

DESCRIPTION

TITLE OF THE INVENTION:

MULTI-TIERED SOCKET JOINT, STEEL PIPE WITH JOINT,
5 STRUCTURE, METHOD OF INSTALLING STRUCTURE, AND METHODS OF
DESIGNING AND MANUFACTURING MULTI-TIERED SOCKET JOINT

Field

[0001] The present invention relates to a mechanical
10 joint used for joining steel pipes, and particularly to a
multi-tiered socket joint that is a socket joint fitted by
inserting and joint an inner joint pipe into a cylindrical
outer joint pipe and that is provided with a plurality of
tiers of engaged portions, and to a steel pipe with such a
15 joint, a structure, a method of installing the structure,
and methods of designing and manufacturing the multi-tiered
socket joint.

Background

[0002] As an alternative to welding steel pipes, a
20 number of patent applications have been filed for methods
of connecting steel pipes using mechanical joints.

Available as one of such mechanical joints is a socket
joint in which a cylindrical outer joint pipe and an inner
joint pipe are provided to the ends of steel pipes to be
25 joined, respectively, and the steel pipes are connected by
inserting the inner joint pipe into the outer joint pipe.
An example of such a socket joint is disclosed in Patent
Literature 1, for example.

[0003] The "steel pipe joint structure" disclosed in
30 Patent Literature 1 includes "slits that are formed on one
of the outer joint pipe and the inner joint pipe, and that
split the joint pipe into a plurality in the
circumferential direction; a projection that is formed on

an outer circumferential surface of the inner joint pipe;
and an engaged portion that is formed on an inner
circumferential surface of the outer joint pipe, that is
engaged with the projection when the inner joint pipe is
5 inserted into the outer joint pipe, and that resists a
tensile load together with the projection" (see claim 1 of
Patent Literature 1). Because the slits split the inner
joint pipe into a plurality, each of such split pieces of
the inner joint pipe elastically deforms inwards at the
10 time of insertion, and the projection of the inner joint
pipe becomes engaged with the engaged portion of the outer
joint pipe, as the elastic deformation is recovered upon
completion of the insertion. In this configuration, bolts
are inserted into bolt holes provided to the base-end side
15 of the outer joint pipe and the tip-end side of the inner
joint pipe, and are fastened to complete the connection.

[0004] Because the projection disclosed in Patent
Literature 1 is a part that resists the tensile load in
cooperation with the engaged portion, when a high load is
20 expected or when a high bearing capacity is required, e.g.,
as required in a large-diameter steel pipe, the strength of
the projection needs to be increased such that the
resistance to the tensile load is improved. To increase
the strength of the projection, the size of the projection
25 may be increased, but when the size of the projection is
increased, the amount of elastic deformation required in an
insertion process becomes increased, such that the load
required for joint increases.

[0005] Therefore, as a way to improve the resistance to
30 the load without increasing the size of the projection,
there has been a multi-tiered socket joint that is provided
with two or more of tiers of projections (see FIGS. 11 and
12 in Patent Literature 1). By providing multi-tiered

projections and engaged portions that correspond to the respective projections, the plurality of projections can be utilized to resist the load, such that the overall resistance can be improved without increasing the size of the individual projections.

Citation List

Patent Literature

[0006] Patent Literature 1: Japanese Patent No. 4600407

Summary

10 Technical Problem

[0007] However, if a plurality of projections are provided to one of the inner joint pipe and the outer joint pipe, the other needs to be provided with a plurality of recesses that serve as engaged portions. Therefore, a projection may become meshed with a recess that is not a target to be engaged, and become caught during the insertion, and may worsen the workability. Such an example will now be explained specifically with reference to FIGS. 5A, 5B, and 6.

20 [0008] FIGS. 5A and 5B are schematic diagrams illustrating the insertion process in a conventional multi-tiered socket joint 27, and illustrate a sectional view of a section corresponding to the section across the line A-A in FIG. 1 of Patent Literature 1. In the examples
25 illustrated in FIGS. 5A and 5B, an inner joint pipe 3 is attached to a lower end of an upper steel pipe 7, and a cylindrical outer joint pipe 5 is attached to an upper end of a lower steel pipe 7. The inner joint pipe 3 is provided with a split cylindrical portion 11 including a
30 plurality of split pieces 9 that are split in the circumferential direction. On the outer circumferential surface of the split cylindrical portion 11, projections 13 projecting outwards in the radial direction are provided in

two tiers in the axial direction. The outer joint pipe 5 has a cylindrical portion 17. On the inner circumferential surface of the cylindrical portion 17, recesses 19 with which the projections 13 are to be engaged, respectively, are provided in two tiers in the axial direction. In this explanation, the projection 13 and the recess 19 becoming engaged at the same position in the axial direction when the joints are fitted are considered to form one "tier", and the tiers are counted as a first tier and a second tier, from the bottom of the drawing.

[0009] Hereinafter, of the two-tiered projections 13, the lower projection 13 (on the tip-end side of the inner joint pipe) is referred to as a first-tier projection 131, and the upper projection 13 (on the base-end side of the inner joint pipe) is referred to as a second-tier projection 132. Similarly, of the two-tiered recesses 19, the lower recess 19 (on the base-end side of the outer joint pipe) is referred to as a first-tier recess 191, and the upper recess 19 (on the tip-end side of the outer joint pipe) is referred to as a second-tier recess 192. In a state in which the joints are fitted, the projection 13 and the recess 19 engaged with each other are together referred to as an engaged portion 23.

[0010] In the conventional multi-tiered socket joint 27 having the structure described above, when the inner joint pipe 3 is inserted into the outer joint pipe 5, with the lower steel pipe 7 restrained, the first-tier projection 131 on an inner joint pipe 3 is brought into abutment against the inner surface of the cylindrical portion 17 of the outer joint pipe 5, and applies a horizontal force indicated by the white arrow in FIG. 5A to the split pieces 9 of the inner joint pipe 3, and causes an inward elastic deformation in the radial direction. Each of the split

pieces 9 elastically deforms inwards in the radial direction, and makes the diameter of the split cylindrical portion 11 smaller.

[0011] As the inner joint pipe 3 is inserted further from this configuration, and the first-tier projection 131 reaches the second-tier recess 192, as illustrated in FIG. 5B, the horizontal force having been applied is lost temporarily, and a restoring force recovering from the elastic deformation is generated in the split pieces 9. As this restoring force makes the diameter of the split cylindrical portion 11 larger, an outer circumference portion of the first-tier projection 131 becomes engaged with the second-tier recess 192, and becomes caught.

[0012] If this engagement is shallow, it might be possible to release the engagement by applying a higher pushing load. However, if the engagement is deep, it will become difficult to continue the installation any longer. In such a case, it is not possible to insert or to pull out the inner joint pipe 3, unless the diameter of the split cylindrical portion 11 is reduced using some auxiliary device, and this process will require a great deal of labor.

[0013] As described above, if the projection 13 becomes engaged with the recess 19 that is not a target to be engaged during the insertion, the installation load may need to be increased significantly, such that the workability may become worsened, and installation difficulties such as joint failure may occur.

[0014] Furthermore, the examples illustrated in FIGS. 5A and 5B are examples in which a pipe axis 3a of the inner joint pipe 3 is aligned with a pipe axis 5a of the outer joint pipe 5. However, if the pipe axis 3a of the inner joint pipe 3 and the pipe axis 5a of the outer joint pipe 5

are misaligned, the difficulties explained above become even more likely to occur. Such an example is illustrated in FIG. 6.

[0015] FIG. 6 is a diagram during the insertion where
5 the inner joint pipe 3 is inserted into the outer joint pipe 5 with the pipe axis 3a of the inner joint pipe 3 misaligned with the pipe axis 5a of the outer joint pipe 5 in the same conventional multi-tiered socket joint 27 illustrated in FIGS. 5A and 5B. When the installation is
10 carried out under a poor connecting environment condition (e.g., on-site, large-diameter, or long-pipe installations), it will become difficult to control a verticality of the inner joint pipe 3 and the outer joint pipe 5, and the installation may be proceeded with the pipe
15 axis 3a of the inner joint pipe 3 misaligned with the pipe axis 5a of the outer joint pipe 5, as illustrated in FIG. 6.

[0016] In such a case, because the first-tier projection 131 is more likely to collide with the lower side wall of
20 the second-tier recess 192, as illustrated in FIG. 6, the difficulties such as installation failures described above will be even more likely to occur.

[0017] The present invention is made to address such difficulties, and an object of the present invention is to
25 provide a multi-tiered socket joint, a steel pipe with a joint, a structure, a structure installation method, and methods of designing and manufacturing the multi-tiered socket joint exhibiting excellent workability when the steel pipes are to be joined, by preventing the engagement
30 of a projection with a recess that is not a target to be engaged at the time of insertion.

Solution to Problem

[0018] (1) A multi-tiered socket joint according to the

present invention includes: a cylindrical inner joint pipe;
and a cylindrical outer joint pipe, the inner joint and the
outer joint being attached to ends of steel pipes to be
joined, respectively, wherein one of the inner joint pipe
5 and the outer joint pipe includes a split cylindrical
portion including a plurality of split pieces that are
split in a circumferential direction, and a plurality of
tiers of projections arranged in an axial direction on the
plurality of split pieces, the projections being configured
10 to project in a radial direction, another one of the inner
joint pipe and the outer joint pipe includes a cylindrical
portion that is not split, and a plurality of tiers of
recesses arranged in the axial direction on the cylindrical
portion, the recesses being configured to engage with the
15 projections, the steel pipes are joined by inserting the
inner joint pipe into the outer joint pipe and by engaging
the projections with the recesses, while bending the split
cylindrical portion in the radial direction, the plurality
of tiers of projections have axial widths gradually
20 becoming smaller from a tip-end side toward a base-end
side, the plurality of tiers of recesses have axial widths
gradually becoming smaller from a base-end side toward a
tip-end side, and the axial width of each of the
projections is set so as to have a size equal to or larger
25 than an axial width of a recess that is on the tip-end side
with respect to a recess with which the projection is to be
engaged when the joints are fitted.

[0019] (2) Moreover, a multi-tiered socket joint
according to the present invention includes: a cylindrical
30 inner joint pipe; and a cylindrical outer joint pipe, the
inner joint pipe and the outer joint pipe being attached to
ends of steel pipes to be joined, respectively, wherein one
of the inner joint pipe and the outer joint pipe includes a

split cylindrical portion including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of recesses arranged in an axial direction on the plurality of split pieces, another one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and a plurality of tiers of projections arranged in the axial direction on the cylindrical portion, the projections being configured to project in a radial direction, and engage with the recesses, the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction, the plurality of tiers of projections have axial widths gradually becoming smaller from a projection on a tip-end side toward a projection on a base-end side, the plurality of tiers of recesses have axial widths gradually becoming smaller from a recess on a base-end side toward a recess on a tip-end side, and the axial width of each of the projections is set so as to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

[0020] (3) Moreover, in the above-described (1) or (2), axial clearances formed between the projections and the respective recesses that are engaged with each other are same across all engaged portions in a state in which the joints are fitted.

[0021] (4) Moreover, in any one of the above-described (1) to (3), a projection height of the plurality of tiers of projections is set equal to or smaller than a projection height of the projection that is nearest to the tip-end side, and a projection height of at least one of the

plurality of tiers of projections is set smaller than of that of the projection that is nearest to the tip-end side.

[0022] (5) Moreover, in the above-described (4), the plurality of tiers of projections have projection heights
5 gradually becoming smaller from a projection on the tip-end side toward a projection on the base-end side.

[0023] (6) Moreover, a steel pipe with a joint according to the present invention includes any one or both ends provided with any one or both of the inner joint pipe and
10 the outer joint pipe included in the multi-tiered socket joint according to any one of the above-described (1) to (5).

[0024] (7) Moreover, a structure according to the present invention includes a plurality of steel pipes
15 connected by a multi-tiered socket joint according to any one of the above-described (1) to (5).

[0025] (8) Moreover, a method of installing according to the present invention is a method of installing the structure according to the above-described (7), and
20 includes: restraining an axial position of one of a steel pipe with the outer joint pipe being attached to an end and a steel pipe with the inner joint pipe being attached to an end; aligning an axial position of another one of the steel pipe with the one of the steel pipes; inserting the other
25 one of the steel pipes into the one of the steel pipes to fit the other one of the steel pipes with the one of the steel pipes.

[0026] (9) Moreover, a method of designing a multi-tiered socket joint according to the present invention is a
30 method of designing a multi-tiered socket joint including a cylindrical inner joint pipe; and a cylindrical outer joint pipe, the inner joint and the outer joint being attached to ends of steel pipes to be joined, respectively, wherein one

of the inner joint pipe and the outer joint pipe includes a split cylindrical portion including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of projections arranged in an axial
5 direction on the plurality of split pieces, the projections being configured to project in a radial direction, another one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and a plurality of tiers of recesses arranged in the axial
10 direction on the cylindrical portion, the recesses being configured to engage with the projections, and the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in
15 the radial direction, and includes: setting the plurality of tiers of projections to have axial widths gradually becoming smaller from a projection on a tip-end side toward a projection on a base-end side; setting the plurality of tiers of recesses to have axial widths gradually becoming
20 smaller from a recess on a base-end side toward a recess on a tip-end side; and setting the axial width of each of the projections to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when
25 the joints are fitted.

