly, it is possible to confirm easily whether or not an axial force matches a target axial force.

[0050] Fig. 3 illustrates an example of respective distribution maps for detected axial forces and target axial forces in axial force monitoring.

[0051] As illustrated in A of Fig. 3, coordinates having a plurality of coordinate axes $y_1, y_2, \dots, y_8$ are configured radially about a point 0 at the center. [1], [2], $\dots$, [8] are bolt numbers, and the coordinate axes $y_1, y_2, \dots, y_8$ correspond to the arrangement of the plurality of bolts 12-1, 12-2, $\dots$, 12-8.

[0052] In this example, although the number of coordinate axes corresponds to the number of bolts that is 8, the number of coordinate axes y may be configured according to the number of arranged bolts. A scale denoting a positive axial force level is provided in a direction moving away from point 0, for each of the coordinate axes $y_1, y_2, \dots, y_8$, and an axis x is configured on the same scale.

[0053] $F_{1ref}, F_{2ref}, \dots, F_{8ref}$ represent target axial forces of each of the bolts 12-1, 12-2, $\dots$, 12-8 for suitable tightening forces on the gasket 8. Normally, $F_{1ref},$

$F_{2ref}, \dots, F_{8ref}$ are configured having the same value F_{ref} . When each of the target axial forces $F_{1ref}, F_{2ref}, \dots, F_{8ref}$ are linked via two-dot chain lines, for example, the distribution map 26-1 of target axial forces F_{ref} is generated as a first distribution map. In this case, the distribution map 26-1 is an octagonal distribution map of $F_{1ref}, F_{2ref}, \dots, F_{8ref}$. Here, because $\theta = 45(^{\circ})$, the distribution map 26-1 is a regular octagon, and if the number of bolts is different, the distribution map 26-1 is a polygon with the corresponding polygonal shape.

[0054] Supposing that the detected axial forces of each of the bolts 12-1, 12-2, $\dots$, 12-8 are $F_1, F_2, \dots, F_8$, the respective axial forces $F_1, F_2, \dots, F_8$ at the detection time points are plotted in scalar positions on $y_1, y_2, \dots, y_8$, and in this case, constitute a distribution map 26-2.

[0055] The relationships between the detected axial forces $F_1, F_2, \dots, F_8$ at the detection time points and the target axial forces $F_{1ref}, F_{2ref}, \dots, F_{8ref}$ are:

$$F_{1ref} > F_1, F_{1ref} - F_1 = \Delta F_1 \quad (\text{Equation 1})$$

5 $F_{2ref} > F_2, F_{2ref} - F_2 = \Delta F_2 \quad (\text{Equation 2})$

$$F_{3ref} > F_3, F_{3ref} - F_3 = \Delta F_3 \quad (\text{Equation 3})$$

.....

$$F_{8ref} > F_8, F_{8ref} - F_8 = \Delta F_8 \quad (\text{Equation 4}).$$

[0056] The axial forces F are increased by $\Delta F_1, \Delta F_2, \dots, \Delta F_8$ using the tightening tool 16 while confirming the distribution map 26-2, and the detected axial forces $F_1, F_2, \dots, F_8$ may be made to reach the target axial forces $F_{1ref}, F_{2ref}, \dots, F_{8ref}$.

[0057] However, supposing that, for example, as illustrated in B of Fig. 3, the axial force F_1 is increased in the direction of an arrow a so as to reach the target axial force F_{1ref} .

[0058] Here, in the vicinity of the bolt 12-1, $F_{1ref} = F_1, F_1 - F_{1ref} = 0$ (Equation 5). However, in the vicinity of the bolt 12-2, the axial force F_2 decreases to F_2' under the effect of the elastic interaction of the flanges 6-1 and 6-2, and

$F_2' < F_2, F_2 - F_2' = \Delta F_2' > 0$ (Equation 6). Likewise, in the vicinity of the bolt 12-8, the axial force F_8 decreases to F_8' under the effect of the elastic interaction of the flanges 6-1 and 6-2, and

$$F_8' < F_8, F_8 - F_8' = \Delta F_8' > 0 \quad (\text{Equation 7}).$$

[0059] Therefore, in the vicinity of the bolts 12-2 and 12-8, Equation (1) and Equation (4) then become:

30 $F_{2ref} - F_2' = \Delta F_2 + \Delta F_2' > \Delta F_2 \quad (\text{Equation 8})$

$F_{8ref} - F_8' = \Delta F_8 + \Delta F_8' > \Delta F_8$ (Equation 9). That is, when the axial force F_1 in the vicinity of the bolt 12-1 is made to reach the target axial force F_{1ref} , in the vicinity of the bolts 12-2 and 12-8, the axial forces required to reach

the target axial forces F_{2ref} and F_{8ref} must be increased.

[0060] That is, a decrease in the axial forces F_2 and F_8 in the vicinity of the bolts 12-2 and 12-8 which are adjacent to each other with the bolt 12-1 sandwiched therebetween

5 generates expansion in the vicinity of the bolts 12-2 and 12-8 due to the elastic interaction of the flanges 6-1 and 6-2 between the tightened flanges 6-1 and 6-2 in the vicinity of the bolt 12-1, which means slack is generated in the vicinity of the bolts 12-2 and 12-8.

10 [0061] Being able to easily recognize an elastic interaction effect of this kind from a variation in the distribution map 26-2 is highly advantageous. That is, by visualizing the phenomenon whereby axial force degradation occurs due to elastic interaction, the effect of elastic
15 interaction can be visually recognized, and an increase or decrease in the axial force can be sensed physically via the torque T from the tightening tool 16, thereby enabling an operator to learn flange tightening skills.

