

DESCRIPTION

MECHANICAL JOINT, JOINT-EQUIPPED STEEL PIPE, METHOD FOR
MANUFACTURING JOINT-EQUIPPED STEEL PIPE, STRUCTURE, METHOD
FOR INSTALLING STRUCTURE, AND METHOD FOR DESIGNING

5 MECHANICAL JOINT

Field

[0001] The present invention relates to a mechanical
joint used for joining steel pipes together, a joint-
equipped steel pipe including a mechanical joint, a method
10 for manufacturing a joint-equipped steel pipe, a mechanical
joint, and a structure including a plurality of steel pipes
joined together with a mechanical joint, a method for
installing a structure, and a method for designing a
mechanical joint.

15 Background

[0002] Conventionally, welding has mainly been used for
joining steel pipes together, but in recent years,
mechanical joining has also come into use due to shortened
construction periods and quality control issues. As to
20 this mechanical joint, Patent Literature 1 discloses a
joint with excellent installability that enables joining
simply by insertion.

[0003] The "joint structure of steel pipes" described in
Patent Literature 1 provides an outer joint pipe and an
25 inner joint pipe at the respective ends of steel pipes to
be joined together, and the outer joint pipe and the inner
joint pipe are inserted and fit to each other in a pipe
axial direction to join the steel pipes together. Either
the outer joint pipe or the inner joint pipe is split in a
30 circumferential direction at its tip and can bend in a
radial direction. A push-in load is applied in the axial
direction to bend the tip of either the outer joint pipe or
the inner joint pipe and to insert them to each other. In

this process, at an insertion end position, the bending is restored, and protrusions formed on the outer circumferential face of the inner joint pipe and an engagement part formed on the inner circumferential face of the outer joint pipe are engaged and fit together, or protrusions formed on the inner circumferential face of the outer joint pipe and an engagement part formed on the outer circumferential face of the inner joint pipe are engaged and fit together.

10 Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Patent Application Laid-open No. 2004-36329

Summary

15 Technical Problem

[0005] In the joint described in Patent Literature 1, the part split in the circumferential direction at the tip has an arc-shaped section and thus has higher bending rigidity than those with a rectangular section, requiring a large push-in load when fitting the joints together. In addition, joints generally require to be equal in compressive and tensile strength to steel pipes, and thus when the plate thickness of the joints is increased along with the specification of steel pipes, an even larger push-in load is required. An increase in the push-in load required for fitting by insertion worsens installability, and thus methods to reduce the push-in load are being considered.

[0006] To reduce the required push-in load, the number of splits of the part to be bent may be increased; however, if the part is fabricated by cutting, the number of cutting points increases to require processing costs. Furthermore, as the number of splits increases, the strength of the part

decreases, and unexpected loads during transportation or during work may cause irreversible deformation such as twisting, which may result in the failure of fitting during installation. Thus, there has been a demand for a
5 mechanical joint that can reduce the push-in load without increasing the number of splits.

[0007] The present invention has been made in view of the above problems, and an object thereof is to provide a mechanical joint, a joint-equipped steel pipe, a method for
10 manufacturing a joint-equipped steel pipe, a structure, a method for installing a structure, and a method for designing a mechanical joint that can reduce a push-in load required for fitting to improve installability without bringing about an increase in processing costs and a
15 reduction in strength.

Solution to Problem

[0008] A mechanical joint according to one aspect of the present invention includes: an inner joint pipe and an outer joint pipe provided at respective ends of a steel
20 pipe to be joined; a protrusion formed on an outer circumferential face of the inner joint pipe; an engagement part formed on an inner circumferential face of the outer joint pipe and configured to be engaged with the protrusion and resist a tensile load together with the protrusion in a
25 case where the inner joint pipe and the outer joint pipe are fit together; and a guide part provided in the outer joint pipe closer to a tip than the engagement part, the guide part being configured to abut the protrusion to bend split pieces in cooperation with the protrusion and
30 maintain a bent state until the protrusion reaches the engagement part in a fitting process of fitting the inner joint pipe and the outer joint pipe together, wherein either one of the inner joint pipe and the outer joint pipe

includes the split pieces split at regular intervals in a circumferential direction and configured to bend in a radial direction, the split pieces being grouped into a plurality of groups satisfying the following conditions (1) and (2), and configured to shift timing to reach maximum bending for each of the split pieces of the same group in the fitting process: (1) the axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part are the same, and the axial positions are different for each group; and (2) in the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line forms a straight line passing through a pipe center or a polygon whose center of gravity matches the pipe center.

[0009] A mechanical joint according to one aspect of the present invention includes: an inner joint pipe and an outer joint pipe provided at respective ends of a steel pipe to be joined; a protrusion formed on an inner circumferential face of the outer joint pipe; an engagement part formed on an outer circumferential face of the inner joint pipe and configured to be engaged with the protrusion and resist a tensile load together with the protrusion in a case where the inner joint pipe and the outer joint pipe are fit together; and a guide part provided in the inner joint pipe closer to a tip than the engagement part, the guide part being configured to abut the protrusion to bend split pieces in cooperation with the protrusion and maintain a bent state until the protrusion reaches the engagement part in a fitting process of fitting the inner joint pipe and the outer joint pipe together, wherein either one of the inner joint pipe and the outer joint pipe includes the split pieces split at regular intervals in a

circumferential direction and configured to bend in a radial direction, the split pieces being grouped into a plurality of groups satisfying the following conditions (1) and (2), and configured to shift timing to reach maximum bending for each of the split pieces of the same group in the fitting process: (1) the axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part are the same, and the axial positions are different for each group; and (2) in the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line forms a straight line passing through a pipe center or a polygon whose center of gravity matches the pipe center.

[0010] In the above-described mechanical joint according to the present invention, before the split pieces of one of the groups reach the maximum bending, radial bending does not start in the split pieces of another group.

[0011] A joint-equipped steel pipe according to one aspect of the present invention includes: at least one of the inner joint pipe and the outer joint pipe of the mechanical joint according to the present invention at both ends or one ends of the steel pipe.

[0012] A method for manufacturing the joint-equipped steel pipe according to one aspect of the present invention includes: mounting at least one of the outer joint pipe and the inner joint pipe of the mechanical joint according to the present invention on an end or ends of a steel pipe to be joined together.

[0013] A structure according to one aspect of the present invention includes: the mechanical joints according to the present invention; and a plurality of steel pipes joined together with the mechanical joints.

[0014] A method according to one aspect of the present invention for installing the structure according to the present invention includes: erecting either one of a first steel pipe mounted with the outer joint pipe at a first end and a second steel pipe mounted with the inner joint pipe at a second end in the ground; placing another one of the first and the second steel pipes on the one of the first and the second steel pipes; and fitting and joining the inner joint pipe and the outer joint pipe together.