[0027] (10) Moreover, a method of designing a multi-tiered socket joint according to the present invention is a method of designing a multi-tiered socket joint including: a cylindrical inner joint pipe; and a cylindrical outer
30 joint pipe, the inner joint pipe and the outer joint pipe being attached to ends of steel pipes to be joined, respectively, wherein one of the inner joint pipe and the outer joint pipe includes a split cylindrical portion

including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of recesses arranged in an axial direction on the plurality of split pieces, another one of the inner joint pipe and the
5 outer joint pipe includes a cylindrical portion that is not split, and a plurality of tiers of projections arranged in the axial direction on the cylindrical portion, the projections being configured to project in a radial direction, and engage with the recesses, and the steel
10 pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction, and includes: setting the plurality of tiers of projections such that that axial widths
15 gradually become smaller from a projection on a tip-end side toward a projection on a base-end side; setting the plurality of tiers of recesses such that axial widths gradually become smaller from a recess on a base-end side toward a recess on a tip-end side; and setting the axial
20 width of each of the projections to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

[0028] (11) In the above-described (9) or (10), the
25 axial widths of the plurality of projections and the plurality of respective recesses are set in such a manner that axial clearances formed between the projections and the respective recesses that are engaged with each other are same across all engaged portions in a state in which
30 the joints are fitted.

[0029] (12) Moreover, a method of manufacturing a multi-tiered socket joint according to the present invention is a method of manufacturing a multi-tiered socket joint

including a cylindrical inner joint pipe; and a cylindrical outer joint pipe, the inner joint and the outer joint being attached to ends of steel pipes to be joined, respectively, wherein one of the inner joint pipe and the outer joint

5 pipe includes a split cylindrical portion including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of projections arranged in an axial direction on the plurality of split pieces, the projections being configured to

10 project in a radial direction, another one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and a plurality of tiers of recesses arranged in the axial direction on the cylindrical portion, the recesses being configured to engage with the

15 projections, and the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction, and includes: forming the plurality of tiers of projections

20 such that axial widths gradually become smaller from a projection on a tip-end side toward a projection on a base-end side; forming the plurality of tiers of recesses such that axial widths gradually become smaller from a recess on a base-end side toward a recess on a tip-end side; and

25 forming the axial width of each of the projections so as to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

30 [0030] (13) Moreover, a method of manufacturing a multi-tiered socket joint according to the present invention is a method of manufacturing a multi-tiered socket joint including a cylindrical inner joint pipe; and a cylindrical

outer joint pipe, the inner joint pipe and the outer joint pipe being attached to ends of steel pipes to be joined, respectively, wherein one of the inner joint pipe and the outer joint pipe includes a split cylindrical portion

5 including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of recesses arranged in an axial direction on the plurality of split pieces, another one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not

10 split, and a plurality of tiers of projections arranged in the axial direction on the cylindrical portion, the projections being configured to project in a radial direction, and engage with the recesses, and the steel pipes are joined by inserting the inner joint pipe into the

15 outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction, and includes: forming the plurality of tiers of projections such that axial widths gradually become smaller from a projection on a tip-end side toward a

20 projection on a base-end side; forming the plurality of tiers of recesses such that axial widths gradually become smaller from a recess on a base-end side toward a recess on a tip-end side; and forming the axial width of each of the projections so as to have a size equal to or larger than an

25 axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

[0031] (14) Moreover, in the above-described (12) or (13), the plurality of projections and the plurality of

30 respective recesses are formed in such a manner that axial clearances formed between the projections and the respective recesses that are engaged with each other are same across all of engaged portions in a state in which the

joints are fitted.

Advantageous Effects of Invention

[0032] In the present invention, the plurality of tiers of projections have axial widths gradually becoming smaller from a projection on the tip-end side toward a projection on the base-end side, and the plurality of tiers of recesses have axial widths gradually becoming smaller from a recess on the base-end side toward a recess on the tip-end side. The axial width of each of the projections is larger than the width of a recess that is on the tip-end side with respect to the recess with which the projection is to be engaged when the joints are fitted. Therefore, it is possible to prevent the projection and the recess that are not the targets to be engaged from becoming meshed with each other at the time of insertion. In this manner, it is possible to suppress the projections becoming caught when the steel pipes are joined, to reduce the occurrence of installation difficulties that significantly increase the installation load, that worsen the workability, and that make it impossible to achieve engagement, and therefore, it is possible to improve the workability.

Brief Description of Drawings

[0033] FIG. 1 is an explanatory diagram of a multi-tiered socket joint and is a sectional view of a part of the multi-tiered socket joint with joint pipes fitted according to a first embodiment of the present invention.

FIG. 2 is a diagram illustrating a state in which the multi-tiered socket joint illustrated in FIG. 1 is during the joint (without misalignment of axes).

FIG. 3 is a diagram illustrating a state in which the multi-tiered socket joint illustrated in FIG. 1 is during the joint (with the misalignment of the axes).

FIG. 4 is an explanatory diagram of a multi-tiered

socket joint and is a sectional view of a part of the multi-tiered socket joint in a state of being during the joint according to a second embodiment of the present invention.

5 FIG. 5A is a diagram for explaining difficulties of a conventional multi-tiered socket joint (without the misalignment of the axes).

 FIG. 5B is a diagram for explaining the difficulties of the conventional multi-tiered socket joint (without the
10 misalignment of the axes).

 FIG. 6 is a diagram for explaining the difficulties of the conventional multi-tiered socket joint (with the misalignment of the axes).

Description of Embodiments

15 [0034] [First Embodiment]

 An overall structure of a multi-tiered socket joint according to the present embodiment is not illustrated, because the structure is generally the same as that illustrated in FIG. 12 disclosed in aforementioned Patent
20 Literature 1, and FIG. 1 illustrates only a sectional view of a part of the multi-tiered socket joint. FIG. 1 illustrates a section of a portion corresponding to the section across the line A-A in FIG. 1 of Patent Literature 1. The same reference numerals are assigned to the
25 portions that are the same as or correspond to those illustrated in FIGS. 5A, 5B, and 6, which illustrate a conventional multi-tiered socket joint 27.

 [0035] A multi-tiered socket joint 1 according to the present embodiment includes an inner joint pipe 3 and a
30 cylindrical outer joint pipe 5 that are attached to ends of steel pipes that are to be joined, respectively. FIG. 1 illustrates an example in which the inner joint pipe 3 is attached to the lower end of an upper steel pipe 7, and the

outer joint pipe 5 is attached to the upper end of a lower steel pipe 7. As illustrated in FIG. 1, the upper and lower steel pipes 7 are joined by inserting the inner joint pipe 3 into the outer joint pipe 5, and joint the inner joint pipe 3 into the outer joint pipe 5. The inner joint pipe 3 and the outer joint pipe 5 will now be explained in detail.

[0036] <Inner Fitting Pipe>

The inner joint pipe 3 is formed of a substantially cylindrical body, and includes a split cylindrical portion 11 having a plurality of split pieces 9 that are split in the circumferential direction. Across the entire circumference of the outer circumferential surface of the split cylindrical portion 11, projections 13 projecting outward in the radial direction are provided in two tiers in the axial direction. For the two-tiered projections 13, the lower projection 13 (on the tip-end side of the inner joint pipe 3) will be referred to as the first-tier projection 131, and the upper projection 13 (on the base-end side of the inner joint pipe 3) will be referred to as the second-tier projection 132, in the same manner as in FIGS. 5A, 5B, and 6. FIG. 1 illustrates the section of one of the split pieces 9, but the other split pieces 9 also have the same sections as that illustrated in FIG. 1. On the tip-end side with respect to the first-tier projection 131, a bolt hole 15 for joining the outer joint pipe 5 with a bolt is provided.

[0037] <Outer Fitting Pipe>

The outer joint pipe 5 is formed of a cylindrical body, and includes a cylindrical portion 17 that is not split. Across the entire circumference of the inner circumferential surface of the cylindrical portion 17, recesses 19 that are recessed outwards in the radial

direction are provided in two tiers in the axial direction. For the two-tiered recesses 19, the lower recess 19 (on the base-end side of the outer joint pipe 5) will be referred to as a first-tier recess 191, and the upper recess 19 (on the tip-end side of the outer joint pipe 5) will be referred to as a second-tier recess 192, in the same manner as in the projections 13 of the inner joint pipe. As illustrated in FIG. 1, in the state in which the joints are fitted, the first-tier recess 191 is engaged with the first-tier projection 131, and the second-tier recess 192 is engaged with the second-tier projection 132. On the base-end side with respect to the first-tier recess 191, a bolt hole 21 for inserting a bolt is provided at a position facing the bolt hole 15 on the inner joint pipe 3.

[0038] As illustrated in the enlarged view in FIG. 1, an axial width and a radially outward projection height of the first-tier projection 131 are denoted as $T1$ and $H1$, respectively, and an axial width and a radially outward recess depth of the first-tier recess 191 are denoted as $K1$ and $L1$, respectively. In the same manner, an axial width and a radially outward projection height of the second-tier projection 132 are denoted as $T2$ and $H2$, respectively, and an axial width and a radially outward recess depth of the second-tier recess 192 are denoted as $K2$ and $L2$, respectively (not illustrated in the enlarged view). $T1$ and $T2$ correspond to the axial widths across the top (tip portion) of the projections 13, respectively. $K1$ and $K2$ correspond to the axial widths of the openings of the recesses, respectively.

[0039] As described above, the axial widths $T1$ and $T2$ denote the axial widths across the top of the first-tier projection 131 and the second-tier projection 132, respectively. The axial widths across the base end of the

first-tier projection 131 and the base end of the second-tier projection 132, on the contrary, may be set based on the shear capacity required for the entire projections 13. Generally, because the shear capacity of the projections 13
 5 can be set with sufficient margin, even if the shear capacity of the projections 13 changes slightly by changing the axial widths across the top of the projections 13, the bearing capacity of the entire joints is not affected very much.

10 [0040] The recessed depth L1 of the first-tier recess 191 is larger than the projection height H1 of the first-tier projection 131 ($H1 < L1$) such that the first-tier projection 131 can become engaged with the first-tier recess 191. In the same manner, the recessed depth L2 of
 15 the second-tier recess 192 is larger than the projection height H2 of the second-tier projection 132 ($H2 < L2$).

[0041] Among the two-tiered projections 13 provided to the split cylindrical portion 11 of the inner joint pipe 3, the axial width T2 of the projection 13 on the base-end
 20 side (the second-tier projection 132) is smaller than the axial width T1 of the projection 13 on the tip-end side (first-tier projection 131) ($T2 < T1$). In the two-tiered recess 19 provided to the cylindrical portion 17 of the outer joint pipe 5, the axial width K2 of the recess 19 on
 25 the tip-end side (the second-tier recess 192) is smaller than the axial width K1 of the recess 19 on the base-end side (first-tier recess 191) ($K2 < K1$). Furthermore, the axial width T1 of the first-tier projection 131 is equal to or larger than the axial width K2 of the recess 19 (second-
 30 tier recess 192) that is on the tip-end side with respect to the recess 19 (first-tier recess 191) with which the projection is to be engaged when the joints are fitted ($K2 \leq T1$). From the above, the multi-tiered socket joint 1

according to the present embodiment satisfies following relation Equations (1) to (3).

$$H1 < L1 \quad (1)$$

$$H2 < L2 \quad (2)$$

$$5 \quad T2 < K2 \leq T1 < K1 \quad (3)$$

[0042] As described above, it is assumed that the split cylindrical portion 11 of the inner joint pipe 3 includes the split pieces 9 arranged in the circumferential direction, and the two-tiered projections 13 of all of the split pieces 9 are formed to have the same axial widths $T1$, $T2$ and the same projection heights $H1$, $H2$. The two-tiered recesses 19 provided to the cylindrical portion 17 of the outer joint pipe 5 are provided on the inner circumferential surface of the cylindrical portion 17, continuously in the circumferential direction, and the axial widths $K1$, $K2$ and the recessed depths $L1$, $L2$ remain constant across the entire circumference.

[0043] An axial clearance δ (specifically, a distance between the position of the center of the side wall of the first-tier projection 131 in the projecting direction and the side wall of the first-tier recess 191) in the first-tier engaged portion 23 illustrated in the enlarged view in FIG. 1 is the same as the axial clearance in the second-tier engaged portion 23. As described above, by ensuring the same axial clearance between the projections 13 and the recesses 19 that are engaged with each other in the state in which the joints are fitted, respectively, for all of the engaged portions 23, the load is transmitted properly, such that the multi-tiered socket joint 1 is made suitable for use as a part of a structure.

[0044] Advantageous effects achieved by the multi-tiered socket joint 1 according to the present embodiment having the structure described above will now be explained in

detail. In the conventional multi-tiered socket joint 27, as explained with reference to FIGS. 5A and 5B, when the first-tier projection 131 reaches the second-tier recess 192 during the joint, the tip portion of the first-tier projection 131 goes into and becomes caught by the second-tier recess 192.

[0045] In this respect, the multi-tiered socket joint 1 according to the present embodiment does not have such a problem because the axial width T1 of the first-tier projection 131 is larger than the axial width K2 of the second-tier recess 192 ($K2 \leq T1$). Specifically, as illustrated in FIG. 2, even when the first-tier projection 131 reaches the second-tier recess 192, a part of the first-tier projection 131 always remains in contact with the inner circumferential surface of the cylindrical portion 17. Therefore, the first-tier projection 131 can be carried across the second-tier recess 192 with the inward elastic deformation of the split piece 9 in the radial direction maintained, such that the first-tier projection 131 is less likely to become caught. Even if $K2 = T1$, such a problem does not occur because factors such as friction only permit the first-tier projection 131 to get into the second-tier recess 192 shallowly, and become caught only by a small degree. In this regard, it is preferable for the axial width T1 of each of the projections to be larger than the axial width K2 of the recess that is on the tip-end side with respect to the recess with which the projection is to be engaged when the joints are fitted, because the risk of the projection becoming caught can be reduced.

[0046] Furthermore, in the conventional multi-tiered socket joint 27, the projection becomes caught in the recess particularly when the pipes are installed with the

pipe axis 3a of the inner joint pipe 3 not aligned with the pipe axis 5a of the outer joint pipe 5, as explained with reference to FIG. 6. In this respect, the present embodiment has the effect of reducing the risk of projections becoming caught, even when the pipes are installed with their axes misaligned, in the manner described above. This point will now be explained using FIG. 3.

[0047] FIG. 3 is a diagram during the insertion where the inner joint pipe 3 is inserted into the outer joint pipe 5 with the pipe axis 3a of the inner joint pipe 3 misaligned with the pipe axis 5a of the outer joint pipe 5 in the multi-tiered socket joint 1 according to the present embodiment. As illustrated in the enlarged view in FIG. 3, if the outer joint pipe 5 is tilted, the first-tier projection 131 may collide with the lower side wall of the second-tier recess 192. In this case, as illustrated in the enlarged view in FIG. 6, in the conventional example, due to the restoring force for recovering from the elastic deformation, the entire tip portion of the first-tier projection 131 is pushed into the second-tier recess 192, such that the projection may become deeply caught and make the installation impossible to continue. In the condition illustrated in FIG. 6, even if one tries to pull out the inner joint pipe 3 to redo the installation, the first-tier projection 131 becomes caught on the upper side wall of the second-tier recess 192, such that it is necessary to use the auxiliary device to reduce the diameter of the split cylindrical portion 11.

[0048] In this respect, the multi-tiered socket joint 1 according to the present embodiment does not have such a problem because the axial width T1 of the first-tier projection 131 is larger than the axial width K2 of the

second-tier recess 192 ($K2 \leq T1$). Specifically, as illustrated in the enlarged view in FIG. 3, even if the first-tier projection 131 collides with the lower side wall of the second-tier recess 192, the tip portion of the first-tier projection 131 does not entirely push into the second-tier recess 192. Therefore, the projection becomes caught on the recess only shallowly, and it is possible to release the caught projection merely by increasing the insertion load slightly, and to continue the installation.

Even if $K2 = T1$, such a problem does not occur because factors such as friction only permit the first-tier projection 131 to get into the second-tier recess 192 shallowly, and become caught only by a small degree. In this regard, it is preferable for the axial width $T1$ of each of the projections to be larger than the axial width $K2$ of the recess that is on the tip-end side with respect to the recess with which the projection is to be engaged when the joints are fitted, because the risk of the projection becoming caught can be reduced.

[0049] In addition, even when one attempts to pull out the inner joint pipe 3 to redo the installation, for example, the first-tier projection 131 does not get caught on the upper side wall of the second-tier recess 192, as in the conventional example, so it is easier to pull out in the middle of the installation process.

[0050] The above is an example in which the outer joint pipe 5 attached to the lower steel pipe 7 is tilted, but the same effect can be achieved even when the inner joint pipe 3 attached to the upper steel pipe 7 is tilted.

[0051] As described above, according to the present embodiment, the axial width $T2$ of the second-tier projection 132 is smaller than the axial width $T1$ of the first-tier projection 131 ($T2 < T1$), and correspondingly, the

axial width K2 of the second-tier recess 192 is smaller than the axial width K1 of the first-tier recess 191 ($K2 < K1$). With this, the axial width T1 of the first-tier projection 131 is equal to or larger than the axial width K1 of the recess 19 (second-tier recess 192) that is on the tip-end side with respect to the recess 19 (first-tier recess 191) with which the projection is to be engaged when the joints are fitted ($K1 \leq T1$). Therefore, it is possible to prevent the projection 13 from becoming engaged with the recess 19 that is not a target to be engaged, at the time of insertion process. In this manner, even in a poor connecting environment and under conditions where rattling is likely to occur, it is possible to reduce the occurrence of installation problems that can worsen workability by increasing the installation load significantly, and that can make it impossible to achieve the engagement, and to improve workability.

[0052] Although in the first embodiment described above, two-tiered engaged portions 23 are provided, but the number of tiers of the engaged portions 23 may be any number as long as such a number of tiers can be processed. When the number of tiers are three or more, the axial widths gradually become smaller from the projection 13 on the tip-end side toward the projection 13 on the base-end side. Correspondingly, the recesses 19 also have the axial widths gradually becoming smaller from the recess 19 on the base-end side toward the recess 19 on the tip-end side. The axial width of each of such projections 13 is set larger than the axial width of the recess 19 that is on the tip-end side with respect to the recess 19 with which the projection 13 is to be engaged when the joints are fitted. In the conventional multi-tiered socket joint 27, the risk of the projection becoming caught during the insertion

increases as the number of tiers of the engaged portions 23 is increased, but with the multi-tiered socket joint 1 according to the present embodiment, it is possible to suppress such a risk of a projection becoming caught, regardless of the number of tiers in which the engaged portions 23 are provided. Therefore, the present invention is particularly suitable for a multi-tiered socket joint having a large number of tiers of the engaged portion.

[0053] [Second Embodiment]

While the first embodiment described above provides an example in which the projection heights of all of the projections 13 are the same ($H1=H2$), the present embodiment explains an example in which the projection height $H1$ of the first-tier projection 131 is greater than the projection height $H2$ of the second-tier projection 132.

FIG. 4 illustrates a multi-tiered socket joint according to the present embodiment, and the same and corresponding parts as those in FIGS. 1 to 3 are assigned with the same reference numerals.

[0054] As illustrated in FIG. 4, the projection height $H1$ of the first-tier projection 131 is greater than the projection height $H2$ of the second-tier projection 132 ($H2 < H1$) in a multi-tiered socket joint 25 according to the present embodiment. Correspondingly to the increase in the projection height $H1$ of the first-tier projection 131, the recessed depth $L1$ of the first-tier recess 191 is also increased such that $H1 < L1$ is established. Because the multi-tiered socket joint 25 according to the present embodiment is the same as the multi-tiered socket joint 1 according to the first embodiment except for the points described above, the multi-tiered socket joint 25 satisfies the following relation (4), in addition to the relations (1) to (3) explained in the first embodiment.

$$H2 < H1$$

(4)

[0055] The projection height H1 of the first-tier projection 131 is greater than the projection height H2 of the second-tier projection 132. In other words, the projection height H2 of the second-tier projection 132 is smaller than the projection height H1 of the first-tier projection 131. In the process of inserting the inner joint pipe 3 into the outer joint pipe 5, a clearance is ensured between the second-tier projection 132 and the inner circumferential surface of the cylindrical portion 17, as illustrated in FIG. 4. With this clearance, because no friction is generated between the second-tier projection 132 and the inner circumferential surface of the cylindrical portion 17, it is possible to reduce the installation resistance generated when the inner joint pipe 3 is inserted into the outer joint pipe 5.

[0056] Although in the second embodiment described above, two-tiered of engaged portions are provided, but the number of tiers in the engaged portions 23 may be any number as long as such a number of tiers can be processed. For example, when there are three tiers of engaged portions, the second-tier projection will become engaged with the second-tier recess after being carried across the third-tier recess at the time of insertion. Because the second-tier projection is not brought into abutment against the inner circumferential surface of the cylindrical portion 17, as illustrated in FIG. 4, the risk of the second-tier projection becoming caught by the third-tier recess can be reduced.

[0057] When the multi-tiered projections 13 have three or more tiers, the projection heights of the multi-tiered projections 13 are set equal to or smaller than the projection height of the projection 13 that is nearest to

the tip-end side, and the projection height of at least one of the multi-tiered projections 13 is set smaller than that of the projection 13 nearest to the tip-end side. In other words, it is also possible to place the projections 13

5 having the same projection height as the first-tier projection 131 in every few tiers, and with this configuration, too, the installation resistance is reduced, compared with that including the projections 13 all of which have the same projection height. The projection 13
10 having a projection height smaller than the first-tier projection 131 is less likely to become caught during the insertion than the projection 13 having the same projection height as the first-tier projection 131. However, the first-tier projection 131 and the other projections 13
15 having the same projection height as the first-tier projection 131 are also less likely to become caught, compared with the conventional example, because their axial widths are greater than that of the recess 19 across which such projections need to be carried during the insertion.

20 [0058] Because the above requirement is satisfied when at least one of the multi-tiered projections 13 has a projection height smaller than that of the projection 13 nearest to the tip end, the projection heights may be set to become gradually smaller from the projection 13 on the
25 tip-end side toward the projection 13 on the base-end side, for example.

[0059] An upper bound of the height of the projections 13 is determined by verifying the thickness of the steel plate required in the joint pipe having the corresponding
30 recess 19, and a lower bound is determined by the bearing force required to prevent a failure due to the dislocation between the projection 13 and the recess 19. The height of each of the projections 13 can be changed as long as the

height is within the upper and the lower bounds described above, and as long as the total bearing capacity of the tiers are equal to or greater than the required bearing capacity.

5 [0060] The first embodiment and the second embodiment described above are examples in which a side to be inserted into (inner joint pipe 3) is split, but the present invention is not limited thereto, and the side to be disposed outside (outer joint pipe 5) may also be split.

10 In other words, the joint may include a cylindrical outer joint pipe 5 including the split cylindrical portion 11 having the multi-tiered projections 13 on the inner circumferential surface thereof, and the inner joint pipe 3 having the cylindrical portion 17 with the multi-tiered

15 recesses 19 on the outer circumferential surface thereof. With this configuration, too, the multi-tiered projections 13 have axial widths gradually becoming smaller from the projection 13 on the tip-end side toward the projection 13 on the base-end side. The multi-tiered recesses 19 have

20 axial widths gradually becoming smaller from the recess 19 on the base-end side toward the recess 19 on the tip-end side. Furthermore, the axial width of each of the projections 13 is equal to or larger than the axial width of the recess 19 that is on the tip-end side with respect

25 to the recess 19 with which the projection is to be engaged when the joints are fitted.

[0061] The above is an example where the multi-tiered projections 13 are formed on the split side (split cylindrical portion 11) and the multi-tiered recesses 19

30 are formed on the unsplit side (cylindrical portion 17), but the present invention is not limited thereto. In other words, the split cylindrical portion 11 may be provided with the multi-tiered recesses 19 and the cylindrical

portion 17 may be provided with the multi-tiered projections 13. In other words, as illustrated in FIG. 11 of Patent Literature 1, the multi-tiered socket joint may include the outer joint pipe 5 having the split cylindrical portion 11 provided with the multi-tiered recesses 19, and the inner joint pipe 3 having the cylindrical portion 17 provided with the multi-tiered projections 13. The multi-tiered socket joint may also include the inner joint pipe 3 having the split cylindrical portion 11 provided with the multi-tiered recesses 19, and the outer joint pipe 5 having the cylindrical portion 17 provided with the multi-tiered projections 13. In this case, too, the multi-tiered projections 13 have axial widths gradually becoming smaller from the projection 13 on the tip-end side toward the projection 13 on the base-end side. The multi-tiered recesses 19 have axial widths gradually becoming smaller from the recess 19 on the base-end side toward the recess 19 on the tip-end side. Furthermore, the axial width of each of the projections 13 is equal to or larger than the axial width of the recess 19 that is on the tip-end side with respect to the recess 19 with which the projection is to be engaged when the joints are fitted. In either of the above configurations, it is possible to achieve the same advantageous effects as those in the first embodiment and the second embodiment.

[0062] In the first embodiment and the second embodiment described above, the joints are explained to be connected by moving vertically. However, the direction of the movement may be any direction as long as the direction is in the axial direction of the steel pipe, and the joints may connect diagonal piles or a horizontal transverse joint.

[0063] The shapes of the projections 13 and the recesses

19 are not limited, as long as such shapes satisfy the
aforementioned Equations (1) to (3), or additionally
Equation (4) (when the engaged portions 23 are two-tiered).
Even if the shapes are different from those explained in
5 the first embodiment and the second embodiment, the
advantageous effects can be achieved.

[0064] In the embodiments described above, the multi-
tiered socket joint 1, 25, which are attached to the
respective ends of the steel pipes 7 are explained, but it
10 is also possible to manufacture a steel pipe with a joint
by attaching any one or both of the inner joint pipe 3 and
the outer joint pipe 5 of the multi-tiered socket joint 1,
25 to the respective ends of steel pipes 7 by welding, for
example, in a factory or the like in advance. In other
15 words, any one or both of the ends of the steel pipe with a
joint may be provided with one or both of the inner joint
pipe 3 and the outer joint pipe 5 included in the multi-
tiered socket joint 1, 25 described in the first embodiment
and the second embodiment.

20 [0065] By then connecting a plurality of steel pipes
with a joint in a construction site or the like, it is
possible to form a structure such as a steel pipe pile, a
steel pipe sheet pile, a steel pipe sheet pile wall
connecting steel pipe sheet piles, a steel pipe column, or
25 a steel pipe beam. In other words, these structures have a
plurality of steel pipes connected by the multi-tiered
socket joint 1, 25 described above in the first embodiment
and the second embodiment.

[0066] To install these structures, while keeping the
30 axial position of one of the steel pipe 7 having an end
with the outer joint pipe 5 attached and that having an end
with the inner joint pipe 3 attached restrained, the axial
position of the other steel pipe 7 is aligned with the

axial position of the one steel pipe 7, and the other steel pipe 7 is inserted and fitted into the one steel pipe 7.

[0067] Although the first embodiment and the second embodiment are pertinent to the multi-tiered socket joint as an invention of a product, the first embodiment and the second embodiment may be re-configured as inventions pertinent to a designing method and a manufacturing method, and such reconfigurations are as follows.