[0062] <Effects of one embodiment>

20 [0063] According to this one embodiment, the following effects are obtained.

[0064] (1) Because the distribution maps 26-1 and 26-2 for the target axial forces F_{ref} and detected axial forces F are plotted via coordinates and displayed on a screen, the axial
25 forces F can be increased or decreased by ascertaining the direction of an increase/decrease in a relative axial force difference by comparing the distribution maps 26-1 and 26-2, whereby the target axial force F_{ref} can be reached and a suitable sealing state can be achieved.

30 [0065] (2) The magnitude of the detected axial forces F can be easily ascertained by comparing the size of the detected axial forces F plotted on the scale, that is, the distance moving away from point 0 and the distortion in the shape of the distribution map 26-2, and so forth, with the

distribution map 26-1, and the relationships between increases and decreases in tightening states can be easily recognized visually from the detected axial forces F .

[0066] (3) Because the size of the detected axial forces F is represented by the distance in a direction moving away from point 0, the direction of an increase/decrease in the tightening force can be recognized using point 0 as a reference, and the direction in which the tightening tool 16 manipulates the detected axial forces F , that is, the direction of an increase/decrease in the torque T , can be easily ascertained.

[0067] (4) Although there is a fixed tightening procedure for the bolts 12-1, 12-2, ...12-8, if this tightening procedure is not executed, the tightening procedure can be determined from the shape or distorted state of the distribution map 26-2 of detected axial forces F .

[0068] (5) Mastery of seal handling can be accelerated for the learner of seal handling, and even for an expert, its usage also serves the level of such mastery and correction of handling.

[0069] (6) Possible examples of the tightening tool 16 are a ratchet torque wrench, digital torque wrench, bolt tensioner, ratchet wrench, spanner, ring wrench or impact wrench, or the like. The results of tightening using such tools can be compared via a distribution map for the detected axial forces, and selection information when selecting a suitable tool for high-quality seal handling can be obtained.

[0070] (7) An ideal sealing state can be achieved via an operation to cause the detected axial forces F to attain the target axial forces F_{ref} while comparing the distribution maps 26-1 and 26-2 of the target axial forces F_{ref} and detected axial forces F at common coordinates.

[0071] (8) Variations in the distribution map 26-2 can be recognized according to the detected axial forces F , the

impact of the elastic interaction of the flange joint 6 can be easily recognized, and tightening forces based on the impact of the elastic interaction can be applied, thereby enabling tightening work skills to be enhanced.

5 Example 1

[0072] Fig. 4 illustrates a seal material handling monitoring device according to an Example 1. The same reference signs are assigned to the same parts as Fig. 1.

[0073] In a handling monitoring device 2 of this Example 1,
10 in addition to the plurality of first sensors 18-1, 18-2, ...18-8, four sets of second sensors 28-1, 28-2, 28-3 and 28-4 are provided as a plurality of second sensor groups 28. The sensors 28-1, 28-2, 28-3 and 28-4 may use a displacement gauge, for example, which detects gaps between the flanges 6-1
15 and 6-2.

[0074] In this example, the sensors 28-1, 28-2, 28-3 and 28-4 are arranged at 90 [degree] angular gaps, for example, with sensor 28-1 disposed in the vicinity of bolt 12-1, sensor 28-2 disposed in the vicinity of bolt 12-3, sensor 28-3
20 disposed in the vicinity of bolt 12-5, and sensor 28-4 disposed in the vicinity of bolt 12-7, and detect a gap in peripheral positions in four locations of the flanges 6-1 and 6-2. Parallelism is determined from each of the gaps. The parallelism detection positions may be configured in more than
25 four locations.

[0075] The sensor outputs from each of sensors 28-1, 28-2, 28-3 and 28-4 are captured by a data accumulation unit 20 and supplied to an information generation unit 22. The information generation unit 22 generates parallelism information from the
30 sensor outputs and executes information processing for generating parallelism plot information.

[0076] The information processing includes processing such as:

- e) The capture and storage of each sensor output.

f) The generation of position information of each gap, parallelism information from each sensor output, and parallelism plot information.

g) The generation of coordinates representing parallelism.

5 [0077] The monitor 24 generates a third distribution map 26-3 (Fig. 6) which represents parallelism of the flanges 6-1 and 6-2 by means of the plot information provided by the information generation unit 22.

[0078] <Parallelism monitoring>

10 [0079] Fig. 5 illustrates a processing procedure for parallelism monitoring. This processing procedure is an example of the handling monitoring program and handling monitoring method of the present invention.

[0080] So too in this processing procedure, it is
15 determined whether to tighten the bolts 12-1, 12-2, ...12-8 (S201), and if tightening is to be performed (YES in S201), each sensor output is fed from the sensor group 28 to the data accumulation unit 20, and the sensor outputs are accumulated (S202). Plot processing for parallelism between the flanges 6-
20 1 and 6-2 based on the detected gaps is performed (S203).

[0081] After this plot processing, the distribution map 26-3 representing the parallelism via coordinates is displayed on the monitor 24 (S204).

[0082] In this display, variations in the detected axial
25 forces are monitored and it is determined whether the tightening of the bolts 12-1, 12-2, ...12-8 is complete (S205). If prior to completion of the tightening of the bolts 12-1, 12-2, ...12-8 (NO in S205), the processing of S202 to S205 is continued. Accordingly, variations in the parallelism are
30 reflected in the distribution map 26-3 displayed on the monitor 24, and the variations in parallelism are dynamically displayed.

[0083] If the tightening of the bolts 12-1, 12-2, ...12-8 is complete (YES in S205), a distribution map of parallelism

at the time the tightening is completed is displayed via coordinates (S206), and the handling monitoring processing is completed.

[0084] Fig. 6 illustrates a distribution map representing a parallelism state of the flanges 6-1 and 6-2 which arises in the flange joint 6.

[0085] As illustrated in A of Fig. 6, in the display of the parallelism distribution map, coordinate axes y11, y12, y13, and y14 corresponding to the positions of the sensors 28-1, 28-2, 28-3 and 28-4 are configured. [1], [2], [3] and [4] are sensor numbers, and indicate gap detection positions. A scale for plotting gaps is assigned to each of the coordinate axes y11, y12, y13, and y14. A coordinate axis x which links the same scales is displayed.

[0086] As illustrated in A of Fig. 6, gaps D1, D2, D3, and D4, which are detected on the coordinate axes y11, y12, y13, and y14, are plotted. Based on $D1 \approx D2 \approx D3 \approx D4$, the distribution map 26-3 shows a substantially square shape. That is, in the state illustrated in A of Fig. 6, the allowed parallelism is attained.

[0087] However, in the state illustrated in B of Fig. 6, $D1 < D2 \approx D3 \approx D4$, the distribution map 26-3 has a distorted shape. That is, in the state illustrated in B of Fig. 6, parallelism is not attained.

[0088] <Effects of an Example 1>

[0089] According to an Example 1, the following effects are obtained.

[0090] (1) Even though, based on the axial force monitoring, the axial forces are in a suitable target axial force range, when parallelism between the flanges is lacking and uneven clamping is produced, there is a risk of an offset in gasket surface pressure. However, this trouble can be avoided by means of parallelism monitoring.

[0091] (2) The generation of uneven clamping when

parallelism between the flanges is lacking even though, based on the axial force monitoring, the axial forces are in a suitable target axial force range can be easily recognized by an operator via parallelism monitoring. Even when the
5 respective tightening forces between the flanges due to axial forces are suitable, a variation in parallelism between flanges can be recognized by means of a procedure for tightening between flanges.

[0092] (3) Seal handling skills enhancement can be
10 achieved through axial force monitoring and parallelism monitoring.

Example 2

[0093] Fig. 7 illustrates a handling monitoring system according to an Example 2. This handling monitoring system 30
15 is obtained by configuring the foregoing seal material handling monitoring device as a training system. In Fig. 7, the same reference signs are assigned to the same parts as Fig. 1, and a description of the sensors 28-1, 28-2, and 28-3 is omitted.

20 [0094] This handling monitoring system 30 is provided with first and second stands 32 and 34. The stand 32 is a fixed stand which is rigidly secured to a floor 36. The stand 34 is a movable stand that can be moved by means of castors 38, and can be moved to a desired position on the floor 36 relative to
25 the stand 32.

[0095] The foregoing seal handling unit 4 is built into the stand 32, and a cable 40 for each of the sensors 18-1, 18-2, ...18-8 (Fig. 1) is passed through the interior of the stand 32, drawn from the side surface portion in the vicinity
30 of a pedestal 42, and guided toward the stand 34. In this example, the foregoing pipe 10-2 is provided in the vicinity of the stand 32.

[0096] A data logger 46 and a personal computer (PC) 48 are installed in the vicinity of a shelf 44 of the stand 34,

and the monitor 24 is installed on a top plate 50. The data logger 46 is an example of the foregoing data accumulation unit 20, and the PC 48 is an example of the foregoing information generation unit 22. The data logger 46 has the cable 40 in the vicinity of the sensor group 18 connected thereto and captures the sensor outputs of each of the sensors 18-1, 18-2, ...18-8. The data logger 46 and PC 48 are interconnected by means of a cable 52, and data can be sent and received between the data logger 46 and PC 48.

10 [0097] If a trainee 54 who is operating the tightening tool 16 moves the stand 34 toward to the stand 32 and places the screen 56 of the monitor 24 in a visible position, the distribution map 26-2 of detected axial forces F , or the like, which varies according to the torque T applied to each of the bolts 12-1, 12-2, ...12-8 can be easily confirmed from an image, and handling in conjunction with this confirmation is feasible.

[0098] <Sensors 18-1, 18-2, ...18-8>

20 [0099] Fig. 8 illustrates a bolt which includes a strain gauge. A strain gauge 60 is provided inside a bolt main body 58. This strain gauge 60 is an example of the sensors 18-1, 18-2, ...18-8, and detects strain in the bolt main body 58 caused by the torque T acting on the bolts 12-1, 12-2, ...12-8, and the strain represents the axial force F . The cable 40 is connected to the strain gauge 60, and the detected axial force F is extracted as a sensor output via the cable 40.

[0100] <PC48>

30 [0101] Fig. 9 illustrates a configuration example of the handling monitoring system 30. The PC 48 is provided with a processor 62, a storage unit 64, an input/output unit (I/O) 66, a communication unit 68, and an operation input unit 70.

[0102] The processor 62 executes information processing of an operating system (OS) and various computer programs such as the handling monitoring program, in the storage unit 64. The

information processing includes, in addition to the processing including the foregoing processing a) to e), various processing which can be executed by a computer such as tightening force computation, handling history recording, control of the monitor 24, handling monitoring, and handling management.

