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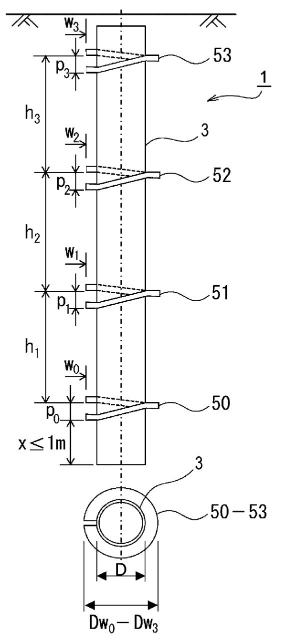
(54) **STEEL PIPE PILE**

(57) An object is to provide a steel pipe pile having multiple steps of blades and capable of most effectively exerting a supporting force. Another object is to provide a steel pipe pile that has blades with optimum thicknesses and/or fixture strengths and that can be manufactured with reduced costs.

An open-end steel pipe pile 1 includes a pile body 3 composed of a steel pipe with an outer diameter of ϕ800 mm or less and a plurality steps of blades 5 fixed by welding to the pile body 3 to project from an outer periphery of the pile body 3, and a relationship of $10 \leq h_k/w_k \leq 30$ (where k is an integer of 1 or more) is satisfied, where k is an integer of 1 or more, w_k is a projecting length of a (k+1)th blade of the plurality steps of blades counted from bottom, and h_k is an interval between the (k+1)th blade and another one of the plurality steps of blades that is downwardly adjacent to the (k+1)th.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to steel pipe piles that are installed by being rotated into the ground, and more particularly to a steel pipe pile including a steel pipe having an outer diameter of ϕ800 mm or less and a plurality steps of blades having the same diameter that are fixed by welding to the steel pipe such that the blades project from an outer periphery of the steel pipe and are arranged at a certain pitch.

Background Art

[0002] Many steel pipe piles that have spiral blades attached to an end or a peripheral surface thereof and that are rotationally inserted into the ground to exert a supporting force have been developed.

[0003] A steel pipe pile that focuses on exerting a large supporting force at an end portion thereof is structured such that one or a pair of blades are attached mainly at the end thereof. Examples of such a steel pipe pile are disclosed in Patent Literatures 1 and 2.

[0004] In areas where earthquakes are common, it is considered important that the piles exert a large supporting force at the end thereof, and most piles are installed to extend to a hard support layer. Such piles that are commonly used have diameters ranging from small diameters to large diameters (more than ϕ1000 mm).

[0005] The piles need to extend to the hard support layer to exert a sufficient supporting force at the end thereof. Therefore, the length of the piles is increased when the support layer is deep in the ground, and the costs are increased accordingly.

[0006] Therefore, in areas where earthquakes are less common, where the required supporting force is not high, and where the hard support layer is deep in the ground, the steel pipe pile designed to exert a large supporting force at the end thereof is not always suitable.

[0007] An example of a steel pipe pile suitable in such an area is a steel pipe pile that focuses more on a supporting force based on skin friction than on the supporting force at the end.

[0008] The steel pipe pile that focuses on the skin friction may have a short length because it does not need to extend to the hard support layer, but is not capable of exerting a large supporting force alone. Accordingly, steel pipe piles of this type are used for small-scale construction and commonly have diameters ranging from small diameters to intermediate diameters (up to about ϕ800 mm).

[0009] Patent Literature 3 discloses an example of such a steel pipe pile. This steel pipe pile is a small-diameter steel pipe pile including a steel pipe having an outer diameter of 100 to 200 mm and a pipe wall thickness of 3.2 to 6.0 mm; a plurality of spiral blades of one or two turns having an outer diameter of 1.5 to 2.5 times the outer diameter of the steel pipe, the spiral blades being non-continuously welded to an outer surface of the steel pipe with intervals of 1 to 3 m therebetween; a trapezoidal plate-shaped support piece that projects from the center of an end portion of the steel pipe and narrows downward; and a plurality of plate-shaped drilling assisting pieces having a bit function that are attached to the outer periphery of the end portion of the steel pipe at an angle in accordance with a rotational drilling direction.

Citation List

Patent Literature

[0010]

PTL 1: Japanese Unexamined Patent Application Publication No. 9-324419
PTL 2: Japanese Unexamined Patent Application Publication No. 2009-209674
PTL 3: Japanese Unexamined Patent Application Publication No. 1-142122

Summary of Invention

Technical Problem

[0011] According to the "small-diameter steel pipe pile" disclosed in Patent Literature 3, the reason why the intervals between the spiral blades are set to 1 to 3 m (reason 1) and the reason why the outer diameter of the spiral blades is set to 1.5 to 2.5 times the outer diameter of the steel pipe (reason 2) are as follows.

<Regarding Reason 1>

[0012] According to Patent Literature 3, it is assumed that the small-diameter steel pipe pile includes the steel pipe having an outer diameter of 100 to 200 mm and a pipe wall thickness of 3.2 to 6.0 mm. The reason why the intervals between the multiple steps of spiral blades are set is that when the intervals are 3 m or more, the limit load is reduced and the rotational torque is increased. When the intervals are less than 1 m, spaces between the spiral blades that are vertically adjacent to each other are clogged with soil. The soil is agglomerated and cannot be moved upward. Accordingly, the propulsive force is reduced, and the insertion performance is degraded (see page 2, column 4, line 15 to page 3, column 5, line 5 of Patent Literature 3).

<Regarding Reason 2>

[0013] