DESCRIPTION

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

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 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 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 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.

Citation List

Patent Literature

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

Summary

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 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 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 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 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 an inclined face provided in the outer joint pipe closer to a tip than the engagement part, the inclined face being configured to abut the protrusion to bend split pieces in cooperation with the protrusion in a fitting process of fitting the inner joint pipe and the outer joint pipe together, the inclined face being provided continuously from an end of the outer joint pipe to the engagement part, 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.

[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 an inclined face provided in the inner joint pipe closer to a tip than the engagement part, the inclined face being configured to abut the protrusion to bend split pieces in cooperation with the protrusion in a fitting process of fitting the inner joint pipe and the outer joint pipe together, the inclined face being provided continuously from an end of the inner joint pipe to the engagement part, 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.

[0010] 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 end of the steel pipe.

[0011] 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.

[0012] 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.

[0013] 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.

[0014] 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 an inclined face provided in the outer joint pipe closer to a tip than the engagement part, the inclined face being configured to abut the protrusion to bend split pieces in cooperation with the protrusion 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: providing the

inclined face continuously from an end of the outer joint pipe to the engagement part; and converting a vertical load into a horizontal stress bending the split pieces.

[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 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 an inclined face provided in the inner joint pipe closer to a tip than the engagement part, the inclined face being configured to abut the protrusion to bend split pieces in cooperation with the protrusion in a fitting process of fitting the inner joint pipe and the outer joint pipe together, the inclined face being provided continuously from an end of the inner joint pipe to the engagement part, 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: providing the inclined face continuously from an end of the inner joint pipe to the engagement part; and converting a vertical load into a horizontal stress bending the split pieces.

Advantageous Effects of Invention

[0016] The present invention provides the inclined face continuously from the end of the outer joint pipe to the engagement part and thereby has a smaller maximum push-in load in a fitting process than ever before and improves installability. In addition, the push-in load can be

reduced without increasing the number of the split pieces, thus providing no increase in processing costs and no reduction in strength.

Brief Description of Drawings

[0017] FIG. 1A is a diagram of a mechanical joint according to an embodiment of the present invention, the diagram schematically illustrating the state of bending of a split piece in a joining process.

FIG. 1B is a diagram of the mechanical joint according to the embodiment of the present invention, the diagram schematically illustrating the state of bending of the split piece in the joining process.

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

FIG. 1D is a diagram of the mechanical joint according to the embodiment of the present invention, the diagram schematically illustrating the state of bending of the split piece in the joining process.

FIG. 2 is a graph of a relation between an axial displacement and a load in the joining process: the broken line indicates the case of a conventional mechanical joint in FIG. 5, whereas the solid line indicates the case of the mechanical joint in FIG. 1.

FIG. 3 is a schematic diagram of the conventional mechanical joint, the diagram illustrating a state before fitting.

FIG. 4 is diagram of the mechanical joint in FIG. 3 after fitting.

FIG. 5A is a diagram illustrating a joining process of the conventional mechanical joint.

FIG. 5B is a diagram illustrating the joining process

of the conventional mechanical joint.

FIG. 5C is a diagram illustrating the joining process of the conventional mechanical joint.

FIG. 5D is a diagram illustrating the joining process of the conventional mechanical joint.

FIG. 6 is a graph of a relation between an axial displacement and a load in the joining process in FIG. 5A to FIG. 5D.

FIG. 7A is a diagram illustrating a conversion relation between a press-fit load W and a horizontal force P on an inclined face.

FIG. 7B is a diagram illustrating the conversion relation between the press-fit load W and the horizontal force P on the inclined face.

FIG. 8A is a diagram illustrating a relation among an inclination angle θ, an inclined face length L, and an engagement part height H.

FIG. 8B is a diagram illustrating the relation among the inclination angle θ, the inclined face length L, and the engagement part height H.

FIG. 9 is a diagram illustrating a relation between the inclined face length L and the press-fit load W/the horizontal force P.

FIG. 10 is a schematic diagram of a state before fitting of a mechanical joint according to a modification of the embodiment of the present invention.

FIG. 11 is a schematic diagram of a state after fitting of the mechanical joint according to the modification of the embodiment of the present invention.