[0103] The storage unit 64 is provided with a ROM (Read-Only Memory) and a RAM (Random-Access Memory), for example, as storage devices, and the ROM stores the OS and monitoring program. A database (DB) 72 for storing detection information and plot information, and the like, is constructed in the storage unit 64, and the DB 72 stores the detection information which is captured from the data logger 46. The detection information includes each sensor output of the sensor groups 18 and 28.

[0104] The I/O 66 is used to send and receive image data to/from the monitor 24. The data logger 46 is connected to the communication unit 68 by means of the cable 52.

[0105] The operation input unit 70 is configured from an input device such as a keyboard or mouse, and is used for screen operations and information inputs.

[0106] <Tightening procedure>

[0107] Fig. 10 illustrates a procedure for tightening the gasket 8. Handling conditions are input prior to tightening (S301). These handling conditions are assumed information regarding the selection of the gasket 8 and the size of tightening force.

[0108] The selection of a gasket 8 which is compatible with the handling conditions is performed (S302). The selection of the gasket 8 involves selecting a gasket 8 which is compatible with the target for the sealing between the flanges 6-1 and 6-2, and if a mistake is made in the selection of gasket, a suitable sealing state cannot be attained even when the tightening procedure and alignment are appropriate.

[0109] The inclusion or exclusion of tightening management is chosen (S303). Tightening management involves managing the tightening tool 16, the applied tightening force, and the tightening procedure. More specifically, it is necessary to at

5 least perform the following steps:

h) select an appropriate tightening tool 16

i) obtain the tightening force required for sealing by means of the appropriate tightening tool 16

j) perform tightening by means of the correct procedure.

10 Therefore, the foregoing steps are satisfied when tightening management is to be included, and when tightening management is "excluded," the foregoing steps are not satisfied or are left to the discretion of the handler.

[0110] When tightening management is included (YES in
15 S303), computation of a tightening force according to the handling conditions is performed (S304). The tightening force may be computed using a gasket tightening force (total load), a tightening torque, the bolt diameter, the recommended tightening surface pressure, the gasket contact area, a torque
20 coefficient, and the number of bolts, and the like.

[0111] Supposing that the gasket tightening force is W , the recommended tightening surface pressure is σ_g , and the gasket contact area is A_g , the gasket tightening force W is then:

25 $W = \sigma_g \times A_g$ (Equation 10).

Based on the contact outside diameter and contact inside diameter of the gasket 8, the gasket contact area A_g is

$A_g = (\pi/4) \times \{(\text{contact outside diameter})^2 - (\text{contact inside diameter})^2\}$ (Equation 11).

30 Supposing that the gasket tightening force is W , the tightening torque is $T(\text{N}\cdot\text{m})$, the torque coefficient (0.2) is k , the male screw outside diameter (m) is d , and the number of bolts is b_n , the tightening torque T is given by:

$T = k \times W \times d/b_n$ (Equation 12).

[0112] After such a computation result, designation of the tightening tool 16 and tightening procedure is performed (S305), and tightening by means of the designated tightening tool 16 and tightening procedure is carried out (S306). This
5 tightening may be performed using a predetermined tightening procedure, which may, for example, be a tightening procedure based on JIS (Japanese Industrial Standards) or ASME (American Society of Mechanical Engineers) standards, and the procedure includes a tightening sequence round direction, the number of
10 rounds, and measurement using calipers between the flanges, and so forth.

[0113] The tightening tool 16 is applied to the nuts 14 which have been temporarily tightened on each of the bolts 12-1, 12-2, ...12-8, and a suitable tightening force is added by
15 applying the torque T via the tightening tool 16. The tightening force is transmitted from each of the bolts 12-1, 12-2, ...12-8 to the flanges 6-1 and 6-2.

[0114] Elastic interaction is generated in the flanges 6-1 and 6-2 as a result of the axial forces F on each of the bolts
20 12-1, 12-2, ...12-8. Elastic interaction is a phenomenon whereby, for example, when the bolt 12-1 is tightened, slack is generated in each of the bolts 12-2 and 12-8 which lie adjacent to each other with the bolt 12-1 sandwiched therebetween, and the tightening force in the vicinity of each
25 of the bolts 12-2 and 12-8 is diminished.

[0115] During this tightening, handling monitoring processing is performed (S307). In this handling monitoring processing, a distribution map of the detected axial forces is dynamically displayed via coordinates.

30 [0116] In this handling monitoring processing, it is determined whether tightening is complete (S308). When tightening is continued (NO in S308), steps S306 to S308 are repeated, and if tightening is complete (YES in S308), the processing ends.

[0117] In S303, if tightening management is "excluded" (NO in S303), handling substitutes S304 to S308. That is, handling is left to the discretion of the trainee, and tightening is carried out using any tightening tool 16 and tightening
5 procedure, relying on the intuition of the trainee (S309). For the tightening state, handling monitoring as per S307 is executed (S310), and handling ends according to the purpose of the trainee.

[0118] <Handling monitoring>

10 [0119] Fig. 11 illustrates a processing procedure for the handling monitoring processing of S307 in the seal handling illustrated in Fig. 10. This processing procedure is an example of an execution procedure for a program executed by a computer, and an example of the seal material handling
15 monitoring method according to the present invention.

[0120] The seal material handling includes temporary tightening and final tightening steps. The temporary tightening is processing that is executed prior to final tightening, and includes mounting the nut 14 on each of the
20 bolts 12-1, 12-2, ...12-8, alignment adjustment, and tightening prior to the final tightening of the nuts 14, or similar. Alignment adjustment includes configuration of the positions of the gasket 8 and bolts 12-1, 12-2, ...12-8. The final tightening involves applying the torque T to the bolts
25 12-1, 12-2, ...12-8 by means of the tightening tool 16 so that the target axial force (target tightening force) is reached in stages.

[0121] In the handling monitoring processing, each of the detected axial forces is captured from the sensor group 18 as
30 a result of the processor 62 executing a program (S401), and processing to render a graphic from the detected axial forces F and target axial forces Fref is performed (S402).

[0122] Through control by the processor 62, a distribution map 26-1 of the target axial forces Fref and a distribution

map 26-2 of the detected axial forces F are dynamically displayed via coordinates on the monitor 24 (S403).

[0123] During the processing to render a graphic from the detected axial forces F and tightening handling, monitoring of
 5 whether the tightening processing reaches a predetermined number of rounds is performed (S404). As long as the predetermined number of rounds, for example, four to six rounds, has not been reached (NO in S404), S401 to S404 are continuously executed. Further, if the tightening processing
 10 reaches the predetermined number of rounds (YES in S404), seal handling is complete (S405), and the processing is terminated.

[0124] <Axial force table 74>

[0125] Fig. 12 illustrates an axial force table 74. This handling monitoring system 30 is provided with the axial force
 15 table 74 which records the numbers of rounds and the detected axial forces in the tightening. The axial force table 74 is included in the DB 72.

[0126] This axial force table 74 stores the numbers of rounds and the detected axial forces F of each of the sensors
 20 18-1, 18-2, ...18-8. For the number of rounds, a single pass operation for tightening all the bolts 12-1, 12-2, ...12-8 by means of a predetermined procedure is set, which is a plurality of rounds, for example, four to six. Each detected axial force is captured from the sensor group 18 with
 25 predetermined timing for each round. For example, in a number of rounds I , detected axial forces F_{1101} , F_{1102} , ... are captured with predetermined timing from the sensor 18-1, and detected axial forces F_{2101} , F_{2102} , ... are captured with the same timing from the sensor 18-2, with similar processing
 30 thereafter. The captured detected axial forces F are stored in the axial force table 74 and used in plot information processing.

[0127] <Parallelism table 76>

[0128] Fig. 13 illustrates a parallelism table 76. The

handling monitoring system 30 is provided with a parallelism table 76 which stores detected parallelism. The parallelism table 76 is included in the DB 72.

[0129] This parallelism table 76 stores numbers of rounds
 5 and the dimensions of gaps between the flanges which are detected by each of the sensors 28-1, 28-2, 28-3 and 28-4. Each gap dimension detected by the sensor group 28 is captured with predetermined timing for each round. For example, in a number of rounds I, gap dimensions D1101, D1102, D1103, and
 10 D1104 are captured with predetermined timing from the sensor 28-1, and gap dimensions D2101, D2102, ... are captured with the same timing from the sensor 28-2, with similar processing thereafter. The captured gap dimensions D are stored in the parallelism table 76 and are used in determining and
 15 displaying parallelism between the flanges.

[0130] <Generation of distribution map of target axial forces and detected axial forces, and operation to increase/decrease tightening force>

[0131] A in Fig. 14 illustrates each distribution map for
 20 target axial forces and initial detected axial forces. At the point in time when handling monitoring processing starts, the distribution map 26-1 of the target axial forces Fref is displayed via coordinates, and the distribution map 26-2 of the detected axial forces F for a temporary tightening state
 25 is displayed superposed on the distribution map 26-1, for example. At this point in time, the detected axial forces F are small at close to point 0, and the distribution map 26-2 is displayed over a far narrower area than the distribution map 26-1 of the target axial forces Fref. That is, it can thus
 30 be recognized that the detected axial forces F are small.

[0132] B in Fig. 14 illustrates each distribution map for target axial forces and intermediate detected axial forces. If the number of rounds in the tightening is increased, the detected axial forces F become large, and the distribution map

26-2 expands accordingly. At this point in time, although close to the distribution map 26-1 of target axial forces F_{ref} from the vicinity of point 0, the detected axial forces F are smaller than the target axial forces F_{ref} of the distribution map 26-1 and the distribution map 26-2 is displayed over a narrow area. It can also be seen that the detected axial forces F are inadequate at this point in time. Furthermore, on coordinate axis y_4 , the detected axial force F_4 is prominent on the same scale. It can be ascertained from this prominent state that the tightening due to the detected axial force F_4 is large relative to the other axial forces F .

[0133] C in Fig. 14 illustrates each distribution map for target axial forces and final detected axial forces. The number of rounds in the tightening has reached the final number, and the detected axial forces F match the target axial forces F_{ref} or have reached the neighborhood thereof. In other words, the distribution map 26-2 of the detected axial forces F graphically matches the distribution map 26-1 of the target axial forces F_{ref} or has a similar shape, and thus the required sealing state or ideal sealing state is obtained.

[0134] <Axial force adjustment>

[0135] A in Fig. 15 illustrates a state where the detected axial forces F are close to the target axial forces F_{ref} . For bolt 12-1 on coordinate axis y_1 , the detected axial force F_1 has reached the target axial force F_{ref} . However, for bolt 12-2 on coordinate axis y_2 , the axial force F_2 is inadequate.