10 [0015] A method according to one aspect of the present invention designs a mechanical joint including: an inner joint pipe and an outer joint pipe provided at respective ends of a steel pipe to be joined; a protrusion formed on an outer circumferential face of the inner joint pipe; an engagement part formed on an inner circumferential face of the outer joint pipe and configured to be engaged with the protrusion and resist a tensile load together with the protrusion in a case where the inner joint pipe and the outer joint pipe are fit together; and a guide part provided in the outer joint pipe closer to a tip than the engagement part, the guide part being configured to abut the protrusion to bend split pieces in cooperation with the protrusion and maintain a bent state until the protrusion reaches the engagement part in a fitting process of fitting the inner joint pipe and the outer joint pipe together, wherein either one of the inner joint pipe and the outer joint pipe includes the split pieces split at regular intervals in a circumferential direction and configured to bend in a radial direction, and the method includes: grouping the split pieces into a plurality of groups satisfying the following conditions (1) and (2), (1) the axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part are the

same, and the axial positions are different for each group,
(2) in the split pieces belonging to the same group,
connecting adjacent circumferential centers to each other
with a straight line forms a straight line passing through
5 a pipe center or a polygon whose center of gravity matches
the pipe center; designing the split pieces to be
configured to shift timing to reach maximum bending for
each of the split pieces of the same group in the fitting
process; and designing the split pieces to be configured to
10 cancel horizontal stresses occurring by the bending of the
split pieces.

[0016] A method according to one aspect of the present
invention designs a mechanical joint including: an inner
joint pipe and an outer joint pipe provided at respective
15 ends of a steel pipe to be joined; a protrusion formed on
an inner circumferential face of the outer joint pipe; an
engagement part formed on an outer circumferential face of
the inner joint pipe and configured to be engaged with the
protrusion and resist a tensile load together with the
20 protrusion in a case where the inner joint pipe and the
outer joint pipe are fit together; and a guide part
provided in the inner joint pipe closer to a tip than the
engagement part, the guide part being configured to abut
the protrusion to bend split pieces in cooperation with the
25 protrusion and maintain a bent state until the protrusion
reaches the engagement part in a fitting process of fitting
the inner joint pipe and the outer joint pipe together,
wherein either one of the inner joint pipe and the outer
joint pipe includes the split pieces split at regular
30 intervals in a circumferential direction and configured to
bend in a radial direction, and the method includes:
grouping the split pieces into a plurality of groups
satisfying the following conditions (1) and (2), (1) the

axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part are the same, and the axial positions are different for each group, (2) in the split pieces belonging to the same group,

5 connecting adjacent circumferential centers to each other with a straight line forms a straight line passing through a pipe center or a polygon whose center of gravity matches the pipe center; designing the split pieces to be configured to shift timing to reach maximum bending for
10 each of the split pieces of the same group in the fitting process; and designing the split pieces to be configured to cancel horizontal stresses occurring by the bending of the split pieces.

Advantageous Effects of Invention

15 [0017] The present invention groups the split pieces into a plurality of groups so as to satisfy the certain conditions and shifts the timing to reach the maximum bending for each split pieces of the same group in the fitting process and can thereby reduce the push-in load
20 required for fitting and improve installability. In addition, the present invention can reduce the push-in load without increasing the number of the split pieces, thus causing no increase in processing costs and no reduction in strength.

25 Brief Description of Drawings

[0018] FIG. 1A is a diagram of a mechanical joint according to an embodiment of the invention, the diagram schematically illustrating how a split piece in a joining process bends.

30 FIG. 1B is a diagram of the mechanical joint according to the embodiment of the invention, the diagram schematically illustrating how the split piece in the joining process bends.

FIG. 1C is a diagram of the mechanical joint according to the embodiment of the invention, the diagram schematically illustrating how the split piece in the joining process bends.

5 FIG. 1D is a diagram of the mechanical joint according to the embodiment of the invention, the diagram schematically illustrating how the split piece in the joining process bends.

10 FIG. 2 is a diagram of an example in which eight split pieces are grouped so as to satisfy the conditions of the present invention.

FIG. 3A is a diagram for illustrating a push-in load when a conventional mechanical joint is used as a comparative example.

15 FIG. 3B is a diagram for illustrating the push-in load when the conventional mechanical joint is used as the comparative example.

20 FIG. 3C is a diagram for illustrating the push-in load when the conventional mechanical joint is used as the comparative example.

FIG. 4A is a diagram for illustrating a push-in load in the mechanical joint according to the embodiment of the present invention.

25 FIG. 4B is a diagram for illustrating the push-in load in the mechanical joint according to the embodiment of the present invention.

FIG. 4C is a diagram for illustrating the push-in load in the mechanical joint according to the embodiment of the present invention.

30 FIG. 5 is a diagram of an example in which four split pieces are grouped so as to satisfy the conditions of the present invention.

FIG. 6 is a diagram of an example in which eight split

pieces are grouped so as not to satisfy the conditions of the present invention.

FIG. 7 is a schematic diagram of a state before fitting of a mechanical joint according to a modification
5 of the embodiment of the present invention.

FIG. 8 is a schematic diagram of a state after fitting of the mechanical joint according to the modification of the embodiment of the present invention.

FIG. 9A is a diagram for illustrating a joining
10 process of the mechanical joint according to another aspect.

FIG. 9B is a diagram for illustrating the joining process of the mechanical joint according to the other aspect.

15 FIG. 9C is a diagram for illustrating the joining process of the mechanical joint according to the other aspect.

FIG. 9D is a diagram for illustrating the joining process of the mechanical joint according to the other
20 aspect.

FIG. 10A is a diagram of another aspect of the mechanical joint in FIG. 1A, the diagram schematically illustrating how the split piece in the joining process bends.

25 FIG. 10B is a diagram of another aspect of the mechanical joint in FIG. 1B, the diagram schematically illustrating how the split piece in the joining process bends.

FIG. 10C is a diagram of another aspect of the
30 mechanical joint in FIG. 1C, the diagram schematically illustrating how the split piece in the joining process bends.

FIG. 10D is a diagram of another aspect of the

mechanical joint in FIG. 1D, the diagram schematically illustrating how the split piece in the joining process bends.

FIG. 11 is a schematic diagram of a conventional
5 mechanical joint, the diagram illustrating a state before fitting.

FIG. 12 is a diagram of a state after fitting in the mechanical joint in FIG. 11.

FIG. 13 is an A-A arrow view of FIG. 11.

10 FIG. 14A is a diagram for illustrating a joining process of the conventional mechanical joint.

FIG. 14B is a diagram for illustrating the joining process of the conventional mechanical joint.

15 FIG. 14C is a diagram for illustrating the joining process of the conventional mechanical joint.

FIG. 14D is a diagram for illustrating the joining process of the conventional mechanical joint.

20 FIG. 15 is a graph of a relation between axial displacement and a load in one split piece in the joining process illustrated in FIG. 14.

Description of Embodiments

[0019] Before describing a mechanical joint according to an embodiment of the present invention, the following describes a structure of a conventional mechanical joint
25 based on FIG. 11, FIG. 12, FIG. 13, FIG. 14A, FIG. 14B, FIG. 14C, and FIG. 14D.

[0020] As illustrated in FIG. 11, an example of a conventional mechanical joint 23 includes an inner joint pipe 5 and an outer joint pipe 25 provided at the
30 respective ends of steel pipes 3 to be joined together. The inner joint pipe 5 and the outer joint pipe 25 are positioned facing each other up and down. In the state in FIG. 11, an axial load is applied to the inner joint pipe 5

positioned above to insert the inner joint pipe 5 into the outer joint pipe 25, to fit the inner joint pipe 5 and the outer joint pipe 25 together, and to join the upper and lower steel pipes 3 together as illustrated in FIG. 12.

5 [0021] The inner joint pipe 5 has a basal end 9 that is welded to the steel pipe 3, and the tip side of the basal end 9 is provided with split pieces 11 split by forming slits extending in an axial direction in a cylindrical member having a smaller outer diameter than that of the
10 basal end 9. FIG. 13 is an A-A arrow view of FIG. 11, illustrating only the tips of the split pieces 11. As illustrated in FIG. 11 and FIG. 13, the mechanical joint 23 is formed by splitting the tip of the inner joint pipe 5 into, for example, eight pieces, with eight split pieces 11
15 with an arc-shaped section arranged at regular intervals in a circumferential direction. The split pieces 11 can bend in a radial direction, and protrusions 13 protruding outward are formed on the outer circumferential face of the tip.

20 [0022] The inner diameter of the outer joint pipe 25 is smaller than the outer diameter of the part of the inner joint pipe 5 formed with the protrusions 13, and a recess 15 is formed on the basal end side of the inner circumferential face of the outer joint pipe 25. While the
25 inner joint pipe 5 is inserted and fit to the outer joint pipe 25, the inner circumferential face of the outer joint pipe 25 and the protrusions 13 of the inner joint pipe 5 make pressing contact with each other, thereby bending the split pieces 11 of the inner joint pipe 5 inward in the
30 radial direction. In an insertion completion state, the bending of the split pieces 11 is restored, and the protrusions 13 of the inner joint pipe 5 enter the recess 15 of the outer joint pipe 25 to complete fitting.

[0023] The following describes a joining process between the inner joint pipe 5 and the outer joint pipe 25 more specifically based on FIG. 14A, FIG. 14B, FIG. 14C, and FIG. 14D. FIG. 14A to FIG. 14D schematically illustrate an axial section of the part B in FIG. 11. As illustrated in FIG. 14A, the inner circumferential face of the outer joint pipe 25 is provided with an engagement part 17 and a guide part 19. The engagement part 17 forms a side wall of the recess 15 and is engaged with the protrusion 13 of the inner joint pipe 5. The guide part 19 cooperates with the protrusion 13 to bend the split pieces 11 and maintains a bent state as far as the engagement part 17 while the inner joint pipe 5 is inserted and fit to the outer joint pipe 25. The guide part 19 has an inclined face 19a starting the bending of the split piece 11 and guiding it to maximum bending and a flat face 19b maintaining the maximum bending as far as the engagement part 17. On the outer circumferential side of the tip of the protrusion 13 of the inner joint pipe 5, an inclined face 13a with a shape corresponding to the inclined face 19a of the guide part 19 is formed.

[0024] FIG. 14A illustrates a state before the inner joint pipe 5 and the outer joint pipe 25 are made pressing contact with each other, that is, before the split piece 11 starts to bend. The axial position of the protrusion 13 at this time is X_0 . When the split piece 11 moves downward by the application of the axial load to the inner joint pipe 5, as illustrated in FIG. 14B, the inclined face 13a of the protrusion 13 of the inner joint pipe 5 makes contact with the inclined face 19a of the guide part 19 of the outer joint pipe 25, thereby pressing the protrusion 13 and bending the split piece 11 inward in the radial direction. Thus, the guide part 19 and the protrusion 13

are provided with the correspondingly shaped inclined faces 19a and 13a, respectively, so that force in a pipe axial direction is converted into force in the radial direction, thus enabling fitting by insertion to be performed

5 smoothly. FIG. 14B illustrates a state when the outer circumferential face of the protrusion 13 reaches the top of the inclined face 19a, that is, when the split piece 11 has bent to the maximum. The axial position of the protrusion 13 at this time is X_1 .

10 [0025] Then, as illustrated in FIG. 14C, the split piece 11 is inserted while maintaining the maximum bent state. The axial position of the protrusion 13 illustrated in FIG. 14C is X_2 . When the tip of the outer joint pipe 25 makes contact with the basal end 9 of the inner joint pipe 5, as
15 illustrated in FIG. 14D, the bending of the split pieces 11 is restored, and the protrusion 13 and the engagement part 17 are engaged and fit together to complete joining. The axial position of the protrusion 13 at this time is X_3 .

[0026] In the mechanical joint 23 for which joining has
20 been completed as described above, the basal end 9 of the inner joint pipe 5 and the tip of the outer joint pipe 25 resist a compressive load exerting in the axial direction of the inner joint pipe 5 and the outer joint pipe 25. In the mechanical joint 23, the protrusions 13 of the inner
25 joint pipe 5 and the engagement part 17 of the outer joint pipe 25 resist a tensile load exerting in the axial direction of the inner joint pipe 5 and the outer joint pipe 25.

[0027] In the joining process described above, the load
30 required to insert the inner joint pipe 5 varies depending on the state of bending of the split pieces 11. The following describes this point with reference to FIG. 15. FIG. 15 is a graph of a relation between axial displacement

and the magnitude of a load required to bend one split piece 11 and to insert it.

[0028] As illustrated in FIG. 15, in the process (X_0 to X_1) in which the inclined face 19a of the guide part 19 and the inclined face 13a of the protrusion 13 make contact with each other to insert and fit the split piece 11 while bending it, a large load is required for insertion. In particular, when the split piece 11 reaches its maximum bending (X_1), the largest load is required. On the other hand, in the process (X_1 to X_3) in which the flat face 19b of the guide part 19 and the inner circumferential face of the engagement part 17 and the outer circumferential face of the protrusion 13 make contact with each other to insert and fit the split piece 11 while maintaining the maximum bending, only a load exceeding the friction resistance between the inner joint pipe 5 and the outer joint pipe 25 is required, and thus fitting can be performed with a small load.

[0029] FIG. 15 is a graph of the load required to insert and fit one split piece 11 while bending it; the load as illustrated in FIG. 15 is required for each of the other seven split pieces 11 as well. That is to say, in the case of the mechanical joint 23 illustrated in FIG. 11 to FIG. 13, the eight split pieces 11 uniformly bend, and thus the load required to insert and fit the inner joint pipe 5 is about eight times the load illustrated in FIG. 15.

[0030] As described above, in the conventional mechanical joint 23, all the split pieces 11 were inserted while being uniformly bent. Thus, a particularly large load was required when the eight split pieces 11 reached the maximum bending (X_1) at the same time. From this point of view, the inventor of the present invention has devised a method to shift the timing of the split pieces 11 to

reach the maximum bending. This can reduce the maximum value of the load required for insertion of the mechanical joint 23 as a whole.

[0031] By the way, when joining the steel pipes 3 together using the mechanical joint 23 described above, either the steel pipe 3 mounted with the outer joint pipe 25 or the steel pipe 3 mounted with the inner joint pipe 5 is erected in the ground, and the other is lifted by a crane or the like to be placed above the steel pipes 3 erected in the ground and is inserted. In this process, it is difficult to restrain the horizontal movement of the upper steel pipe 3 lifted by the crane, and thus it is preferable to cancel horizontal stresses that occur when the split pieces 11 bend in the joining process as a whole. In this regard, in the conventional mechanical joint 23, the center of gravity of a polygon (the dash-double-dot lines in FIG. 13) obtained by connecting the respective centers of the arcs (the × marks in FIG. 13) of the split pieces 11 matches a pipe center 21. This cancels the horizontal stresses caused by the bending of the split pieces 11. The cancelling of the horizontal stresses during insertion should also be considered when the timing of the split pieces 11 to reach the maximum bending is shifted as described above. The present invention is based on such findings. In the embodiment described below, one with the inner joint pipe split into, for example, eight pieces will be described as an example. In the following description, the same parts as those in FIG. 11 to FIG. 14, which illustrate the conventional example, are denoted by the same symbols.

[0032] A mechanical joint 1 according to the embodiment of the present invention includes the inner joint pipe 5 and an outer joint pipe 7 provided at the respective ends

of the steel pipes 3 to be joined together. The inner joint pipe 5 includes the split pieces 11 that are split into, for example, eight pieces at regular intervals in the circumferential direction and can bend in the radial direction. The protrusions 13 are formed on the outer circumferential face of the split pieces 11. The inner circumferential face of the outer joint pipe 7 is provided with the engagement part 17 that is engaged with the protrusions 13 to resist a tensile load together with the protrusions 13 with the inner joint pipe 5 and the outer joint pipe 7 completed to be fit together. The part of the outer joint pipe 7 closer to a tip than the engagement part 17 is provided with the guide part 19 making contact with the protrusions 13 to bend the split pieces 11 in cooperation with the protrusions 13 and maintaining a bent state as far as the engagement part 17 while the inner joint pipe 5 and the outer joint part 7 are fit together. The guide part 19 has the inclined face 19a starting the bending of the split pieces 11 and guiding it to the maximum bending and the flat face 19b maintaining the maximum bending as far as the engagement part 17. On the outer circumferential side of the tip of the protrusion 13 of the inner joint pipe 5, the inclined face 13a with a shape corresponding to the inclined face 19a of the guide part 19 is formed. These configurations are the same as those of the conventional mechanical joint 23 described in FIG. 11 to FIG. 14D, and thus descriptions thereof are omitted. The following specifically describes characteristic parts according to the present embodiment.

[0033] The inner joint pipe 5 according to the present embodiment has the same shape as that of the conventional example except for the split pieces 11. The eight split pieces 11 according to the present embodiment are divided

into a plurality of groups satisfying the following condition (1) and condition (2). The eight split pieces 11 are configured in such a way that the time to reach the maximum bending is shifted for each split pieces of the same group in a fitting process.

[0034] <Conditions>

(1) The axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part shall be the same, and the axial positions shall be different for each group.

The condition (1) is for shifting the timing (time) to reach the maximum bending for each split pieces of the same group in the fitting process.

(2) In the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line shall form a straight line passing through a pipe center or a polygon the center of gravity of which matches the pipe center.

The condition (2) is a condition for cancelling the horizontal stresses caused by the bending of the split pieces 11 as a whole in the fitting process of the mechanical joint.

[0035] As a premise to satisfy these conditions (1) and (2), the number of splits is four or more. When the number of splits is three or less, one split piece may belong to one group, and in this case, the straight line or the polygon of the condition (2) cannot be formed.

[0036] In the present embodiment, the eight split pieces 11 of the inner joint pipe 5 are divided into two groups, or A_1 to A_4 and B_1 to B_4 , as illustrated in FIG. 2. From the condition (1), the axial positions of the inclined faces 19a bending the split pieces 11 of each group are different for each group. FIG. 1A is a sectional view of

the split pieces 11 of A_1 to A_4 and the guide part 19 as the part making contact with the split pieces 11 of A_1 to A_4 . FIG. 1B is a sectional view of the split pieces 11 of B_1 to B_4 and the guide part 19 as the part making contact with the split pieces 11 of B_1 to B_4 . FIG. 1A and FIG. 1B illustrate an initial state of inserting the inner joint pipe 5 into the outer joint pipe 7.

[0037] As illustrated in FIG. 1A, the inclined face 19a with which the split pieces 11 of A_1 to A_4 make contact is formed between X_0 and X_1 , and the position of the top of the inclined face 19a, which is a position at which bending is maximum, is X_1 . As illustrated in FIG. 1B, the inclined face 19a with which the split pieces 11 of B_1 to B_4 make contact is formed between X_1 and X_2 , and the position of the top of the inclined face 19a, which is a position at which bending is maximum, is X_2 .

[0038] Thus, in the initial stage of insertion illustrated in FIG. 1A and FIG. 1B, the split pieces 11 of A_1 to A_4 make contact with the inclined face 19a and are in the process of bending, whereas the split pieces 11 of B_1 to B_4 neither make contact with the inclined face 19a nor bend.

[0039] Next, FIG. 1C and FIG. 1D illustrate a state in which the inner joint pipe 5 has been inserted further from the positions in FIG. 1A and FIG. 1B, respectively. As illustrated in FIG. 1C and FIG. 1D, when the split pieces 11 of A_1 to A_4 make contact with the flat face 19b to maintain the maximum bending, the split pieces 11 of B_1 to B_4 make contact with the inclined face 19a and are in the process of bending.

[0040] Thus, in the present embodiment, the axial positions of the split pieces 11 to reach the maximum bending are the same position in the same group and are

different positions for each group. In other words, in the fitting process, the timing to reach the maximum bending is shifted for each split pieces 11 of the same group.

[0041] In the present embodiment, as illustrated in FIG. 2, in the split pieces 11 of the same group, connecting adjacent circumferential centers to each other with a straight line forms, for each, a rectangle the center of gravity of which matches the pipe center 21 (the dash-double-dot lines in FIG. 2) (the condition (2)). In FIG. 2, the group of the split pieces 11 of A_1 to A_4 are indicated with the $\times$ mark, whereas the group of the split pieces 11 B_1 to B_4 are indicated with the $\square$ mark. The "circumferential centers" described above are assumed to be at the same position in the axial direction among the split pieces 11. When the split pieces 11 of A_1 to A_4 bend, the horizontal stresses are cancelled between the split pieces 11 of A_1 and A_3 and between the split pieces 11 of A_2 and A_4 , which are placed at positions facing each other, so that no horizontal stresses occur as a whole. Similarly, when the split pieces 11 of B_1 to B_4 bend, the horizontal stresses are cancelled between the split pieces 11 of B_1 and B_3 and between the split pieces 11 of B_2 and B_4 , which are placed at positions facing each other, so that no horizontal stresses occur as a whole.

[0042] Next, the following describes the effect of load reduction in the mechanical joint 1 of the present embodiment configured as described above. First, as a comparative example, the following describes a case in which the 8-split inner joint pipe 5 as in FIG. 2 is inserted and fit to the conventional outer joint pipe 25 (see FIG. 14). As described above, in the conventional outer joint pipe 25, all the inclined faces 19a with which the eight split pieces 11 make contact are formed at the

same position in the axial direction (the position between X_0 and X_1 illustrated in FIG. 14). FIG. 3A, FIG. 3B, and FIG. 3C each illustrate a relation between axial displacement and the load required for insertion when the inner joint pipe 5 is inserted and fit to the conventional outer joint pipe 25 as described above.

[0043] FIG. 3A illustrates the load required to bend the four split pieces 11 corresponding to the positions of A_1 to A_4 illustrated in FIG. 2 and the timing of the occurrence of bending in the conventional outer joint pipe 25. As illustrated in FIG. 3A, when the split pieces 11 of A_1 to A_4 reach the maximum bending (X_1), the largest load is required. FIG. 3B illustrates the load required to bend the four split pieces 11 corresponding to the positions of B_1 to B_4 illustrated in FIG. 2 and the timing of the occurrence of bending in the conventional outer joint pipe 25. As illustrated in FIG. 3B, the split pieces 11 of B_1 to B_4 also reach the maximum bending at the same timing (X_1) as in the split pieces 11 of A_1 to A_4 , and the largest load is required at this time.

