

DESCRIPTION

Title of Invention:

GASKET CONTROL METHOD, SYSTEM, AND PROGRAM

5 Technical Field

[0001] The present disclosure relates to a gasket control technique used, for example, for tightening a piping system.

Background Art

[0002] For tightening a gasket, tightening torque applied
10 to a flange by a bolt or a bolt axial force value has been traditionally used. The tightening torque and the bolt axial force value are information related to bolt tightening to tighten between flanges.

[0003] As for the gasket tightening, a system has been
15 known which uses a tightening surface pressure corresponding to the gasket and a type of internal fluid, a plurality of tightening forces, information on a bolt in order to grasp tightening torque (e.g., refer to Patent Literature 1). As for bolt tightening, a technique of creating data on strain on the
20 bolt and making a state in which the bolt is tightened visible has been known (e.g., refer to Patent Literature 2). In addition, a device has been known which measures a force applied to a part of a gasket by tightening with a sheet-type pressure sensor embedded inside the gasket (e.g., refer to
25 Patent Literature 3).

Citation List

Patent Literature

[0004] Patent Literature 1: JP 2014-225219 A
30 Patent Literature 2: JP 2015-141345 A
Patent Literature 3: JP 4699935 B2

Summary of Invention

Technical Problem

[0005] Incidentally, the reason why tightening torque and an axial force value of a bolt are used for gasket tightening control includes the following: the bolt is a means for tightening between flanges; and a tightening force applied from the bolt to the gasket can be easily found by measuring bolt strain.

[0006] However, as a result of examining a relationship between the bolt, the flange and the gasket very carefully, the tightening force of the bolt acts on the flange, and acts on the gasket only indirectly through the flange. That is, the flange is subject to a load due to the tightening of the bolt, and the load merely acts on the gasket through the flange. The torque value and the axial force value acting on the bolt are loads acting on a part of the flange, and do not represent a surface pressure acting on the gasket.

[0007] In light of the above, the gasket tightening control has the following issues.

[0008] a) A torque value and an axial force value acquired from a bolt are information on the bolt, and it cannot be said that a surface pressure to which the gasket is subjected is measured.

[0009] b) In view of the surface pressure applied to the gasket from a flange, the torque value and the axial force value of the bolt are merely indirect information, and are merely rough standards of the surface pressure.

[0010] c) The torque value and the axial force value of the bolt are influenced by a state in which the bolt and the flange are tightened, and this fluctuation tendency cannot be ignored.

[0011] In a case where the surface pressure on the gasket is estimated based on the torque value and the axial force value measured by a torque wrench or a bolt axial force meter, the relationship between the surface pressure (= estimated surface pressure) applied to the gasket and the surface

pressure (= actual surface pressure) to which the gasket is actually subjected under the influence of the state in which the bolt and the flange are tightened is as follows:

estimated surface pressure $\neq$ actual surface pressure.

5 Even if the measurement accuracy of the torque value and the axial force value is increased, the estimated surface pressure and the actual surface pressure on the gasket do not match. The surface pressure to which the gasket is subjected cannot be perceived.

10 [0012] Regarding such issues, the inventor has obtained findings that a change in the shape of a gasket depends on a load applied from between flanges and it is beneficial to observe the shape change in order to control the gasket tightening. Patent Literatures 1 to 3 do not disclose or
15 suggest such issues. The configuration disclosed in Patent Literatures 1 to 3 cannot solve such issues.

[0013] Therefore, an object of the present disclosure is to observe a change in the shape of a gasket that is subjected to a load between flanges and to use the observation result
20 for the gasket tightening control based on the issues and findings described above.

Solution to Problem

[0014] In order to achieve the above object, a control
25 method according to one aspect of the present disclosure includes a step of applying a load to a gasket restrained between flanges, and a step of observing a shape change occurring in the gasket due to the load, in which tightening of the gasket is controlled based on the shape change.

30 [0015] In the control method, the shape change includes at least one or both of a change occurring in the gasket in an interval direction between the flanges and a change occurring in a crossing direction with respect to the interval direction.

[0016] In order to achieve the above object, a control system according to one aspect of the present disclosure includes a measurement unit configured to measure a shape change in a gasket that is restrained between flanges and is subjected to a load, a control server configured to generate control information for controlling tightening between the flanges based on the shape change, and an information presentation unit configured to present the control information.

10 [0017] In order to achieve the above object, a program according to one aspect of the present disclosure is a program for causing a computer to implement a function of acquiring, in a case where a gasket restrained between flanges is subjected to a load, shape information indicating a shape change occurring in the gasket due to the load, and a function of generating control information for controlling tightening of the gasket based on the shape change.

Advantageous Effects of Invention

20 [0018] According to the present invention, any one of the following effects can be obtained.

[0019] (1) The change in the shape of the gasket occurring between the flanges represents a load applied to the gasket from between the flanges and a state in which the gasket is tightened, and the tightening of the gasket can be controlled by observing the change in the shape of the gasket.

[0020] (2) The change in the shape of the gasket caused between the flanges represents the state in which the gasket between the flanges is tightened and sealability between the flanges, and in a case where the change in the shape is directly observed from the gasket itself, the tightening state and the sealability between the flanges can be easily evaluated.

[0021] (3) As compared with the conventional control by a

torque value and an axial force value of a bolt, the accuracy of the gasket tightening control can be enhanced without depending on the skill of an operator.

[0022] Other objects, features, and advantages of the present invention will become more apparent from the accompanying drawings and the exemplary embodiments.