[0136] Based on this state, when the axial force F_2 of the bolt 12-2 is increased, slack is generated due to elastic interaction acting in the vicinity of the bolts 12-1 and 12-3 which sandwich bolt 12-2, and, as illustrated in B of Fig. 15, the axial forces F_1 and F_3 are reduced. Based on this state, in order to cause the detected axial forces F_1 and F_3 to reach the target axial forces F_{1ref} and F_{3ref} , increase/decrease processing in which the axial forces F_1 and F_3 are increased

and the axial force F2 on the bolt 12-2 is reduced must be performed.

[0137] <Effects of Example 2>

[0138] According to Example 2, the following effects are
5 obtained.

[0139] (1) When, for example, a torque wrench is used as the tightening tool 16, inconsistencies at the level of the tightening force are produced. If there is a predetermined tightening procedure prescribed by JIS or the like for
10 tightening each of the bolts 12-1, 12-2, ...12-8, and this procedure is ignored or the procedure is executed erroneously, misalignment occurs, and a so-called uneven clamping state is generated. In this regard, in order to attain suitable sealing and improve tightening efficiency, the axial forces F applied
15 to each of the bolts 12-1, 12-2, ...12-8 must be monitored in real time, and the handling skills necessary for suitable tightening must be attained. Furthermore, even for the expert, there is a need to confirm skills, correct habits and so forth, and further enhance skills. Sealing is completed on condition
20 that tightening is performed through the application of suitable axial forces F and that a suitable procedure is carried out. By way of a suitable procedure, a suitable tightening force, prevention of inadequate tightening and overtightening, and by preventing tightening defects, suitable
25 tightening forces are applied to the gasket 8 between the flanges 6-1 and 6-2, and suitable sealing can be achieved by filling any gaps between the flanges 6-1 and 6-2 with the gasket 8.

[0140] (2) According to the handling monitoring system 30,
30 the relationship between tightening by an operator and the tightening forces acting on parts can be visually recognized.

[0141] (3) The tightening states of the bolts tightened by the operator can be visualized and the feel of the operator for tightening can be supported and corrected.

[0142] (4) Can be used as a training system for tightening bolts of pipe connections, and can be used for operator handling practice.

[0143] (5) Using this handling monitoring system 30 can
5 contribute toward improving operator handling capabilities.

[0144] (6) The part functions such as sealing for tightening can be exhibited without affecting handling, and handling reliability can be improved.

Example 3

10 [0145] A of Fig. 16 illustrates a processing procedure for configuring target axial forces for each gasket 8 according to an Example 3. In this processing procedure, target axial forces are calculated (S502) on the basis of the selection of the gasket 8 (S501). A distribution map representing these
15 target axial forces is displayed via coordinates (S503).

[0146] B of Fig. 16 illustrates a distribution map which is displayed via coordinates and which represents target axial forces according to the gasket 8. A distribution map 26-11 illustrates target axial forces for a gasket 8-1, for example,
20 a distribution map 26-12 illustrates target axial forces for a gasket 8-2, for example, and a distribution map 26-13 illustrates target axial forces for a gasket 8-3, for example.

[0147] If suitable target axial forces are calculated for each gasket 8 thus selected and a distribution map is
25 displayed via coordinates, the required tightening forces can be easily realized according to the selection of the gasket 8. The target axial forces and target tightening forces differ depending on the gasket 8 and bolts 12, but a well-known system, which computes a tightening torque by using the
30 recommended tightening surface pressure of the gasket and bolt dimension information, for example, in calculating the tightening forces, may be employed.

Example 4

[0148] Fig. 17 illustrates a bolt tightening procedure

display according to an Example 4.

[0149] Temporary tightening and final tightening of a plurality of bolts arranged on the circumference of the flange joint 6 must be performed by means of a fixed procedure.

5 [0150] For example, as illustrated in A of Fig. 17, a tightening mark 78 is moved from bolt 12-8 for which tightening has ended to bolt 12-1 which is to be tightened next, and bolt 12-1, whose tightening is impending, is suggested.

10 [0151] In this case, as illustrated in B of Fig. 17, the tightening mark 78 is displayed with a broken line, for example, to show that tightening has ended for bolt 12-1 whose tightening has just ended, and the tightening mark 78 may be moved to bolt 12-2 which is to be tightened next to suggest
15 the tightening procedure.

[0152] By causing tightening to be performed according to the display of a procedure in this way, misalignment can be prevented, and it is possible to prevent the generation of uneven clamping. Reliable handling and improved skills
20 enhancement are possible. Instead of the tightening mark 78, the number of a bolt whose tightening is impending may be provided with a color display or a flashing display that differs from the other bolt numbers.

Example 5

25 [0153] Fig. 18 illustrates a processing procedure that determines detected axial forces according to an Example 5. This processing procedure is an example of a computer program executed by the PC 48.

[0154] In this processing procedure, target axial forces
30 for the surface pressure required by the selected gasket 8 are calculated (S601), and these target axial forces are compared with detected axial forces (S602).

[0155] It is determined whether the detected axial forces F lie within tolerance of the target axial forces F_{ref} , for

example, $\pm 15\%$ (S603). If the detected axial forces F lie within tolerance of the target axial forces F_{ref} (YES in S603), the axial forces are accepted (S604) due to this determination result, and if the detected axial forces F lie out of

5 tolerance of the target axial forces F_{ref} (NO in S603), the axial forces are rejected (S605) due to this determination result.

[0156] A comprehensive evaluation is performed using these discrete determination results (S606). In the comprehensive

10 evaluation, acceptance occurs if all the discrete evaluations yield acceptance, rejection occurs if there is just one rejection, and the determination result is displayed on the monitor 24, and notification of the acceptance/rejection determination is issued (S607).