[0044] FIG. 3C is a composite of FIG. 3A and FIG. 3B. FIG. 3C illustrates the load required to bend the eight split pieces 11 and its timing when the inner joint pipe 5 is inserted and fit to the outer joint pipe 25. As illustrated in FIG. 3C, when all the eight split pieces 11 of A_1 to A_4 and B_1 to B_4 reach the maximum bending (X_1), the required load reaches its maximum value. The maximum value of the required load is the sum of the maximum value of the load in FIG. 3A and the maximum value of the load in FIG. 3B.

[0045] The following describes a case in which the inner joint pipe 5 illustrated in FIG. 2 is inserted and fit to the outer joint pipe 7 according to the present embodiment.

In the outer joint pipe 7 according to the present embodiment, the inclined faces 19a with which the four split pieces 11 of A_1 to A_4 make contact are each formed at the position between X_0 and X_1 illustrated in FIG. 1. In
5 the outer joint pipe 7, the inclined faces 19a with which the four split pieces 11 of B_1 to B_4 make contact are each formed at the position between X_1 and X_2 illustrated in FIG. 1. FIG. 4A, FIG. 4B, and FIG. 4C each illustrate a relation between axial displacement and the load required
10 for insertion when the inner joint pipe 5 is inserted and fit to the outer joint pipe 7 according to the present embodiment.

[0046] FIG. 4A illustrates the load required to bend the four split pieces 11 of A_1 to A_4 and the timing of the
15 occurrence of bending. As illustrated in FIG. 4A, the load required to bend the four split pieces 11 becomes the largest when the split pieces 11 of A_1 to A_4 reach the maximum bending (X_1). FIG. 4B illustrates the load required to bend the four split pieces 11 of B_1 to B_4 and
20 the timing of the occurrence of bending. As illustrated in FIG. 4B, the load required to bend the four split pieces 11 becomes the largest when the split pieces 11 of B_1 to B_4 reach the maximum bending (X_2).

[0047] FIG. 4C is a composite of FIG. 4A and FIG. 4B.
25 FIG. 4C illustrates the load required to bend the eight split pieces 11 and its timing when the inner joint pipe 5 is inserted into the outer joint pipe 7. As illustrated in FIG. 4C, the timing to reach the maximum bending is shifted for each split pieces 11 of the same group of A_1 to A_4 and
30 B_1 to B_4 , so that the timing requiring a large load is dispersed to two parts. Thus, it is found that the maximum value of the load required for the insertion of the mechanical joint 1 is almost halved compared to that in

FIG. 3C.

[0048] The above example is an example in which the eight split pieces 11 are divided into two groups and the timing to reach the maximum bending is shifted between the two groups; for example, if the timing to reach the maximum bending is shifted for each two split pieces 11 facing each other, the maximum load can be further reduced. That is to say, four groups, or A_1 and A_3 , A_2 and A_4 , B_1 and B_3 , and B_2 and B_4 illustrated in FIG. 2, are set. Then, the positions of the inclined faces 19a of the outer joint pipe 7 are made different from each other in the axial direction so that the timing to reach the maximum bending is shifted among these four groups. This enables insertion with about 1/4 the load compared to that in FIG. 3C.

[0049] Thus, even if the number of the split pieces 11 is the same, the effect of load reduction changes depending on the number of groups. For installation, it is desirable that insertion and fitting can be achieved only by the own weight of the steel pipe 3 placed above, and thus the number of groups is preferably determined by setting a load reduction target with the number of splits, the thickness of the split pieces 11, the weight of the steel pipe 3, and the like taken into account.

[0050] The example described above shows the tip of the inner joint pipe 5 split into eight pieces; the number of splits is not limited to this example. For example, in general, the number of splits is desirably four or more for smaller ones with a steel pipe diameter of 400 mm or less and eight or more for those exceeding 400 mm. Given these circumstances, FIG. 5 illustrates an example in which the tip of the inner joint pipe 5 is split into four pieces as a minimum number of splits. When there are four split pieces 11, as illustrated in FIG. 5, A_1 and A_2 and B_1 and

B_2 , which each face each other, may each be the same group. In the example in FIG. 5, too, the straight line connecting the circumferential centers of the split pieces 11 of the same group to each other (the dash-double-dot line in FIG. 5) passes through the pipe center 21, thus satisfying the condition (2) of the present invention.

[0051] The number of the split pieces 11 is not limited to a multiple of 2 so long as it satisfies the condition (2) of the present invention and may be a multiple of 3.

For example, the tip of the inner joint pipe 5 may be split into nine pieces, and three groups may be set such that the figure formed by connecting the circumferential centers of the split pieces 11 to each other with straight lines is an equilateral triangle. In that case, too, the centers of gravity of the three equilateral triangles each match the pipe center 21, thus being within the application of the present invention (not illustrated).

[0052] As described above, the condition (2) of the present invention is a condition for cancelling the horizontal stress caused by the bending of the split piece 11 by the horizontal stress of the other split piece 11 bending at the same timing when the inner joint pipe 5 is inserted and fit to the outer joint pipe 7. Each group satisfies the condition (2) of the present invention, whereby the horizontal stresses are cancelled within the group, thus not worsening workability during installation.

[0053] In contrast, FIG. 6 illustrates an example not satisfying the condition (2). FIG. 6 illustrates the eight split pieces 11 divided into three groups, or A_1 to A_2 , B_1 to B_3 , and C_1 to C_3 . In the example illustrated in FIG. 6, the straight line connecting the circumferential centers of the split pieces 11 of A_1 to A_2 (see the $\times$ marks in FIG. 6) does not pass through the pipe center 21, and thus the

horizontal stresses are not cancelled each other when only the split pieces 11 of A_1 to A_2 are bent. Similarly, the centers of gravity of the triangles formed by connecting the centers of the split pieces 11 of B_1 to B_3 to each other (see the $\square$ marks in FIG. 6) and the circumferential centers of the split pieces 11 of C_1 to C_3 to each other (see the Δ marks in FIG. 6), respectively, do not match the pipe center 21 either, and thus the horizontal stresses are not cancelled within the same group. Although the above example reduces the load required for insertion and fitting during installation, it is undesirable because it causes horizontal movement of the upper steel pipe 3, which is suspended by a crane or the like, thus worsening workability.

[0054] As described above, the mechanical joint 1 according to the present embodiment groups all the split pieces 11 into a plurality of groups and makes the positions with which the split pieces 11 make contact to produce the maximum bending different for each group, and thus the timing to reach the maximum bending is shifted for each split pieces 11 of the same group in the fitting process, thus reducing the push-in load required for fitting and improving installability. In addition, the push-in load can be reduced without increasing the number of the split pieces 11, thus causing no increase in processing costs and no reduction in strength.

[0055] The embodiment described above is configured such that, before the split pieces 11 of one group reach the maximum bending, radial bending does not start in the split pieces 11 of the other group; the present invention is not limited to this aspect. As described above, the largest load is required when the split pieces 11 reach the maximum bending, and thus the effect of the invention can be

obtained so long as at least there is a time difference in the timing to reach the maximum bending. Thus, at least the positions of the tops of the inclined faces 19a may be formed to be different in the axial direction for each group.