Brief Description of Drawings

[0023] Fig. 1 is a diagram illustrating a flange tightening portion according to a first embodiment.

Fig. 2 is a diagram illustrating an end surface cut along the line II-II in Fig. 1.

Fig. 3 is a diagram illustrating a gasket control system according to the first embodiment.

Fig. 4 is a diagram illustrating a gasket control database.

Fig. 5 is a diagram illustrating a gasket control system according to a third embodiment.

Fig. 6A is a diagram illustrating a gasket according to Example 1, and Fig. 6B is a diagram illustrating an example of a shape observation portion with respect to the gasket.

Fig. 7 is a diagram illustrating a change in the shape of the gasket according to Example 1 with respect to a load.

Fig. 8A is a diagram illustrating a gasket according to Example 2, Fig. 8B is a perspective view of an outer cut of a gasket, and Fig. 8C is a diagram illustrating a shape change occurring in the outer cut.

Fig. 9 is a diagram illustrating a change in the shape of the outer cut according to Example 2 with respect to a load.

Fig. 10A is a diagram illustrating a gasket according to Example 3, Fig. 10B is a perspective view for explaining an inner cut, and Fig. 10C is a diagram illustrating a shape change occurring in the inner cut.

Fig. 11 is a diagram illustrating a change in the shape

of the gasket according to Example 3 with respect to a load.

Fig. 12 is a diagram illustrating an example of observation of the shape of a gasket according to Example 4.

Fig. 13 is an example of shape observation according to Example 4, in which Fig. 13A is a diagram illustrating a shape change on an outer diameter side and an inner diameter side, and Fig. 13B is a diagram illustrating a shape change in a circumferential direction and a radial direction.

Fig. 14A is a diagram illustrating the shape of a gasket according to Example 5, Fig. 14B is a diagram illustrating an example of a state before a load is applied, and Fig. 14C is a diagram illustrating an example of a state in a case where a load of a predetermined value is applied.

Fig. 15 is a diagram illustrating an example of shape observation according to Example 5.

Description of Embodiments

[0024] [First Embodiment]

Fig. 1 illustrates a flange tightening portion 2 according to the first embodiment. The configuration illustrated in Fig. 1 is an example, and the present disclosure is not limited to such a configuration. In Fig. 1, as an example, an X-axis, a Y-axis, and a Z-axis are illustrated at the center of the flange tightening portion 2.

In the flange tightening portion 2, a pipeline 4-1 and a pipeline 4-2 are arranged in the Z-axis direction. In the pipeline 4-1, a flange 6-1 is formed as a tightening means on the pipeline 4-2. In the pipeline 4-2, a flange 6-2 is formed as a tightening means on the pipeline 4-1.

[0025] A gasket 8 is disposed between the flanges 6-1 and 6-2. The flanges 6-1 and 6-2 have a plurality of bolts 10 passing therethrough at predetermined angular intervals (45 degrees, for example) to be tightened with the bolts 10 and nuts 12.

The gasket 8 is a sealing member between the flanges 6-1 and 6-2, and is, for example, a sheet gasket made by combining polytetrafluoroethylene (PTFE) and a filler. The gasket 8 may be a gasket made of a resin other than PTFE or rubber. The
5 gasket 8 may be made of a metal material, or a combination of a metal material and ceramic, a heat-resistant fiber material, other materials, or the like. Further, examples of the gasket 8 include a spiral wound gasket 80 (Fig. 5), a flat gasket to which a sheet such as PTFE or graphite is attached, a
10 Kammprofile gasket in which a groove is formed on the gasket surface or a flange portion is provided in an outer edge portion, and the like.

[0026] The gasket 8 has a restrained portion 8-1 on the inner peripheral side, and a non-restrained portion 8-2 on the
15 outer peripheral side. The restrained portion 8-1 is sandwiched and restrained between the flanges 6-1 and 6-2, is a contact portion with the flanges 6-1 and 6-2, and is a region that is subjected to a load F from the flanges 6-1 and 6-2. The load F is a tightening load applied by the individual
20 bolts 10 and nuts 12.

[0027] The non-restrained portion 8-2 is integrated with the restrained portion 8-1, is not restrained by the flanges 6-1 and 6-2, and is a region on the peripheral edge side of the gasket 8. That is, the non-restrained portion 8-2 is not
25 in contact with the flanges 6-1 and 6-2, is not restrained by the flanges 6-1 and 6-2, and is a region that is not subjected to the load F from the flanges 6-1 and 6-2.

[0028] Then, the non-restrained portion 8-2 has a plurality of shape observation portions 14-1, 14-2, 14-3, and
30 14-4. Each of the shape observation portions 14-1, 14-2, 14-3, and 14-4 is a region with which to observe a shape change occurring in the non-restrained portion 8-2 due to the load F applied to the restrained portion 8-1. In the first embodiment, an observation plane formed by the X-axis and the

Y-axis is assumed, and the shape observation portions 14-1, 14-2, 14-3, and 14-4 having arbitrary widths are arranged at angular positions set at intervals of 90 degrees.

[0029] <End surface cut along line II-II in Fig. 1>

5 Fig. 2 illustrates an end surface cut along the line II-II in Fig. 1. The restrained portion 8-1 is sandwiched and restrained between gasket seats 16 of the flanges 6-1 and 6-2. On the other hand, the non-restrained portion 8-2 protrudes in a gap 18 between the flanges 6-1 and 6-2. An end of the gasket
10 8 is a free end at which, in response to the load F applied to the restrained portion 8-1, strain against the load appears as a shape change in the non-restrained portion 8-2, and constitutes a cantilever.

[0030] <Observation of shape change occurring in non-
15 restrained portion 8-2>

When the bolt 10 and the nut 12 are tightened in order to tighten between the flanges 6-1 and 6-2, the load F is applied to the restrained portion 8-1 of the gasket 8 from between the flanges 6-1 and 6-2.

20 [0031] In the gasket 8 subjected to the load F, strain is generated in the restrained portion 8-1, and the strain causes a change in the shape of the non-restrained portion 8-2. The shape change is a change amount according to the load F.

[0032] The shape change varies depending on the magnitude
25 and the direction of action of the load F. The shape change includes a change in an interval direction (Z-axis direction) between the flanges 6-1 and 6-2 and a change in a crossing direction (X-axis direction, Y-axis direction) with respect to the interval direction. The shape change of the gasket 8 of
30 the first embodiment includes a change in the thickness direction, the radial direction, or the circumferential direction of the gasket 8.

[0033] <Control process for gasket 8>

The control process for the gasket 8 is an example of the

control method of the present disclosure. The control process includes a step S1 of generating the restrained portion 8-1 and the non-restrained portion 8-2, a step S2 of applying the load F, a step S3 of acquiring shape information, and a step
5 S4 of presenting the shape information and the like. The signs S1 to S4 given to the steps represent the order of the steps, and the cited terms are merely used for convenience.

[0034] Step S1 of generating the restrained portion 8-1 and the non-restrained portion 8-2: The gasket 8 is placed
10 between the flanges 6-1 and 6-2, a portion of the gasket 8 in contact with the flanges 6-1 and 6-2 functions as the restrained portion 8-1, and a portion of the gasket 8 not in contact with the flanges 6-1 and 6-2 functions as the non-restrained portion 8-2. In other words, the restrained portion
15 8-1 and the non-restrained portion 8-2 of the gasket 8 are generated in response to the gasket 8 placed between the flanges 6-1 and 6-2.

[0035] Step S2 of applying the load F: In the gasket 8, the load F is applied to the restrained portion 8-1 restrained
20 by the flanges 6-1 and 6-2 by tightening the flanges 6-1 and 6-2. In response to the load F, a shape change occurs in the non-restrained portion 8-2 due to strain of the restrained portion 8-1.

[0036] Step S3 of acquiring shape information: A control
25 server 24 (Fig. 3) acquires shape information including the shape change occurring in the non-restrained portion 8-2.

[0037] Step S4 of presenting the shape information and the like: The control server 24 generates presentation information including the shape information and presents the presentation
30 information with an information presentation unit 26 (Fig. 3).

Note that the shape information acquired in step S3 of acquiring the shape information may be subjected to N-th order differentiation (multistage differentiation) to perform processing of highlighting a change point of the shape

information. By reflecting the processing result in the presentation information in the presentation step S4, the change point of the shape information can be clarified.

[0038] <Gasket control system 20>

5 Fig. 3 illustrates a gasket control system 20 according to the first embodiment. The gasket control system 20 is a system for executing the control process described above by information processing. The configuration illustrated in Fig. 3 is an example, and the present disclosure is not limited to
10 such a configuration. In Fig. 3, the same portions as those in Fig. 2 are denoted by the same reference numerals.

The gasket control system 20 includes a strain sensor 22, the control server 24, and the information presentation unit 26.

15 [0039] The strain sensor 22 is an example of a measurement units that measures a shape change from the shape observation portion 14 provided in the non-restrained portion 8-2, and outputs a detection signal indicating a change amount of the shape change occurring in the shape observation portion 14.
20 The strain sensor 22 may be a laser displacement meter, a camera, or the like as a device that detects a shape change and converts the shape change into an electric signal.

[0040] The laser displacement meter applies laser light to the shape observation portion 14, detects a shape change of
25 the shape observation portion 14 with reflected light, and observes a change amount. The camera captures an image of the shape observation portion 14, detects a shape change detected by the control server 24 with the strain sensor 22 by using the number of pixels, and acquires shape change information
30 corresponding to the strain.

[0041] The control server 24 is implemented by a computer having a communication function. The control server 24 includes a processor 28, a storage unit 30, an input/output (I/O) unit 32, and a communication unit 34. The processor 28

executes an operating system (OS) and a control program stored in the storage unit 30 to perform information processing for gasket control. The storage unit 30 includes a storage medium that stores the OS and the control program. The storage unit 5 30 stores, therein, a gasket control database (DB) 36 (Fig. 4). The communication unit 34 inputs and presents information in cooperation with a control terminal (not illustrated) under the control of the processor 28. The control terminal is also used for acquisition of shape information, writing to and 10 reading from the gasket control DB 36, and so on.

[0042] Further, under the control of the control server 24, the information presentation unit 26 presents control information including load information and determination information associated with change information indicating a 15 shape change.

[0043] <Information processing by control server 24>
The information processing by the control server 24 includes:
a) processing of capturing a detection output of the 20 strain sensor 22;
b) acquisition of the shape Information on the gasket 8 Including a shape change of the non-restrained portion 8-2; and
c) presentation of information with the information 25 presentation unit 26.

[0044] <Gasket control DB 36>
Fig. 4 illustrates an example of the gasket control DB 36. The gasket control DB 36 stores a gasket control file 38 therein.