[0068] <Invention 1 of Designing Method>

10 A method of designing a multi-tiered socket joint including a cylindrical inner joint pipe and outer joint pipe that are attached to ends of steel pipes to be joined, respectively, in which one of the inner joint pipe and the outer joint pipe includes a split cylindrical portion
15 having a plurality of split pieces that are split in the circumferential direction, and projections that are provided in a plurality of tiers in the axial direction, the projections being provided on the plurality of split pieces and projecting in the radial direction, and the
20 other one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and recesses that are provided in a plurality of tiers in the axial direction, the recesses being provided on the cylindrical portion, and becoming engaged with the
25 projections, respectively; the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, respectively, while bending the split cylindrical portion in the radial direction, the plurality of tiers of
30 projections are set such that axial widths gradually become smaller from a projection on a tip-end side toward a projection on a base-end side, and the plurality of tiers of recesses are set such that axial widths gradually become

smaller from a recess on a base-end side toward a recess on a tip-end side; and the axial width of each of the projections is set so as to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

[0069] <Invention 2 of Designing Method>

A method of designing a multi-tiered socket joint including a cylindrical inner joint pipe and outer joint pipe that are attached to ends of steel pipes to be joined, respectively, in which one of the inner joint pipe and the outer joint pipe includes a split cylindrical portion having a plurality of split pieces that are split in the circumferential direction, and recesses that are provided in a plurality of tiers in the axial direction, the recesses being provided on the plurality of split pieces; the other one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and projections that are provided in a plurality of tiers in the axial direction, the projections being provided on the cylindrical portion, projecting in the radial direction, and becoming engaged with the recesses, respectively; the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, respectively, while bending the split cylindrical portion in the radial direction, the plurality of tiers of projections are set such that axial widths gradually become smaller from a projection on a tip-end side toward a projection on a base-end side, and the plurality of tiers of recesses are set such that axial widths gradually become smaller from a recess on a base-end side toward a recess on a tip-end side; and the axial width of each of the projections is set so as to have a size

equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

[0070] <Invention 3 of Designing Method>

5 The method of designing a multi-tiered socket joint as described in Invention 1 or 2 of the designing method, in which the axial widths of the projections and the plurality of recesses are set in such a manner that the axial clearance formed between the projections and the respective
10 recesses that are engaged with each other are the same across all engaged portions in a state in which the joints are fitted.

[0071] <Invention 1 of Manufacturing Method>

15 A method of manufacturing a multi-tiered socket joint including a cylindrical inner joint pipe and outer joint pipe that are attached to ends of steel pipes to be joined, respectively, in which one of the inner joint pipe and the outer joint pipe includes a split cylindrical portion having a plurality of split pieces that are split in the
20 circumferential direction, and projections that are provided in a plurality of tiers in the axial direction, the projections being provided on the plurality of split pieces and projecting in the radial direction; the other one of the inner joint pipe and the outer joint pipe
25 includes a cylindrical portion that is not split and recesses that are provided in a plurality of tiers in the axial direction, the recesses being provided on the cylindrical portion, and becoming engaged with the projections, respectively; the steel pipes are joined by
30 inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, respectively, while bending the split cylindrical portion in the radial direction; the plurality of tiers of

projections are formed such that axial widths gradually become smaller from a projection on a tip-end side toward a projection on a base-end side; the plurality of tiers of recesses are formed such that axial widths gradually become
5 smaller from a recess on a base-end side toward a recess on a tip-end side; and the axial width of each of the projections is formed so as to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection
10 is to be engaged when the joints are fitted.

[0072] <Invention 2 of Manufacturing Method>

A method of manufacturing a multi-tiered socket joint that includes a cylindrical inner joint pipe and cylindrical outer joint pipe that are attached to ends of
15 steel pipes to be joined, respectively, in which one of the inner joint pipe and the outer joint pipe includes a split cylindrical portion having a plurality of split pieces that are split in the circumferential direction, and recesses that are provided in a plurality of tiers in the axial
20 direction, the recesses being provided on the plurality of split pieces, and projections that are provided in a plurality of tiers in the axial direction, the projections being provided on the cylindrical portion, projecting in the radial direction, and becoming engaged with the
25 recesses, respectively, and the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, respectively, while bending the split cylindrical portion in the radial direction, the plurality of tiers of
30 projections are formed such that axial widths gradually become smaller from a projection on a tip-end side toward a projection on a base-end side, and the plurality of tiers of recesses are set such that axial widths gradually become

smaller from a recess on a base-end side toward a recess on a tip-end side, and the axial width of each of the projections is set so as to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

[0073] <Invention 3 of Manufacturing Method>

The method of manufacturing a multi-tiered socket joint as described in Invention 1 or 2 of the manufacturing method, wherein the plurality of projections and the plurality of respective recesses are formed in such a manner that axial clearances formed between the projections and the respective recesses that are engaged with each other are same across all engaged portions in a state in which the joints are fitted.

Industrial Applicability

[0074] The invention is suitable for joining steel pipes.

Reference Signs List

[0075] 1 multi-tiered socket joint (first embodiment)
 3 inner joint pipe
 3a pipe axis
 5 outer joint pipe
 5a pipe axis
 7 steel pipe
 9 split pieces
 11 split cylindrical portion
 13 projection
 131 first-tier projection
 132 second-tier projection
 15 bolt hole (inner joint pipe)
 17 cylindrical portion
 19 recess

- 191 first-tier recess
- 192 second-tier recess
- 21 bolt hole (outer joint pipe)
- 23 engaged portion
- 5 25 multi-tiered socket joint (second embodiment)
- 27 multi-tiered socket joint (conventional example)

CLAIMS

1. A multi-tiered socket joint comprising:
 - a cylindrical inner joint pipe; and
 - a cylindrical outer joint pipe, the inner joint and
- 5 the outer joint being attached to ends of steel pipes to be joined, respectively, wherein
 - one of the inner joint pipe and the outer joint pipe includes
 - a split cylindrical portion including a plurality
 - 10 of split pieces that are split in a circumferential direction, and
 - a plurality of tiers of projections arranged in an axial direction on the plurality of split pieces, the projections being configured to project in a radial
 - 15 direction and each of the projections having a rectangular cross section,
 - another one of the inner joint pipe and the outer joint pipe includes
 - a cylindrical portion that is not split, and
 - 20 a plurality of tiers of recesses arranged in the axial direction on the cylindrical portion, the recesses being configured to engage with the projections and each of the recesses having a rectangular cross section,
 - the steel pipes are joined by inserting the inner
 - 25 joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction,
 - the plurality of tiers of projections have axial widths gradually becoming smaller from a tip-end side
 - 30 toward a base-end side,
 - the plurality of tiers of recesses have axial widths gradually becoming smaller from a base-end side toward a tip-end side, and

the axial width of each of the projections is set so as to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

2. A multi-tiered socket joint comprising:
- a cylindrical inner joint pipe; and
 - a cylindrical outer joint pipe, the inner joint pipe and the outer joint pipe being attached to ends of steel pipes to be joined, respectively, wherein
- one of the inner joint pipe and the outer joint pipe includes
- a split cylindrical portion including a plurality of split pieces that are split in a circumferential direction, and
 - a plurality of tiers of recesses arranged in an axial direction on the plurality of split pieces, each of the recesses having a rectangular cross section
- another one of the inner joint pipe and the outer joint pipe includes
- a cylindrical portion that is not split, and
 - a plurality of tiers of projections arranged in the axial direction on the cylindrical portion, the projections being configured to project in a radial direction, and engage with the recesses and each of the projections having a rectangular cross section,
- the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction,
- the plurality of tiers of projections have axial widths gradually becoming smaller from a projection on a

tip-end side toward a projection on a base-end side,

the plurality of tiers of recesses have axial widths gradually becoming smaller from a recess on a base-end side toward a recess on a tip-end side, and

5 the axial width of each of the projections is set so as to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

10

3. The multi-tiered socket joint according to claim 1 or 2, wherein axial clearances formed between the projections and the respective recesses that are engaged with each other are same across all engaged portions in a state in
15 which the joints are fitted.