Description of Embodiments

[0018] <How Invention Came About>

Before describing a mechanical joint according to an embodiment of the present invention, the following

describes a structure of a conventional mechanical joint based on FIG. 3 and FIG. 4. As illustrated in FIG. 3, an example of a conventional mechanical joint 21 includes an inner joint pipe 5 and an outer joint pipe 23 provided at the respective ends of steel pipes 3 to be joined together. The inner joint pipe 5 and the outer joint pipe 23 are positioned facing each other up and down. In the state in FIG. 3, 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 23, to fit the inner joint pipe 5 and the outer joint pipe 23 together, and to join the upper and lower steel pipes 3 together as illustrated in FIG. 4.

[0019] 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 basal end 9 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.

[0020] The inner diameter of the outer joint pipe 23 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 23. While the inner joint pipe 5 is inserted and fit to the outer joint pipe 23, the inner circumferential face of the outer joint pipe 23 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 radial direction, and 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 23 to complete fitting.

[0021] The following describes a joining process between the inner joint pipe 5 and the outer joint pipe 23 more specifically based on FIG. 5A, 5B, 5C, and 5D. FIG. 5A to FIG. 5D each schematically illustrate an axial section of the part A in FIG. 3. As illustrated in FIG. 5A, the inner circumferential face of the outer joint pipe 23 is provided with an engagement part 17 and a guide part 25. 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 25 cooperates with the protrusion 13 to bend the split piece 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 23. The guide part 25 has an inclined face 25a starting the bending of the split piece 11 and guiding it to maximum bending and a flat face 25b 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 25a of the guide part 25 is formed.

[0022] FIG. 5A Illustrates a state before the inner joint pipe 5 and the outer joint pipe 23 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 an axial press-fit load to the inner joint pipe 5, as illustrated in FIG. 5B, the inclined face 13a of the protrusion 13 of the inner joint pipe 5 makes contact with the inclined face 25a of the guide part 25 of the outer joint pipe 23, thereby pressing the protrusion 13 and bending the split piece 11 inward in the radial

direction. Thus, the guide part 25 and the protrusion 13 are provided with the correspondingly shaped inclined faces 25a and 13a, respectively, so that the press-fit load in a pipe axial direction is converted into force in the radial direction, thus enabling insertion and fitting to be performed smoothly. FIG. 5B illustrates a state when the outer circumferential face of the protrusion 13 reaches the top of the inclined face 25a, 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.

[0023] Then, as illustrated in FIG. 5C, the split piece 11 is inserted while maintaining the maximum bent state. The axial position of the protrusion 13 in FIG. 5C at this time is X_2. When the tip of the outer joint pipe 23 makes contact with the basal end 9 of the inner joint pipe 5, as illustrated in FIG. 5D, the bending of the split piece 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.

[0024] In the mechanical joint 21 for which joining has been completed as described above, the basal end 9 of the inner joint pipe 5 and the tip of the outer joint pipe 23 resist a compressive load exerting in the axial direction of the inner joint pipe 5 and the outer joint pipe 23. In the mechanical joint 21, the protrusions 13 of the inner joint pipe 5 and the engagement part 17 of the outer joint pipe 23 resist a tensile load exerting in the axial direction of the inner joint pipe 5 and the outer joint pipe 23.

[0025] In the joining process described above, the load 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. 6.

FIG. 6 is a graph of a relation between an axial displacement and the magnitude of a load required for insertion.

[0026] As illustrated in FIG. 6, in the process (X_0 to X_1) in which the inclined face 25a of the guide part 25 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, the load gradually increases until the split piece reaches the maximum bending. On the other hand, in the process (X_1 to X_3) in which the flat face 25b of the guide part 25 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 frictional resistance between the inner joint pipe 5 and the outer joint pipe 23 is required, and thus fitting can be performed with a small load.

[0027] As described above, in the process (X_0-X_1) in which the inclined face 25a of the guide part 25 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, the press-fit load in the pipe axial direction is converted into a horizontal force in the radial direction. The following describes this point with reference to FIG. 7. FIG. 7A is a diagram of a state in which the inclined face 25a of the guide part 25 and the inclined part 13a of the protrusion 13 make contact with each other in the insertion and fitting process. FIG. 7B is a diagram schematically illustrating the part enclosed by the broken line circle of FIG. 7A in an enlarged manner.

[0028] The press-fit load W and the horizontal force P illustrated in FIG. 7B can be written as Equations (1) and

(2) below, respectively.

$$P = N\sin\theta - F\cos\theta \quad (1)$$

$$W = N\cos\theta + F\sin\theta \quad (2)$$

where N is a resisting force in a direction perpendicular to the inclined faces 13a and 25a, F is a frictional force, and θ is the inclination of the inclined face 25a (hereinafter also referred to simply as an inclination θ).

[0029] The frictional force F is expressed by Equation (3) below.

$$F = \mu N \quad (3)$$

where μ is the coefficient of friction between the inclined faces 13a and 25a.

[0030] From Equation (1) to Equation (3), the relation between the press-fit load W and the horizontal force P is Equation (4) below.

$$P = W \times (\sin\theta - \mu\cos\theta)/(\cos\theta + \mu\sin\theta) \quad (4)$$

[0031] FIG. 8A and FIG. 8B are each a diagram for illustrating a relation among the inclination angle θ, an inclined surface length L, and an engagement part height H. As illustrated in FIG. 8A and FIG. 8B, the inclination θ of the inclined face 25a is determined by the axial length L of the inclined face 25a (hereinafter also referred to simply as a length L) and the height H of the engagement part 17, that is, the depth of the recess 15. Specifically, it is expressed as in Equation (5) below.

$$\theta = \tan^{-1}(L/H) \quad (5)$$

[0032] That is to say, as illustrated in FIG. 8A, when the height H of the engagement part 17 is constant, a shorter length L gives a smaller inclination θ. Conversely, as illustrated in FIG. 8B, when the height H of the engagement part 17 is constant, a longer length L gives a larger inclination θ.

[0033] The coefficient of friction μ between steel

materials is considered to be about 0.05 or more and 0.20 or less, assuming the use of a lubricant. The length L of the inclined face 25a, which depends on the diameter of the steel pipe 3, is generally about 200 mm or more and 400 mm or less. The height H of a standard engagement part 17 is considered to be about 4 mm or more and 7 mm or less. Based on this, FIG. 9 illustrates a relation between the press-fit load W normalized by the horizontal force P, that is, the press-fit load W/the horizontal force P and the inclined face length L. In FIG. 9, for easy comparison, with the height H of the engagement part 17 kept constant, the coefficient of friction μ between the steel materials was varied.

[0034] As illustrated in FIG. 9, when the height H of the engagement part 17 is 5 mm, the value of the press-fit load W/the horizontal force P becomes smaller as the length L of the inclined face 25a becomes longer for any case with the coefficient of friction μ being within the range of 0.05 to 0.20. A smaller value of the press-fit load W/the horizontal force P means that the press-fit load W required to obtain a certain horizontal force P is smaller. That is to say, by lengthening the inclined face 25a, the press-fit load W can be converted into the horizontal force P more efficiently. The embodiment of the present invention described below is based on such diligent study by the inventor of the present invention.

[0035] 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 at equal intervals in the circumferential direction and can bend in the radial direction. The protrusion 13 is formed

on the outer circumferential face of each split piece 11. On the outer circumferential side of the tip of the protrusion 13, the inclined face 13a with a shape corresponding to an inclined face 19 of the outer joint pipe 7 described below is formed. 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. These configurations are the same as those of the conventional mechanical joint 21 described with reference to FIG. 3 to FIG. 5D, and thus descriptions thereof are omitted. The following specifically describes the characteristic parts of the present embodiment.

[0036] FIG. 1A, FIG. 1B, FIG. 1C, and FIG. 1D are diagrams schematically illustrating the axial section of the part A in FIG. 3 as in FIG. 5A to FIG. 5D, respectively. As illustrated in FIG. 1A, the part of the outer joint pipe 7 according to the present embodiment closer to the tip than the engagement part 17 is provided with the inclined face 19 making contact with the protrusion 13 to bend the split piece 11 in cooperation with the protrusion 13 while the inner joint pipe 5 and the outer joint part 7 are fit together. As illustrated in FIG. 5, the outer joint pipe 23 of the conventional mechanical joint 21 is provided with the guide part 25 having the inclined face 25a and the flat face 25b. In contrast, as illustrated in FIG. 1A, the outer joint pipe 7 according to the present embodiment forms a part corresponding to the guide part 25 by the inclined face 19 and is not provided with anything that corresponds to the flat face 25b. Thus, the inclined face 19 of the outer

joint pipe 7 has a length reaching the engagement part 17 from the tip of the outer joint pipe 7, which is longer than the inclined face 25a provided in the conventional outer joint pipe 23.

[0037] As described by FIG. 9 above, a longer axial length of the inclined face 19 can covert the press-fit load into the horizontal force more efficiently. Thus, the inclined face 19 is preferably provided for the entire length from the end of the outer joint pipe 7 to the engagement part 17. For example, it may be necessary to form a flat part in a part of the inner circumferential face on the tip side of the outer joint pipe 7, and the inclined face 19 may not be able to extend in the entire length from the end of the outer joint pipe 7 to the engagement part 17. Even in this case, it is preferable to provide the inclined face 19 in a part 90% or more of the length from the tip of the outer joint pipe 7 to the engagement part 17.

[0038] If the length from the tip of the outer joint pipe 7 to the engagement part 17 is increased, the axial length L of the inclined face 19 can be set longer, which can further reduce the press-fit load. If the joint itself is made longer, the material costs and processing costs of the joint increase, and thus the length from the tip of the outer joint pipe 7 to the engagement part 17 and the axial length L of the inclined face 19 are desirably long enough to ensure a necessary push-in load by the own weight of the upper steel pipe and the upper joint.

[0039] The following describes a joining process of the mechanical joint 1 according to the present embodiment configured as described above. FIG. 1A Illustrates a state before the inner joint pipe 5 and the outer joint pipe 7 are made pressing contact with each other, that is, before

the split piece 11 starts to bend. The axial position of the protrusion 13 in FIG. 1A is the same as in FIG. 5A. As illustrated in FIG. 1A, when the split piece 11 moves downward by the action of the axial press-fit load to the inner joint pipe 5, the inclined face 13a of the protrusion 13 of the inner joint pipe 5 makes contact with the inclined face 19 of the outer joint pipe 7. Thus, the protrusion 13 of the inner joint pipe 5 is pressed to bend the split piece 11 inward in the radial direction. Then, as illustrated in FIG. 1B, when the outer circumferential face of the protrusion 13 reaches the top of the inclined face 19, or in other words, when the outer circumferential face of the protrusion 13 reaches the engagement part 17, the split piece 11 reaches its maximum bending. The axial position of the protrusion 13 at this time is X'_1.

[0040] Then, as illustrated in FIG. 1C, insertion is advanced while maintaining the state of the maximum bending in the split piece 11. The axial position of the protrusion 13 at this time is X'_2. Then, as illustrated in FIG. 1D, when the tip of the outer joint pipe 7 makes contact with the basal end 9 of the inner joint pipe 5, the bending of the split piece 11 is restored, and the protrusion 13 and the engagement part 17 are engaged with each other to complete joining. The axial position of the protrusion 13 in FIG. 1D is the same as in FIG. 5D.

[0041] The following describes the effect of load reduction in the mechanical joint 1 according to the present embodiment configured as described above with reference to FIG. 2. FIG. 2 is a graph of a relation between an axial displacement and the magnitude of a load required for insertion as in FIG. 6. In FIG. 2, the case of the conventional mechanical joint 21 (as in FIG. 6) is indicated by a broken line, whereas the case of the

mechanical joint 1 according to the present embodiment is indicated by a solid line.

[0042] It can be seen from FIG. 2 that in the present embodiment, too, the load gradually increases in the process (X_0 to X'_1) in which the inclined face 19 of the outer joint pipe and the inclined face 13a of the inner joint pipe make contact with each other to insert and fit the split piece 11 while bending it. However, it can be seen from FIG. 2 that the outer joint pipe 7 according to the present embodiment has a gentler inclination of the increase in the load than that of the conventional (the broken line) outer joint pipe 23 and also has a lowered maximum value of the load. This is thought to be because the inclined face 19 according to the present embodiment formed between X_0 and X'_1 has a longer axial length than that of the inclined face 25a (see FIG. 5A) according to the conventional technique formed between X_0 and X_1, and thus the press-fit load is converted into the horizontal force more efficiently. The effect by the outer joint pipe 7 according to the embodiment is easier to be produced with a smaller coefficient of friction μ, and thus it is desirable to apply a lubricant or the like to the inclined face 19 before fitting.

[0043] As described above, the mechanical joint 1 of the present embodiment increases the axial length of the inclined face 19 of the outer joint pipe 7 and can thereby efficiently convert the press-fit load into the horizontal force, reduce the push-in load required for fitting, and improve installability. In addition, the push-in load can be reduced without increasing the number of the split pieces 11, thus inhibiting an increase in processing costs and a reduction in strength.