[0056] (First Modification)

The embodiment described above shows an example in which the side to be inserted inside (the inner joint pipe) is split; the present invention is not limited to this example and may adopt a configuration in which the side to be placed outside (the outer joint pipe) may be split as a first modification of the mechanical joint. In this case, the outer joint pipe is formed with split pieces that can bend in the radial direction at regular intervals in the circumferential direction, and guide parts are formed on the inner circumferential face of the split pieces. In the inner joint pipe, a protrusion is formed on the outer circumferential face of a tubular member provided closer to the tip than the basal end is and having a smaller diameter than that of the basal end. In the above case, too, if the split pieces are grouped into a plurality of groups satisfying the following conditions (1) and (2), and if the axial positions of the guide parts formed on the inner circumferential face of the split pieces causing the maximum bending are made different from each other for each group, the timing to reach the maximum bending can be shifted for each split pieces of the same group in the fitting process, and the same effect as that of the embodiment described above can be obtained.

(1) The axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part shall be the same, and the axial positions shall be different for each group; and

(2) In the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line shall form a straight line passing through a pipe center or a polygon the center of gravity of which matches the pipe center.

[0057] (Second Modification)

The following describes a second modification of this mechanical joint based on FIG. 7, FIG. 8, FIG. 9A, FIG. 9B, FIG. 9C, and FIG. 9D. As illustrated in FIG. 7, this

mechanical joint 2 according to the second modification includes an inner joint pipe 5A and an outer joint pipe 7A provided at the respective ends of the steel pipes 3 to be joined together. The inner joint pipe 5A and the outer joint pipe 7A are positioned facing each other up and down.

In the state illustrated in FIG. 7, an axial load is applied to the outer joint pipe 7A positioned above to fit the outer joint pipe 7A onto the inner joint pipe 5A. Thus, as illustrated in FIG. 8, the outer joint pipe 7A and the inner joint pipe 5A are fit together to join the upper and lower steel pipes 3 together.

[0058] The outer joint pipe 7A has a basal end 9A that is welded to the steel pipe 3, and the tip side of the basal end 9A is provided with split pieces 11A split by forming slits extending in the axial direction in a cylindrical member. The mechanical joint 2 illustrated in FIG. 7 is formed by splitting the tip of the outer joint pipe 7A into, for example, eight pieces, with eight split pieces 11A with an arc-shaped section arranged at regular intervals in the circumferential direction. The split pieces 11A can bend in the radial direction, and protrusions 13A protruding inward are formed on the inner circumferential face of the tip.

[0059] The outer diameter of the inner joint pipe 5A is

larger than the inner diameter of the part of the outer joint pipe 7A formed with the protrusion 13A, and a recess 15A is formed on the basal end side of the outer circumferential face of the inner joint pipe 5A. While the
5 outer joint pipe 7A is fit to the inner joint pipe 5A, the outer circumferential face of the inner joint pipe 5A and the protrusions 13A of the outer joint pipe 7A make pressing contact with each other, thereby bending the split pieces 11A of the outer joint pipe 7A outward in the radial
10 direction. In an insertion completion state, the bending of the split pieces 11A is restored, and the protrusions 13A of the outer joint pipe 7A enter the recess 15A of the inner joint pipe 5A to complete fitting.

[0060] The split pieces 11A in the second modification
15 are divided into a plurality of groups satisfying the conditions (1) and (2) as in the embodiment described above. The eight split pieces 11A are configured in such a way that the time to reach the maximum bending is shifted for each split pieces of the same group in the fitting
20 process. In the second modification, too, as a premise to satisfy the conditions (1) and (2), the number of splits is four or more. The method for dividing the split pieces 11A into the groups is also the same as in the embodiment.

[0061] That is to say, in the second modification, the
25 eight split pieces 11A of the inner joint pipe 5A are divided into two groups, or A_1 to A_4 and B_1 to B_4 , as in FIG. 2. From the condition (1), the axial positions of the inclined faces 19a bending the split pieces 11A of each group are different for each group. FIG. 9A is a sectional
30 view of the split pieces 11A of A_1 to A_4 and a guide part 19A as the part making contact with the split pieces 11A of A_1 to A_4 . The outer circumferential face of the inner joint pipe 5A is provided with an engagement part 17A that

is engaged with the protrusions 13A to resist a tensile strength together with the protrusions 13A with the outer joint pipe 7A and the inner joint pipe 5A completed to be fit together. FIG. 9B is a sectional view of the split
5 pieces 11A of B_1 to B_4 and the guide part 19A as the part making contact with the split pieces 11A of B_1 to B_4 . FIG. 9A and FIG. 9B illustrate an initial state of fitting the outer joint pipe 7A to the inner joint pipe 5A. FIG. 9A and FIG. 9B are diagrams corresponding to FIG. 1A and FIG.
10 1B, respectively, described above.

[0062] As illustrated in FIG. 9A, the inclined face 19a with which the split pieces 11A of A_1 to A_4 make contact is formed between X_0 and X_1 , and the position of the top of the inclined face 19a, which is a position at which bending
15 is maximum, is X_1 . As illustrated in FIG. 9B, the inclined face 19a with which the split pieces 11A of B_1 to B_4 make contact is formed between X_1 and X_2 , and the position of the top of the inclined face 19a, which is a position at which bending is maximum, is X_2 .

20 [0063] Thus, in the initial stage of insertion illustrated in FIG. 9A and FIG. 9B, the split pieces 11A of A_1 to A_4 make contact with the inclined face 19a and are in the process of bending, whereas the split pieces 11A of B_1 to B_4 neither make contact with the inclined face 19a nor
25 bend.

[0064] Next, FIG. 9C and FIG. 9D illustrate a state in which the outer joint pipe 7A has been pushed in further from the positions in FIG. 9A and FIG. 9B, respectively. FIG. 9C illustrates a state in which the outer joint pipe
30 7A has been pushed in from the position illustrated in FIG. 9A. FIG. 9D illustrates a state in which the outer joint pipe 7A has been pushed in from the position illustrated in FIG. 9B. That is to say, FIG. 9C and FIG. 9D are diagrams

corresponding to FIG. 1C and FIG. 1D, respectively,
described above. The configurations illustrated in FIG. 9A
to FIG. 9D are the same as those of the mechanical joint
according to the present invention described with reference
5 to FIG. 1A to FIG. 1D above.

[0065] As illustrated in FIG. 9C and FIG. 9D, when the
split pieces 11A of A_1 to A_4 make contact with the flat
face 19b to maintain the maximum bending, the split pieces
11A of B_1 to B_4 make contact with the inclined face 19a and
10 are in the process of bending. Thus, in the second
modification, too, the axial positions of the split pieces
11A to reach the maximum bending are the same position in
the same group and are different positions for each group.
In other words, in the fitting process, the timing to reach
15 the maximum bending is shifted for each split pieces 11A of
the same group. When the outer joint pipe 7A is further
pushed in, the protrusion 13A is engaged with the recess
15A to complete joining (the axial position of the
protrusion 13A at this time is X_3). The other
20 configurations are the same as those of the embodiment.

[0066] (Third Modification)

The following describes a third modification. That is
to say, in the example illustrated in FIG. 1, both the
protrusion 13 of the inner joint pipe 5 and the guide part
25 19 of the outer joint pipe 7 have the inclined faces 13a
and 19a, respectively; only one of the protrusion 13 and
the guide part 19 may be formed with an inclined face. If
either the protrusion 13 or the guide part 19 is formed
with the inclined face, the split pieces 11 can be bent
30 using a press-fit load to insert the inner joint pipe 5.
Thus, FIG. 10 illustrates an example in which the
protrusion 13 is formed with the inclined face 13a, whereas
the guide part 19 is not formed with the inclined face 19a

as another aspect of the mechanical joint 1 in FIG. 1.