4. The multi-tiered socket joint according to any one of claims 1 to 3, wherein a projection height of the plurality of tiers of projections is set equal to or smaller than a
20 projection height of the projection that is nearest to the tip-end side, and a projection height of at least one of the plurality of tiers of projections is set smaller than of that of the projection that is nearest to the tip-end side.

25

5. The multi-tiered socket joint according to claim 4, wherein the plurality of tiers of projections have projection heights gradually becoming smaller from a projection on the tip-end side toward a projection on the
30 base-end side.

6. A steel pipe with a joint comprising any one or both ends provided with any one or both of the inner joint pipe

and the outer joint pipe included in the multi-tiered socket joint according to any one of claims 1 to 5.

7. A structure comprising a plurality of steel pipes
5 connected by a multi-tiered socket joint according to any one of claims 1 to 5.

8. A method of installing the structure according to claim 7, comprising:

10 restraining an axial position of one of a steel pipe with the outer joint pipe being attached to an end and a steel pipe with the inner joint pipe being attached to an end;

 aligning an axial position of another one of the steel
15 pipe with the one of the steel pipes;

 inserting the other one of the steel pipes into the one of the steel pipes to fit the other one of the steel pipes with the one of the steel pipes.

20 9. A method of designing a multi-tiered socket joint including a cylindrical inner joint pipe; and a cylindrical outer joint pipe, the inner joint and the outer joint being attached to ends of steel pipes to be joined, respectively, wherein one of the inner joint pipe and the outer joint
25 pipe includes a split cylindrical portion including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of projections arranged in an axial direction on the plurality of split pieces, the projections being configured to
30 project in a radial direction and each of the projections having a rectangular cross section, another one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and a plurality of

tiers of recesses arranged in the axial direction on the cylindrical portion, the recesses being configured to engage with the projections and each of the recesses having a rectangular cross section, and the steel pipes are joined
5 by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction, the method comprising:

10 setting the plurality of tiers of projections to have axial widths gradually becoming smaller from a projection on a tip-end side toward a projection on a base-end side;

 setting the plurality of tiers of recesses to have axial widths gradually becoming smaller from a recess on a base-end side toward a recess on a tip-end side; and

15 setting the axial width of each of the projections to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

20

10. A method of designing a multi-tiered socket joint including: a cylindrical inner joint pipe; and a cylindrical outer joint pipe, the inner joint pipe and the outer joint pipe being attached to ends of steel pipes to
25 be joined, respectively, wherein one of the inner joint pipe and the outer joint pipe includes a split cylindrical portion including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of recesses arranged in an axial direction on the
30 plurality of split pieces, each of the recesses having a rectangular cross section another one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and a plurality of tiers of

projections arranged in the axial direction on the cylindrical portion, the projections being configured to project in a radial direction, and engage with the recesses and each of the projections having a rectangular cross section, and the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction, the method comprising:

10 setting the plurality of tiers of projections such that that axial widths gradually become smaller from a projection on a tip-end side toward a projection on a base-end side;

15 setting the plurality of tiers of recesses such that axial widths gradually become smaller from a recess on a base-end side toward a recess on a tip-end side; and

20 setting the axial width of each of the projections to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

11. The method for designing a multi-tiered socket joint according to claim 9 or 10, wherein the axial widths of the plurality of projections and the plurality of respective recesses are set in such a manner that axial clearances formed between the projections and the respective recesses that are engaged with each other are same across all engaged portions in a state in which the joints are fitted.

30

12. A method of manufacturing a multi-tiered socket joint including a cylindrical inner joint pipe; and a cylindrical outer joint pipe, the inner joint and the outer joint being

attached to ends of steel pipes to be joined, respectively, wherein one of the inner joint pipe and the outer joint pipe includes a split cylindrical portion including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of projections arranged in an axial direction on the plurality of split pieces, the projections being configured to project in a radial direction and each of the projections having a rectangular cross section, another one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and a plurality of tiers of recesses arranged in the axial direction on the cylindrical portion, the recesses being configured to engage with the projections and each of the recesses having a rectangular cross section, and the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical portion in the radial direction, the method comprising:

forming the plurality of tiers of projections such that axial widths gradually become smaller from a projection on a tip-end side toward a projection on a base-end side;

forming the plurality of tiers of recesses such that axial widths gradually become smaller from a recess on a base-end side toward a recess on a tip-end side; and

forming the axial width of each of the projections so as to have a size equal to or larger than an axial width of a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

13. A method of manufacturing a multi-tiered socket joint

including a cylindrical inner joint pipe; and a cylindrical outer joint pipe, the inner joint pipe and the outer joint pipe being attached to ends of steel pipes to be joined, respectively, wherein one of the inner joint pipe and the

5 outer joint pipe includes a split cylindrical portion including a plurality of split pieces that are split in a circumferential direction, and a plurality of tiers of recesses arranged in an axial direction on the plurality of split pieces, each of the recesses having a rectangular

10 cross section, another one of the inner joint pipe and the outer joint pipe includes a cylindrical portion that is not split, and a plurality of tiers of projections arranged in the axial direction on the cylindrical portion, the projections being configured to project in a radial

15 direction, and engage with the recesses and each of the projections having a rectangular cross section, and the steel pipes are joined by inserting the inner joint pipe into the outer joint pipe and by engaging the projections with the recesses, while bending the split cylindrical

20 portion in the radial direction, the method comprising:

forming the plurality of tiers of projections such that axial widths gradually become smaller from a projection on a tip-end side toward a projection on a base-end side;

25 forming the plurality of tiers of recesses such that axial widths gradually become smaller from a recess on a base-end side toward a recess on a tip-end side; and

forming the axial width of each of the projections so as to have a size equal to or larger than an axial width of

30 a recess that is on the tip-end side with respect to a recess with which the projection is to be engaged when the joints are fitted.

14. The method of manufacturing a multi-tiered socket joint according to claim 12 or 13, wherein the plurality of projections and the plurality of respective recesses are formed in such a manner that axial clearances formed
5 between the projections and the respective recesses that are engaged with each other are same across all of engaged portions in a state in which the joints are fitted.