30 The gasket control file 38 includes, as an example of control information on the gasket, a gasket information section 40, a shape detection information section 41, a time information section 42, a load information section 44, a strain sensor information section 46, a detection information

section 48, and a history information section 50.

[0045] In the gasket information section 40, specification information for identifying the gasket 8 and identification information of the gasket 8 are stored.

5 [0046] In the shape detection information section 41, information regarding the shape observation portions 14-1, 14-2, 14-3, and 14-4 are stored, for example, shape observation portion information such as forms and arrangement positions of Example 1 (Fig. 6), Example 2 (Fig. 8), Example 3 (Fig. 10),
10 and the like.

[0047] In the time information section 42, time information such as an observed date and time is stored.

[0048] In the load information section 44, load information such as a load F applied between the flanges 6-1
15 and 6-2 by tightening the bolt 10 and load conditions thereof is stored.

[0049] In the strain sensor information section 46, a type of a sensor that observes a shape change, and the like are stored.

20 [0050] In the detection information section 48, detection values acquired by the strain sensor 22 from the shape observation portions 14-1, 14-2, 14-3, and 14-4 are stored.

[0051] In the history information section 50, history information such as observation and information presentation
25 of a shape change, a load, and the like is stored.

[0052] <Effects of first embodiment>

According to the first embodiment, any one of the following effects can be obtained.

[0053] (1) A change in the shape of the gasket 8 is caused
30 by a load applied to the gasket 8 from between the flanges 6-1 and 6-2, and represents a state in which the gasket 8 is tightened. Therefore, the shape change is observed by the shape observation portion 14 of the gasket 8, so that the state in which the gasket 8 is tightened can be perceived and

the tightening state can be controlled.

[0054] (2) The change in the shape of the gasket 8 represents the sealability between the flanges 6-1 and 6-2 by the gasket 8 between the flanges 6-1 and 6-2, and in a case where the change in the shape is directly observed from the gasket itself, the sealability between the flanges 6-1 and 6-2 can be easily evaluated.

[0055] (3) As compared with the conventional control based on a torque value and an axial force value of a bolt, the accuracy of controlling the tightening of the gasket 8 can be enhanced without depending on the skill of an operator.

[0056] [Second Embodiment]

The control method for the gasket 8 according to the second embodiment further includes an estimation step S5 based on inflection point information in addition to the control method of the first embodiment.

In the estimation step S5 based on inflection point information, the shape information includes inflection point information of a shape change due to a specific load F, and the control server 24 can calculate a load F to be applied to the gasket 8 based on the inflection point.

[0057] The inflection point represents, for example, a state in which a shape change of the gasket 8 in the circumferential direction greatly changes, and includes a minimum point. The minimum point is a point at which the direction of change in shape change changes, and is, for example, a transition point from a compressed state to an extended (tensile) state or from an extended (tensile) state to a compressed state.

[0058] <Effects of second embodiment>

According to the second embodiment, any one of the following effects can be obtained.

[0059] (1) The inflection point information can be acquired from the shape information as singular information of

the shape change.

[0060] (2) By associating the inflection point information with the load F to be applied to the gasket 8, optimization of the load on the gasket 8 can be realized by confirming the
5 inflection point information from the shape information.

[0061] (3) It is possible to facilitate load setting and load adjustment for the gasket 8.

[0062] [Third Embodiment]

Fig. 5 illustrates the gasket control system 20 according
10 to the third embodiment.

The configuration illustrated in Fig. 5 is an example, and the technology of the present disclosure is not limited to such a configuration.

[0063] The gasket control system 20 is disposed between
15 the flanges 6-1 and 6-2, and a spiral wound gasket 80 is used as an observation target of a shape change due to a load F applied from the flanges 6-1 and 6-2. For example, as illustrated in Fig. 5, the gasket 80 is a laminate in which a plurality of members having different diameters is coaxially
20 arranged, and the gasket 80 includes an outer ring 801, a gasket body 802, and an inner ring 803.

[0064] The outer ring 801 and the inner ring 803 are made of, for example, a metal material such as stainless steel, carbon steel, or titanium, and are formed in an annular shape
25 having a predetermined thickness or a shape close thereto.

[0065] The gasket body 802 is configured by winding a laminate of a thin plate-like member made of, for example, a metal material and a buffer material (filler) such as graphite or fluororesin in a spiral shape between an inner wall surface
30 of the outer ring 801 and an outer wall surface of the inner ring 803. The laminate constituting the gasket body 802 is formed to have, for example, a "V" shape in cross section, or a waveform shape close thereto. The laminate has end surfaces, for example, adhered to the outer ring 801 and the inner ring

803 by spot welding.

[0066] In the gasket 80, for example, in the flange tightening portion 2, only the inner ring 803, or a part or the whole of the inner ring 803 and the gasket body 802, and a part of the outer ring 801 may be in contact with the gasket seats 16 (Fig. 2) to serve as the restrained portion 8-1 subjected to the load F. In short, a part or the whole of the outer ring 801 of the gasket 80 serves as the non-restrained portion 8-2. In the gasket 80, the gasket body 802 is deformed in response to the load F applied from the flanges 6-1 and 6-2, which causes strain in the outer ring 801.

[0067] In the gasket control system 20, for example, the shape observation portion 14 is provided in a part of the outer ring 801 which is the non-restrained portion 8-2, and the strain sensor 22 measures a shape change such as strain caused in the outer ring 801. The gasket control system 20 then uses a change amount of the shape change to perceive the load F applied to the gasket 80 and the state in which the gasket is tightened. Processing for controlling the state in which the gasket 80 is tightened may be performed in a manner similar to that in the above embodiment.