15 [0157] A of Fig. 19 illustrates a distribution map 26-2 of the detected axial forces F which is displayed via coordinates as an evaluation result. In this example, it can be seen that the axial forces F_3 and F_7 are smaller than the target axial forces F_{3ref} and F_{7ref} , and that the axial force F_6 is larger

20 than the target axial force F_{6ref} .

[0158] B of Fig. 19B illustrates an example of an evaluation table. In the evaluation table 80, a target axial force field, a tolerance field, a detected axial force field, a discrete evaluation field, and a comprehensive evaluation

25 field are configured. Target axial force = $F_{ref} = 30(\text{kN})$, axial force tolerance = $F_{ref} \pm 15\% = 25.5(\text{kN})$ to $34.5(\text{kN})$ are stored. The detected axial force field stores the sensor outputs of the sensor group 18 and the detected axial force of each bolt.

30 [0159] In this example, the axial forces F_1 , F_2 , F_4 , F_5 , and F_8 of the bolts 12-1, 12-2, 12-4, 12-5, and 12-8 are each within tolerance, while the axial forces F_3 , F_6 , and F_7 of the bolts 12-3, 12-6, and 12-7 are each out of tolerance. Therefore, in a discrete evaluation, the axial forces F_1 , F_2 ,

F4, F5, and F8 which are within tolerance are accepted, and the axial forces F3, F6, and F7 which are out of tolerance are rejected. Thus, the comprehensive evaluation yields rejection.

[0160] The foregoing are stored in the evaluation table 80, displayed on the monitor 24, and reported to the operator. For a "rejected" axial force, a red or red flashing alert display may be provided, and for an "accepted" axial force, the fact that secure sealing has been achieved may be displayed in green or another color.

10 [0161] Thus, the fact that sealing reliability is being impaired by a detected axial force which is at variance with a target axial force can be reported, thereby enabling the promotion of suitable sealing handling.

Example 6

15 [0162] Fig. 20 illustrates a processing procedure to determine acceptance/rejection of a tightening sequence, according to an Example 6. This processing procedure illustrates an example of processing which is realized by a computer program executed by the PC 48, or a handling monitoring method.

[0163] In this processing procedure, a tightening sequence is detected (S702) in response to tightening together the flanges 6-1 and 6-2 (S701). This sequence may be detected or determined from variations and transitions in the detected axial forces, and from tightening position movement information. It is determined whether or not the detected sequence coincides with a predetermined procedure which is a tightening standard (S703). As the predetermined tightening standard, the tightening procedure may be compliant with the foregoing JIS or ASME standards, for example.

25 [0164] If the detected procedure coincides with the predetermined tightening procedure (YES in S703), acceptance is displayed on the monitor 24 (S704). This display of acceptance may be made in conjunction with an axial force

distribution map.

[0165] If the detected procedure does not coincide with the predetermined tightening procedure (NO in S703), an error is displayed on the monitor 24 (S705). This error display may

5 likewise be made in conjunction with an axial force distribution map.

[0166] If the tightening sequence is determined by means of a comparison with the predetermined tightening procedure, it is possible to prevent uneven clamping that arises when
10 tightening is not carried out according to procedure, and to mitigate the leakage risk. Moreover, if this acceptance display or error display is made in conjunction with the foregoing axial force distribution map, an operator is able to become familiar with the fact that, if the procedure is
15 unsuitable, the leakage risk due to uneven clamping increases even when the detected axial forces match the target axial forces.

Example 7

[0167] In the foregoing embodiment examples, the flange
20 joint 6 of the seal handling unit 4 is secured in a fixed position, but the flange joint 6 may be freely changed to any position and, as illustrated in A of Fig. 21, the position of the flange joint 6 may be changed in a horizontal direction, for example. If the position of the flange joint 6 can be
25 arbitrarily changed, it is possible to practice performing tightening appropriately even when a different posture is adopted by simulating the actual working environment.

Furthermore, it can be understood that inconsistencies arise in the tightening force due to the working environment or the
30 posture of the operator, and that such inconsistencies degrade the seal performance.

[0168] Although the seal handling unit 4 is provided with a single flange joint 6 in the foregoing embodiment examples, as illustrated in B of Fig. 21, the top section of the stand

32 may also be provided with a first seal handling unit 4-1, and the midsection thereof may be provided with a second seal handling unit 4-2. In Fig. 21, the same reference signs are assigned to the same parts as Figs. 1 and 7. The seal handling unit 4-1 includes, for example, a flange joint 6A which is tightened by eight bolts and the seal handling unit 4-2 includes, for example, a large-diameter flange joint 6B which is tightened by twelve bolts. If the flange joints are combined in this way, handling under different conditions can be performed in substantially the same position.

[0169] (Further embodiments)

[0170] (1) The information generation unit 22 may, for example, determine the tightening procedure for each bolt from an increase or decrease in the axial force, or the like, and present the determination results to the monitor 24. The tightening procedure is according to JIS or ASME standards, but if uneven clamping arises when tightening is not performed according to procedure, the risk of a fluid or gas leak increases, and an error or alert may be displayed on the screen to notify the operator.

[0171] (2) In Example 2, the first sensors 18-1, 18-2, ...18-8 which detect axial forces and the second sensors 28-1, 28-2, 28-3 and 28-4 which detect parallelism are both provided, but the configuration may be such that only either one is provided and either a distribution map representing detected axial forces or a distribution map representing parallelism is generated.

(3) In the foregoing embodiment examples, a first distribution map and a second distribution map are displayed using common coordinates, but each distribution map may be displayed using discrete coordinates, where the areas in each distribution map are given different colors and can be identified by color.