[0044] (First Modification)

The embodiment described above describes 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 split the side to be placed outside (the outer joint pipe). The outer joint pipe is formed with split pieces that can bend in the radial direction at regular intervals in the circumferential direction, and inclined faces 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.

[0045] In this first modification, too, the same effect as in the embodiment described above can be obtained by providing the inclined face in a part at least 90% or more of the part from the end of the outer joint pipe to the engagement part or suitably across the entire length.

[0046] (Second Modification)

The following describes a second modification based on FIG. 10 and FIG. 11. As illustrated in FIG. 10, 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. 10, 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. 11, the outer joint pipe 7A and the inner joint pipe 5A are fit together to join the upper and lower steel pipes 3 together.

[0047] 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. 10 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.

[0048] 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 protrusions 13A, and a recess 15A is formed on the basal end side of the outer circumferential face of the inner joint pipe 5A. On the inner circumferential side of the tip of the protrusion 13A of the outer joint pipe 7A, the inclined face 13a with a shape corresponding to the inclined face 19 of the inner joint pipe 5A is formed. The inner circumferential face of the inner joint pipe 5A is provided with the engagement part 17 (not illustrated) that is engaged with the protrusions 13A to resist a tensile load together with the protrusions 13A with the outer joint pipe 7A and the inner joint pipe 5A completed to be fit together.

[0049] While the outer joint pipe 7A and the inner joint pipe 5A are fit together, 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 inward in the radial 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. These configurations are similar to what is called a swapped state, in which in FIG. 1A to FIG. 1D, the outer joint pipe 7 becomes the inner joint pipe 5A, whereas the inner joint pipe 5 becomes the outer joint pipe 7A. In other words, in the example illustrated in FIG. 1A to FIG. 1D, the right side of the drawing is the outer joint pipe 7A (the inner joint pipe 5 in FIG. 1A to FIG. 1D), whereas the left side of the drawing is the inner joint pipe 5A (the outer joint pipe 7 in FIG. 1A to FIG. 1D). That is to say, the method of fitting in the second modification illustrated in FIG. 10 and FIG. 11 is the same as in the case of the mechanical joint 1 according to the embodiment described above described with reference to FIG. 1A to FIG. 1D, and thus a detailed description thereof is omitted.

[0050] In the second modification illustrated in FIG. 10 and FIG. 11, too, the same effect as in the embodiment described above can be obtained by providing the inclined face in a part 90% or more of the part from the end of the inner joint pipe 5A to the engagement part or suitably across the entire length.

[0051] 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 the outer joint pipe and/or the inner joint pipe of this mechanical joint on the respective ends of steel pipes to be joined together 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 at least one of the inner joint pipe and the outer joint pipe of the mechanical joint described in the embodiment at both ends or one end of the joint-equipped steel pipe.

[0052] Then, coupling a plurality of joint-equipped

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 include the mechanical joint described in the embodiment described above and a plurality of steel pipes joined together with the mechanical joint.

[0053] In installing these structures, with one joint-equipped steel pipe to be joined restrained, the mechanical 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 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 be fit and joined together.

[0054] In the above description, the mechanical joint as the invention of a thing is described; the mechanical joint is designed by the following method of design. That is to say, the method of design 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 an inclined face 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 while the inner joint pipe and the outer joint pipe are fit together, the method including: providing the inclined face continuously from an end of the outer joint pipe to the engagement part; and converting a vertical load into a horizontal stress bending the split pieces.

[0055] The mechanical joint may be designed by the following method of design. That is to say, the method of design 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 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 an inclined face 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 while the inner joint pipe and the outer joint pipe are fit together, the method including:

providing the inclined face continuously from an end of the outer joint pipe to the engagement part; and converting a vertical load into a horizontal stress bending the split pieces.

[0056] The embodiment of the present invention has been specifically described; the present invention is not limited to the embodiment described above and can adopt 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 modification described above, the inclined face 19 and the recess 15A may be provided on the inner circumferential 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

[0057] The present invention is suitably used for joining steel pipes together.

Reference Signs List

[0058] 1, 2 MECHANICAL JOINT
3 STEEL PIPE
5, 5A INNER JOINT PIPE
7, 7A OUTER JOINT PIPE
9, 9a BASAL END
11, 11A SPLIT PIECE
13, 13A PROTRUSION
13a INCLINED FACE
15, 15A RECESS
17 ENGAGEMENT PART
19 INCLINED FACE