[0068] <Effects of third embodiment>

According to the third embodiment, any one of the following effects can be obtained.

[0069] (1) Effects similar to those of the first embodiment and the second embodiment can be obtained.

[0070] (2) Even in a case where the spiral wound gasket 80 is used, the tightening state can be perceived by measuring the shape change of the non-restrained portion 8-2 from the flanges 6-1 and 6-2.

Examples

[0071] <Example 1>

A of Fig. 6 illustrates the gasket 8 according to Example 1. In Example 1, the restrained portion 8-1 and the non-

restrained portion 8-2 are set concentrically with the same width or substantially the same width. The restrained portion 8-1 is provided on the same plane as the gasket 8, and may be a region automatically determined as a contact portion with the gasket seats 16 of the flanges 6-1 and 6-2, and the non-restrained portion 8-2 may be a region outside of the gasket seats 16.

[0072] B of Fig. 6 illustrates the gasket 8 in which the plurality of shape observation portions 14-1, 14-2, 14-3, and 14-4 are arranged. The shape observation portions 14-1, 14-2, 14-3, and 14-4 are arranged at angular intervals of a center angle of 90 degrees in the non-restrained portion 8-2. In B of Fig. 6, θ represents an angular range in which the shape observation portions 14-1, 14-2, 14-3, and 14-4 are provided. The arrangement positions of the shape observation portions 14-1, 14-2, 14-3, and 14-4 may be positions not overlapping with the arrangement positions of the bolts 10, but are not limited thereto.

[0073] In Fig. 7, the horizontal axis shows the load [kN] and the vertical axis shows the strain (shape change), angles = 0 (deg), 45 (deg), and 90 (deg) are used as parameters, and the shape change occurring in the gasket 8 according to Example 1 is shown as a measurement value measured by the strain sensor 22.

[0074] In Fig. 7, m1 represents deformation of the gasket 8 in the 0 (deg) direction (= the circumferential direction of the gasket 8), m2 represents deformation of the gasket 8 in the 45 (deg) direction, and m3 represents deformation in the 90 (deg) direction (= the thickness direction of the gasket 8).

[0075] As described above, in response to the load F applied to the restrained portion 8-1 from the flanges 6-1 and 6-2, the shape change corresponding to the load F occurs in the non-restrained portion 8-2.

An inflection point is generated in the shape change, and an optimum load F can be identified from the relationship between the load F applied to the gasket 8 and the inflection point of the shape change, and the optimum load F can be used as information in order to determine the initial tightening completion.

[0076] <Example 2>

A of Fig. 8 illustrates the gasket 8 according to Example 2. In Example 2, as with Example 1, the restrained portion 8-1 and the non-restrained portion 8-2 are set concentrically with the same width or substantially the same width.

[0077] The non-restrained portion 8-2 has an outer cut 54 on each of the shape observation portions 14-1, 14-2, 14-3, and 14-4. The outer cut 54 is formed in the outermost edge portion of the non-restrained portion 8-2 of the gasket 8 and has a notched shape partly having a non-closed portion.

[0078] In Example 2, the plurality of outer cuts 54 is formed in the gasket 8, and the outer cuts 54 are arranged at angular intervals of a center angle of 90 degrees in the non-restrained portion 8-2.

[0079] For example, as illustrated in B of Fig. 8, the outer cut 54 is a groove having a constant width $W1$ cut by a constant length $L1$ from the peripheral surface of the gasket 8 toward the center direction, and the outer cut 54 penetrates the upper and lower surfaces of the gasket 8. That is, the outer cut 54 has, inside the gasket 8, a vertical surface portion 56 and parallel surface portions 58 and 60 facing each other with a constant width $W1$ therebetween.

[0080] When a load F is applied from the flanges 6-1 and 6-2 to the restrained portion 8-1 of the gasket 8 having the outer cut 54, as illustrated in C of Fig. 8, the vertical surface portion 56 expands in the direction as indicated by an arrow "a" and is displaced in the circumferential direction according to the load F . Each of the parallel surface portions

58 and 60 expands in the circumferential direction as indicated by arrows "b" and "c". At this time, the edge surface of the gasket 8 extends outwardly as indicated by an arrow "d".

5 [0081] Such a shape change can be easily detected by the strain sensor 22. Incidentally, a sensor member such as metal or resin may be placed in a space of the outer cut 54, and a shape change of the outer cut 54 may be found by the sensor member.

10 [0082] In Fig. 9, the horizontal axis shows the load [kN] and the vertical axis shows an opening width (shape change) [mm] of the outer cut 54, and the relationship between the shape change occurring in the gasket 8 according to Example 2 and the load is shown. Similarly, Table 1 shows a relationship
15 between an opening width W2 of the outer cut 54 and the load F.

[0083] [Table 1]

Load F[k N]	Opening width W2[mm]
0	1
2 5	1. 1
5 0	1. 3
7 5	1. 5
1 0 0	1. 7
1 2 5	2. 5
1 5 0	3. 2

20 [0084] In a case where the load F is applied to the restrained portion 8-1 from the flanges 6-1 and 6-2 and the load F on the restrained portion 8-1 increases, the opening width W2 of the outer cut 54 representing the shape change with respect to the load F increases. An inflection point is
25 generated in the shape change. Therefore, in the case of using Example 2, if the inflection point of the shape change occurring in the shape observation portions 14-1, 14-2, 14-3,

and 14-4 is set at a target, a relationship between the shape change and the load F can be identified.