[0172] (4) As described hereinabove, the most preferable

embodiments and embodiment examples of the present invention have been described. The present invention is not limited to or by the foregoing descriptions. Various changes and modifications can be made by a person skilled in the art on the basis of the spirit of the invention which is described within the scope of the claims and which is disclosed in the mode for carrying out the invention or in the embodiment examples. It goes without saying that such changes and modifications lie within the scope of the present invention.

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Industrial Applicability

[0173] According to the present invention, seal material handling monitoring can be performed in real time, distribution maps that represent an axial force distribution, which can be compared with target axial forces, and parallelism of the flange joint, can be displayed on a monitor and the display content confirmed during handling, and the handling results can be evaluated, thereby enabling handling skills enhancement.

20

Reference Signs List

[0174] 2 Handling monitoring device

4 Seal handling unit

4-1 First seal handling unit

25 4-2 Second seal handling unit

6 Flange joint

6-1, 6-2 Flange

8 Gasket

10-1, 10-2 Pipe

30 12-1, 12-2...12-8 Bolt

14 Nut

16 Tightening tool

18 First sensor group

28 Second sensor group

	18-1, 18-2...18-8	Sensor
	28-1, 28-2...28-4	Sensor
	20	Data accumulation unit
	22	Information generation unit
5	24	Monitor
	26-1	First distribution map
	26-2	Second distribution map
	26-3	Third distribution map
	30	Handling monitoring system
10	32	Stand
	34	Stand
	36	Floor
	38	Castor
	40	Cable
15	42	Pedestal
	44	Shelf
	46	Data logger
	48	PC
	50	Top plate
20	52	Cable
	54	Trainee
	56	Screen
	58	Bolt main body
	60	Strain gauge
25	62	Processor
	64	Storage unit
	66	Input/output unit (I/O)
	68	Communication unit
	70	Operation input unit
30	72	DB
	74	Axial force table
	76	Parallelism table
	78	Tightening mark
	80	Evaluation table

CLAIMS

1. A seal material handling monitoring device, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts,
5 the seal material handling monitoring device comprising:

a plurality of first sensors that detect an axial force of each bolt;

an information generation unit that generates distribution information of a target axial force by means of
10 the target axial force and position information for the axial force, and generates distribution information of the axial force by means of the axial force and position information;
and

a monitor that presents a first distribution map
15 representing the target axial force and presents a second distribution map representing the axial force, via coordinates,
and

a second sensor that detects parallelism between flanges of the flange joint,

20 wherein the information generation unit generates parallelism information by means of a sensor output from the second sensor, and the monitor presents a third distribution map representing parallelism between the flanges.

2. The seal material handling monitoring device according to
25 claim 1, wherein the information generation unit also refers to a tightening torque which is calculated by means of dimension information for the flanges of the flange joint and the bolts, determines, for each bolt, whether a tightening force for the seal material has reached a target tightening
30 force configured for each seal material, and presents determination results to the monitor.

3. The seal material handling monitoring device according to claim 1, wherein, by changing a position or an angle of a seal handling unit that includes the flange joint or by changing a

position or an angle of the flange joint, a work environment can be simulated.

4. A seal material handling monitoring program for causing a computer to implement functions to:

5 receive a sensor output from a plurality of first sensors that detect an axial force of each bolt,

generate distribution information of a target axial force by means of the target axial force and position information for the axial force, and generate distribution information of
10 the axial force by means of the axial force and position information; and

present a first distribution map representing the target axial force and present a second distribution map representing the axial force, via coordinates;

15 receive a sensor output from a second sensor that detects parallelism between flanges of a flange joint,

generate parallelism information by means of the sensor output from the second sensor, and

present a third distribution map representing the
20 parallelism between the flanges.

5. The seal material handling monitoring program according to claim 4, for further causing the computer to implement functions to:

configure a target tightening force for each seal
25 material, determine, for each bolt, whether a tightening force for the seal material has reached the target tightening force, and

present the determination results via a monitor.

6. A seal material handling monitoring method, sealing being
30 performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling monitoring method comprising:

a step of detecting an axial force of each bolt;

a step of generating distribution information of a target

axial force by means of the target axial force and position information for the axial force, and generating distribution information of the axial force by means of the axial force and position information; and

5 a step of presenting a first distribution map representing the target axial force and presenting a second distribution map representing the axial force, via coordinates;

10 a step of detecting parallelism between flanges of the flange joint;

 a step of generating parallelism information by means of the parallelism; and

 a step of presenting a third distribution map representing the parallelism between the flanges.

15 7. A seal material handling monitoring system, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling monitoring system comprising:

20 a seal handling unit including a sensor that detects parallelism between flanges of the flange joint;

 an information generation unit which is connected to the sensor by means of a wired or wireless connection, and which generates parallelism information by means of the parallelism; and

25 a monitor which is connected to the information generation unit by means of a wired or wireless connection, and which presents a distribution map representing the parallelism.

30 8. A seal material handling training system, sealing being performed by sandwiching a seal material in a flange joint and tightening the seal material by means of a plurality of bolts, the seal material handling training system comprising:

 a seal handling unit including a sensor that detects parallelism between flanges of the flange joint;

an information generation unit which is connected to the sensor by means of a wired or wireless connection, and which generates parallelism information by means of the parallelism; and

- 5 a monitor which is connected to the information generation unit by means of a wired or wireless connection, and which presents a distribution map representing the parallelism.