[0067] FIG. 10A is a sectional view of the split pieces 11 of A_1 to A_4 and the guide part 19 as the part making contact with the split pieces 11 of A_1 to A_4 , whereas FIG. 10B is a sectional view of the split pieces 11 of B_1 to B_4 and the guide part 19 as the part making contact with the split pieces 11 of B_1 to B_4 . FIG. 10A and FIG. 10B illustrate an initial state of inserting the inner joint pipe 5 into the outer joint pipe 7. FIG. 10C and FIG. 10D illustrate a state in which the inner joint pipe 5 has been inserted further from the positions in FIG. 10A and FIG. 10B, respectively.

[0068] As illustrated in FIG. 10, when the guide part 19 is not formed with the inclined face 19a, the inclined face 13a of the protrusion 13 and the tip side corner of the guide part 19 (the tip side end of the flat face 19b) make pressing contact with each other, bending the split piece 11 inward in the radial direction.

[0069] In this example, too, the time to reach the maximum bending can be shifted for each split pieces of the same group by making the position of contact between the split pieces 11 of A_1 to A_4 and the guide part 19 and the position of contact between the split pieces 11 of B_1 to B_4 and the guide part 19 different from each other in the axial direction. The above is an example in which the protrusion 13 is formed with the inclined face 13a, whereas the guide part 19 is not formed with the inclined face 19a; the same applies to a case in which the guide part 19 is formed with the inclined face 19a, whereas the protrusion 13 is not formed with the inclined face 13a.

[0070] However, the fitting load varies depending on the axial length of the inclined face (specifically, a longer axial length of the inclined face gives a smaller fitting

load), and thus if the inclined face is formed on only one of the protrusion 13 and the guide part 19, providing the inclined face in the guide part 19 can ensure the axial length of the inclined face and is thus reasonable.

5 [0071] The guide part 19 (the gray part in FIG. 1) of the outer joint pipe 7 may be integral with the outer joint pipe 7 or may be manufactured as a separate component and mounted on the inner circumferential face of the outer joint pipe 7. For example, the engagement part 17 of the
10 outer joint pipe 7 is a part to resist the tensile strength together with the protrusions 13 of the inner joint pipe 5 during fitting and thus requires strong durability, whereas the guide part 19, on which only a pressing load is exerted during insertion, with no load exerted during fitting, does
15 not require strong durability. Thus, the guide part 19 may be manufactured as a separate member with a strength of about plain steel and mounted on the inner circumferential face of the outer joint pipe 7 by bolts, welding, or the like, in which the bolts or welding may be as minimal as
20 possible.

[0072] When the guide part 19 is mounted as a separate member, the guide part 19 and the engagement part 17 may be made contact with each other as in FIG. 14, or there may be a gap as in FIG. 1 so long as the maximum bending of the
25 split piece 11 can be maintained as far as the engagement part 17.

[0073] In the embodiment described above, the mechanical joint mounted on the ends of steel pipes is described; a joint-equipped steel pipe can be manufactured by mounting
30 the outer joint pipe and/or the inner joint pipe of this mechanical joint on the end of a steel pipe by welding or the like in a factory or the like in advance. That is to say, the joint-equipped steel pipe described above includes

the inner joint pipe and/or the outer joint pipe of the mechanical joint described in the embodiment at both ends or one ends of the joint-equipped steel pipe.

[0074] Then, coupling a plurality of joint-equipped
5 steel pipes to each other in an installation site or the like can form structures such as steel pipe piles, steel pipe sheet piles, steel pipe sheet pile walls with steel pipe sheet piles coupled to each other, steel pipe columns, and steel pipe beams. That is to say, these structures
10 include the mechanical joint described in the embodiment described above and a plurality of steel pipes joined together with the mechanical joint.

[0075] In installing these structures, with one joint-equipped steel pipe to be joined restrained, the mechanical
15 joint of the other joint-equipped steel pipe may be aligned with the mechanical joint of the one joint-equipped steel pipe and inserted and fit thereto. For example, when the structure is a steel pipe pile or the like, with either a steel pipe mounted with the outer joint pipe on its end or
20 a steel pipe mounted with the inner joint pipe on its end erected in the ground, the other steel pipe may be placed above one steel pipe by lifting it by a crane or the like, the inner joint pipe may be inserted into the outer joint pipe, and the inner joint pipe and the outer joint pipe may
25 be fit and joined together.

[0076] The mechanical joint of the present invention is configured to reduce the load required for insertion and to cancel the horizontal stresses during insertion, and thus there is no need to restrain horizontal movement for the
30 upper steel pipe being lifted by a crane during installation.

[0077] In the above description, the mechanical joint as a thing is described; this mechanical joint is designed by

the following method of design. That is to say, the method for designing the mechanical joint is a method for designing a mechanical joint including an inner joint pipe and an outer joint pipe provided at respective ends of steel pipes to be joined together, either the inner joint pipe or the outer joint pipe including split pieces split at regular intervals in a circumferential direction and capable of bending in a radial direction, the mechanical joint including:

protrusions formed on an outer circumferential face of the inner joint pipe; an engagement part formed on an inner circumferential face of the outer joint pipe and being engaged with the protrusions to resist a tensile load together with the protrusions with the inner joint pipe and the outer joint pipe completed to be fit together; and a guide part provided in the outer joint pipe closer to a tip than the engagement part is and making contact with the protrusions to bend the split pieces in cooperation with the protrusions and maintaining a bent state as far as the engagement part while the inner joint pipe and the outer joint pipe are fit together, the method grouping the split pieces into a plurality of groups satisfying the following conditions (1) and (2), shifting timing to reach maximum bending for each split pieces of the same group in a fitting process, and cancelling horizontal stresses occurring by the bending of the split pieces.

(1) The axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part shall be the same, and the axial positions shall be different for each group; and

(2) In the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line shall form a straight line passing

through a pipe center or a polygon the center of gravity of which matches the pipe center.

[0078] The mechanical joint according to another example is designed by the following method of design. That is to say, the method for designing the mechanical joint is a method for designing a mechanical joint designing a mechanical joint including an inner joint pipe and an outer joint pipe provided at respective ends of steel pipes to be joined together, either the inner joint pipe or the outer joint pipe including split pieces split at regular intervals in a circumferential direction and capable of bending in a radial direction, the mechanical joint including: protrusions formed on an inner circumferential face of the outer joint pipe; an engagement part formed on an outer circumferential face of the inner joint pipe and being engaged with the protrusions to resist a tensile load together with the protrusions with the outer joint pipe and the inner joint pipe completed to be fit together; and a guide part provided in the inner joint pipe closer to a tip than the engagement part is and making contact with the protrusions to bend the split pieces in cooperation with the protrusions and maintaining a bent state as far as the engagement part while the outer joint pipe and the inner joint pipe are fit together,

the method grouping the split pieces into a plurality of groups satisfying the following conditions (1) and (2), shifting timing to reach maximum bending for each split pieces of the same group in a fitting process, and cancelling horizontal stresses occurring by the bending of the split pieces.

(1) The axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part shall be the same, and the axial positions shall be

different for each group; and

(2) In the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line shall form a straight line passing
5 through a pipe center or a polygon the center of gravity of which matches the pipe center.

[0079] The embodiment of the present invention has been specifically described; the present invention is not limited to the embodiment described above and can adopt
10 various variations based on the technical concept of the present invention or aspects with the embodiment and the modifications mutually combined. For example, in the second modification described above, the guide part 19A and the recess 15A may be provided on the inner circumferential
15 face of the outer joint pipe 7A, whereas the protrusions 13A may be provided on the outer circumferential face of the inner joint pipe 5A.

Industrial Applicability

[0080] The present invention is suitably used for
20 joining steel pipes together.

Reference Signs List

[0081] 1, 2 MECHANICAL JOINT
3 STEEL PIPE
5, 5A INNER JOINT PIPE
25 7, 7A OUTER JOINT PIPE
9, 9A BASAL END
11, 11A SPLIT PIECE
13, 13A PROTRUSION
13a INCLINED FACE
30 15, 15A RECESS
17, 17A ENGAGEMENT PART
19, 19A GUIDE PART
19a INCLINED FACE

19b FLAT FACE
21 PIPE CENTER

CLAIMS

1. A mechanical joint comprising:

an inner joint pipe and an outer joint pipe provided at respective ends of a steel pipe to be joined;

5 a protrusion formed on an outer circumferential face of the inner joint pipe;

an engagement part formed on an inner circumferential face of the outer joint pipe and configured to be engaged with the protrusion and resist a tensile load together with the protrusion in a case where the inner joint pipe and the
10 outer joint pipe are fit together; and

a guide part provided in the outer joint pipe closer to a tip than the engagement part, the guide part being configured to abut the protrusion to bend split pieces in
15 cooperation with the protrusion and maintain a bent state until the protrusion reaches the engagement part in a fitting process of fitting the inner joint pipe and the outer joint pipe together,

wherein either one of the inner joint pipe and the
20 outer joint pipe includes the split pieces split at regular intervals in a circumferential direction and configured to bend in a radial direction, the split pieces being grouped into a plurality of groups satisfying the following conditions (1) and (2), and configured to shift timing to
25 reach maximum bending for each of the split pieces of the same group in the fitting process:

(1) the axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part are the same, and the axial positions are
30 different for each group; and

(2) in the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line forms a straight line passing

through a pipe center or a polygon whose center of gravity matches the pipe center.

2. A mechanical joint comprising:

5 an inner joint pipe and an outer joint pipe provided at respective ends of a steel pipe to be joined;

a protrusion formed on an inner circumferential face of the outer joint pipe;

10 an engagement part formed on an outer circumferential face of the inner joint pipe and configured to be engaged with the protrusion and resist a tensile load together with the protrusion in a case where the inner joint pipe and the outer joint pipe are fit together; and

15 a guide part provided in the inner joint pipe closer to a tip than the engagement part, the guide part being configured to abut the protrusion to bend split pieces in cooperation with the protrusion and maintain a bent state until the protrusion reaches the engagement part in a fitting process of fitting the inner joint pipe and the
20 outer joint pipe together,

wherein either one of the inner joint pipe and the outer joint pipe includes the split pieces split at regular intervals in a circumferential direction and configured to bend in a radial direction, the split pieces being grouped
25 into a plurality of groups satisfying the following conditions (1) and (2), and configured to shift timing to reach maximum bending for each of the split pieces of the same group in the fitting process:

(1) the axial positions of the split pieces
30 belonging to the same group causing the maximum bending on the guide part are the same, and the axial positions are different for each group; and

(2) in the split pieces belonging to the same

group, connecting adjacent circumferential centers to each other with a straight line forms a straight line passing through a pipe center or a polygon whose center of gravity matches the pipe center.

5

3. The mechanical joint according to claim 1 or 2, wherein before the split pieces of one of the groups reach the maximum bending, radial bending does not start in the split pieces of another group.

10

4. A joint-equipped steel pipe comprising:
at least one of the inner joint pipe and the outer joint pipe of the mechanical joint according to any one of claims 1 to 3 at both ends or one ends of the steel pipe.

15

5. A method for manufacturing the joint-equipped steel pipe according to claim 4, the method comprising:
mounting at least one of the outer joint pipe and the inner joint pipe of the mechanical joint according to any one of claims 1 to 3 on an end or ends of a steel pipe to be joined together.

20

6. A structure comprising:
the mechanical joints according to any one of claims 1 to 3; and
a plurality of steel pipes joined together with the mechanical joints.

25

7. A method for installing the structure according to claim 6, the method comprising:

30

erecting either one of a first steel pipe mounted with the outer joint pipe at a first end and a second steel pipe mounted with the inner joint pipe at a second end in the

ground;

placing another one of the first and the second steel pipes on the one of the first and the second steel pipes; and

5 fitting and joining the inner joint pipe and the outer joint pipe together.

8. A method for designing a mechanical joint including:
an inner joint pipe and an outer joint pipe provided
10 at respective ends of a steel pipe to be joined;

a protrusion formed on an outer circumferential face of the inner joint pipe;

an engagement part formed on an inner circumferential face of the outer joint pipe and configured to be engaged
15 with the protrusion and resist a tensile load together with the protrusion in a case where the inner joint pipe and the outer joint pipe are fit together; and

a guide part provided in the outer joint pipe closer to a tip than the engagement part, the guide part being
20 configured to abut the protrusion to bend split pieces in cooperation with the protrusion and maintain a bent state until the protrusion reaches the engagement part in a fitting process of fitting the inner joint pipe and the outer joint pipe together,

25 wherein either one of the inner joint pipe and the outer joint pipe includes the split pieces split at regular intervals in a circumferential direction and configured to bend in a radial direction, the method comprising:

grouping the split pieces into a plurality of groups
30 satisfying the following conditions (1) and (2),

(1) the axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part are the same, and the axial positions are

different for each group,

(2) in the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line forms a straight line passing
 5 through a pipe center or a polygon whose center of gravity matches the pipe center;

designing the split pieces to be configured to shift timing to reach maximum bending for each of the split pieces of the same group in the fitting process; and

10 designing the split pieces to be configured to cancel horizontal stresses occurring by the bending of the split pieces.

9. A method for designing a mechanical joint
 15 including:

an inner joint pipe and an outer joint pipe provided at respective ends of a steel pipe to be joined;

a protrusion formed on an inner circumferential face of the outer joint pipe;

20 an engagement part formed on an outer circumferential face of the inner joint pipe and configured to be engaged with the protrusion and resist a tensile load together with the protrusion in a case where the inner joint pipe and the outer joint pipe are fit together; and

25 a guide part provided in the inner joint pipe closer to a tip than the engagement part, the guide part being configured to abut the protrusion to bend split pieces in cooperation with the protrusion and maintain a bent state until the protrusion reaches the engagement part in a
 30 fitting process of fitting the inner joint pipe and the outer joint pipe together,

wherein either one of the inner joint pipe and the outer joint pipe includes the split pieces split at regular

intervals in a circumferential direction and configured to bend in a radial direction, the method comprising:

grouping the split pieces into a plurality of groups satisfying the following conditions (1) and (2),

5 (1) the axial positions of the split pieces belonging to the same group causing the maximum bending on the guide part are the same, and the axial positions are different for each group,

10 (2) in the split pieces belonging to the same group, connecting adjacent circumferential centers to each other with a straight line forms a straight line passing through a pipe center or a polygon whose center of gravity matches the pipe center;

15 designing the split pieces to be configured to shift timing to reach maximum bending for each of the split pieces of the same group in the fitting process; and

 designing the split pieces to be configured to cancel horizontal stresses occurring by the bending of the split pieces.

20