[0085] <Example 3>

5 A of Fig. 10 illustrates the gasket 8 according to Example 3. In Example 3, as with Examples 1 and 2, the restrained portion 8-1 and the non-restrained portion 8-2 are set concentrically with the same width or substantially the same width.

10 [0086] The non-restrained portion 8-2 has an inner cut 62 on each of the shape observation portions 14-1, 14-2, 14-3, and 14-4. The inner cut 62 is a through hole formed in the non-restrained portion 8-2 of the gasket 8.

15 [0087] The inner cuts 62 are arranged at angular intervals of a center angle of 90 degrees in the non-restrained portion 8-2, but the present disclosure is not limited thereto.

20 [0088] As illustrated in B of Fig. 10, the inner cut 62 is an arc-shaped groove which is concentric with the peripheral edge portion of the gasket 8 and has a constant width W, and the inner cut 62 penetrates the upper and lower surfaces of the gasket 8. That is, the inner cut 62 has, inside the gasket 8, vertical surface portions 64 and 66 and concentric arcuate portions 68 and 70 facing each other with a constant width W3 therebetween and a constant length L2.

25 [0089] When a load F is applied from the flanges 6-1 and 6-2 to the restrained portion 8-1 of the gasket 8 having the inner cut 62, as illustrated in C of Fig. 10, the distance between the arcuate portions 68 and 70 is reduced according to the load F as indicated by arrows "e" and "f", and the edge surface of the gasket 8 extends outwardly as indicated by an arrow "g". Such a shape change can be easily detected by the strain sensor 22.

30 [0090] Incidentally, a sensor member such as metal or resin may be placed in a space of the inner cut 62, and a shape change of the inner cut 62 may be found by the sensor

member.

[0091] In Fig. 11, the horizontal axis shows the load [kN] and the vertical axis shows the strain (shape change) of the inner cut 62, and the relationship between the shape change occurring in the gasket 8 according to Example 3 and the load is shown.

[0092] In a case where the load F is applied to the restrained portion 8-1 from the flanges 6-1 and 6-2 and the load F on the restrained portion 8-1 increases, the shape of the inner cut 62 representing the change in the load F changes. A minimum point included in the inflection point is generated in the shape change, and also in Example 3, the relationship between the shape change and the load F can be identified using such a minimum point as a target. As described above, the minimum point is a point at which the direction of the shape change occurring in the non-restrained portion 8-2 of the gasket 8 changes, and in other words, is a transition point from a compressed state to an extended (tensile) state of the inner cut 62 or from an extended (tensile) state to a compressed state of the inner cut 62.

[0093] Therefore, according to Example 3, in the relationship between the load F and the shape change, the minimum point remarkably appears due to the shape change in the circumferential direction, but the minimum point is equal to the inflection point in some cases. In addition, due to the shape change in the circumferential direction, not the minimum point but an inflection point at which the shape change in the circumferential direction greatly changes is generated in some cases.

[0094] <Detection of inflection point of shape information and tightening criteria>

As shown in Example 1, Example 2, and Example 3, an inflection point can be generated in shape information corresponding to a specific load F. As a result, at the time

of tightening the flanges 6-1 and 6-2, the specific load F can be estimated from the inflection point of the shape information, and can be used as criteria for determining tightening completion.

5 [0095] <Comparison of Examples 1, 2 and 3>

[0096] [Table 2]

		Example 1	Example 2	Example 3		
		Outer cut and inner cut: None		3-1	3-2	3-3
Shape	Width [mm]	—	1	1	2	1
	Length [mm]	—	3	30	30	50
Opening width W_2 [mm] of outer cut 54 at applying load 125 kN		—	2.5	—	—	—
Inflection point load [kN] of strain in circumferential direction		140	125	135	115	120
Minimum point load [kN] of strain in circumferential direction		None	None	135	115	120

[0097] Table 2 shows the shape, shape change, and inflection point of Example 1 (= outer cut 54 and inner cut 62: none), Example 2 (= outer cut 54), and Example 3 (= inner cut 62).

[0098] In Example 1, the outer cut 54 and the inner cut 62 were not provided.

In Example 2, the outer cut 54 having a width $W_1 = 1$ mm and a length $L_1 = 3$ mm was formed.

In Example 3-1, the inner cut 62 was set to have a width $W_3 = 1$ mm and a length $L_2 = 30$ mm.

In Example 3-2, the width W_3 was set to 2 mm, and the length L_2 was set to 30 mm.

20 In Example 3-3, the width W_3 was set to 1 mm, and the length L_2 was set to 50 mm.

[0099] In Example 1, the inflection point load = 140 kN was obtained and no minimum point load was obtained from the shape change in the circumferential direction.

25 In Example 2, the inflection point load = 125 kN was

obtained and no minimum point load was obtained from the shape change in the circumferential direction.

In Example 3-1, the inflection point load = 135 kN and the minimum point load = 135 kN were obtained from the shape change in the circumferential direction.

In Example 3-2, the inflection point load = 115 kN and the minimum point load = 115 kN were obtained from the shape change in the circumferential direction.

In Example 3-3, the inflection point load = 120 kN and the minimum point load = 120 kN were obtained from the shape change in the circumferential direction.

[0100] <Effects of Examples 1, 2, and 3>

As is apparent from Examples 1, 2, and 3, in the outer cut 54, an appropriate load F can be estimated by measuring an opening width W2 of the cut shape from the side surface. In a case where the outer cut 54 is used for shape detection, the opening width W2 of the outer cut 54 is measured in advance for each load F to be applied to the gasket 8, and the load F can be estimated by comparing the opening width W2 with a measured value. In the estimation, the opening width W2 of the outer cut 54 is stored as a database for each load F, and the load F can be easily and accurately calculated in comparison with the measured value of the shape change.

[0101] In the inner cut 62, the flanges 6-1 and 6-2 are subjected to the load F, and the inner wall surfaces of the inner cut 62 having a through-hole shape are closed (contact), so that a remarkable change is achieved.

[0102] In monitoring and measuring such a shape change, unlike torque control and measurement of bolt axial force, a shape change of the non-restrained portion 8-2 (Example 1), a shape change of the outer cut 54 (Example 2), and a shape change of the inner cut 62 (Example 3) are measured, and a change representing the load F can be acquired from the gasket 8. Therefore, the load F applied to the flanges 6-1 and 6-2

can be estimated from the shape change of the gasket 8 without the influence of the bolt 10 and the flanges 6-1 and 6-2.

[0103] As for the processing shapes of the outer cut 54 and the inner cut 62, it was confirmed that the gasket 8 is also adaptable to various diameters and thicknesses.

[0104] <Example 4>

Fig. 12 illustrates an example of the configuration of the gasket 80 according to Example 4. In Example 4, for example, at least the outer ring 801 of the spiral wound gasket 80 constitutes the non-restrained portion 8-2. In Example 4, shape changes Qa and Qb on the outer edge side and the inner edge side of the outer ring 801 of the gasket 80 extending and contracting in the circumferential direction and a shape change R of the gasket 80 extending and contracting in the radial direction are to be measured.

[0105] <Measurement of shape changes Qa and Qb in circumferential direction>

In A of Fig. 13, the horizontal axis shows the load [kN] and the vertical axis shows the strain (shape change) in the circumferential direction, and the shape change Qa occurring in the outer edge of the outer ring 801 and the shape change Qb occurring in the inner edge of the outer ring 801 are shown as measurement values measured by the strain sensor 22.

[0106] In the outer ring 801, the strain on the inner edge side is larger than the strain on the outer edge side. That is, since the inner edge side of the outer ring 801 greatly changes in shape, the behavior of the change in the gasket 80 or the gasket body 802 due to the load F is easily detected.

[0107] <Measurement of shape change Qb in circumferential direction and shape change R in radial direction>

In B of Fig. 13, the horizontal axis shows the load [kN] and the vertical axis shows the strain (shape change), and the shape change Qb in the circumferential direction occurring in the inner edge of the outer ring 801 and the shape change R

occurring in the radial direction are shown as measurement values measured by the strain sensor 22.

[0108] From the measurement result, in the shape change Q_b in the circumferential direction, since the measured value increases in the positive direction as the gasket surface pressure increases, it can be perceived that the force in the tensile direction acts. In the shape change R in the radial direction, since the measured value increases in the negative direction as the gasket surface pressure increases, it can be perceived that the gasket is in the compressed state.

[0109] <Example 5>

A of Fig. 14 illustrates an example of the configuration of the gasket 80 according to Example 5. In Example 5, for example, at least the outer ring 801 constitutes the non-restrained portion 8-2. In Example 5, an inner cut 82 having a predetermined length is formed along the outer periphery of a part of the outer ring 801 of the gasket 80. The inner cut 82 is a through hole formed in the non-restrained portion 8-2 of the gasket 8. The inner cut 82 is formed, for example, at a position of 5 [mm], as a predetermined distance t , from the outer edge portion of the outer ring 801. In Example 5, for example, the shape observation portion 14 is provided in the outer edge portion along the position at which the inner cut 82 is formed.

[0110] As illustrated in B of Fig. 14, for example, in the outer ring 801, an inner cut 82a is opened with a predetermined width of, for example, 0.1 [mm] before the load F from the flanges 6-1 and 6-2 is applied to the gasket body 802. When the load F acts through the gasket body 802, for example, as illustrated in C of Fig. 14, a part or the whole of the opening of the outer ring 801 is deformed to form a closed inner cut 82b. In Example 5, a shape change Q_c of the outer ring 801 in the state of the gasket surface pressure and the inner cut 82b due to the load F is measured.

[0111] In Fig. 15, the horizontal axis shows the load [kN] and the vertical axis shows the strain (shape change), and the shape change Q_c in the circumferential direction occurring in the outer edge corresponding to the position at which the inner cut 82b of the outer ring 801 is formed is shown as a measurement value measured by the strain sensor 22.

[0112] In the measurement result, in a case where the load on the gasket increases, for example, there is no large change in strain from the start of application of the load to a predetermined value, and thereafter, when the load exceeds a predetermined value, a negative value is measured in the strain sensor. This means, for example, a shape change showing that the outer edge portion of the outer ring 801 is compressed in the circumferential direction. The value of the strain in the circumferential direction increases in the positive direction after a minimum point appears around 220 kN of the load, for example.

[0113] <Effects of Examples 4 and 5>

According to Examples 4 and 5, the following effects can be expected.

[0114] (1) The shape change of the outer ring 801 of the spiral wound gasket 80 sandwiched between the flanges 6-1 and 6-2 is measured, so that the surface pressure on the gasket 80 due to the load F can be perceived.

[0115] (2) In the spiral wound gasket 80, there is a difference in state of the strain depending on the measurement position of the outer ring 801 due to the shape characteristics of the gasket body 802 formed in a wound shape, and the state of the gasket and the state of the load can be found in detail.

[0116] (3) Since the gasket body 802 and the outer ring 801 are separate members, in the spiral wound gasket 80, the tendency of the strain occurring in the non-restrained portion 8-2 with respect to the load F applied from the flanges 6-1

and 6-2 is different as compared with a sheet gasket made of a single member, but the load F applied from the flanges 6-1 and 6-2 can be estimated from the shape change of the gasket 80.

[0117] (4) In the inner cut 82 formed in the spiral wound
5 gasket 80, the opening is closed in response to the load F applied from the flanges 6-1 and 6-2, so that a remarkable change in the strain occurring in the outer ring 801 is obtained.

[0118] (5) In the flange tightening portion 2 using the
10 spiral wound gasket 80, a change representing the load F can be acquired from the gasket 8 by measuring the shape changes Qa, Qb, and R occurring in the outer ring 801 (Example 4) and the shape change of the inner cut 82 (Example 5), unlike the torque control and the measurement of bolt axial force in
15 monitoring and measuring the shape change. Therefore, the load F applied to the flanges 6-1 and 6-2 can be estimated from the shape change of the gasket 80 without the influence of the bolt 10 and the flanges 6-1 and 6-2.

[0119] [Other Embodiments]

20 (1) Regarding the outer cut 54, the vertical surface portion 56 and the parallel surface portions 58 and 60 are exemplified in Example 2, but they are examples. The outer cut 54 may have a shape without the vertical surface portion 56, or may have, for example, a V-shape in which the parallel
25 surface portions 58 and 60 are not parallel to each other.

[0120] (2) Regarding the inner cut 62, the concentric arcuate portions 68 and 70 are exemplified in Example 3, but they are examples. The inner cut 62 may have a shape in which the arcuate portions 68 and 70 do not have a constant width,
30 or may have a parallel surface or a non-parallel surface instead of the arcuate shape.

[0121] (3) In the presentation step (S4) of the shape information and the like of the control process for the gasket 8, the control server 24 may generate the presentation

information by performing processing such as multistage differentiation on the acquired shape information, or may present a display unit to clearly indicate a change point in the information presentation unit 26 (Fig. 3).

5 [0122] As described above, the most preferred embodiment and the like of the present disclosure have been described. The present disclosure is not limited to the above description. Various modifications and changes can be made by those skilled in the art based on the gist of the invention
10 described in the claims or disclosed in the embodiments for carrying out the invention. It goes without saying that such modifications and changes are included in the scope of the present disclosure.

15 Industrial Applicability

[0123] According to the gasket control method, system, and program of the present disclosure, a change in the shape of the gasket caused by a load applied from the flanges is observed without measuring an axial force or a torque value of
20 the bolt that tightens between the flanges, a load on the gasket can be calculated based on the shape information without the influence of a state in which the bolt or the flange is tightened, and the calculated load can be used for control information such as gasket replacement, which is
25 advantageous.

Reference Signs List

[0124] 2 FLANGE TIGHTENING PORTION
4-1, 4-2 PIPELINE
30 6-1, 6-2 FLANGE
8, 80 GASKET
8-1 RESTRAINED PORTION
8-2 NON-RESTRAINED PORTION
10 BOLT

12 NUT
 14, 14-1, 14-2, 14-3, 14-4 SHAPE OBSERVATION PORTION
 16 GASKET SEAT
 18 GAP
 5 20 GASKET CONTROL SYSTEM
 22 STRAIN SENSOR
 24 CONTROL SERVER
 26 INFORMATION PRESENTATION UNIT
 28 PROCESSOR
 10 30 STORAGE UNIT
 32 INPUT/OUTPUT (I/O) UNIT
 34 COMMUNICATION UNIT
 36 GASKET CONTROL DATABASE (DB)
 38 GASKET CONTROL FILE
 15 40 GASKET INFORMATION SECTION
 41 SHAPE DETECTION INFORMATION SECTION
 42 TIME INFORMATION SECTION
 44 LOAD INFORMATION SECTION
 46 STRAIN SENSOR INFORMATION SECTION
 20 48 DETECTION INFORMATION SECTION
 50 HISTORY INFORMATION SECTION
 54 OUTER CUT
 56 VERTICAL SURFACE PORTION
 58, 60 PARALLEL SURFACE PORTION
 25 62, 82 INNER CUT
 64, 66 VERTICAL SURFACE PORTION
 68, 70 ARCUATE PORTION
 801 OUTER RING
 802 GASKET BODY
 30 803 INNER RING

CLAIMS

1. A control method comprising:
a step of applying a load to a gasket restrained between
flanges; and

5 a step of observing a shape change occurring in the
gasket due to the load; wherein tightening of the gasket is
controlled based on the shape change.

2. The control method according to claim 1, wherein the
shape change includes at least one or both of a change
10 occurring in the gasket in an interval direction between the
flanges and a change occurring in a crossing direction with
respect to the interval direction.

3. A control system comprising:
a measurement unit configured to measure a shape change
15 in a gasket that is restrained between flanges and is
subjected to a load;

a control server configured to generate control
information for controlling tightening between the flanges
based on the shape change; and

20 an information presentation unit configured to present
the control information.

4. A program for causing a computer to implement:

a function of acquiring, in a case where a gasket
restrained between flanges is subjected to a load, shape
25 information indicating a shape change occurring in the gasket
due to the load; and

a function of generating control information for
controlling tightening of the gasket based on the shape
change.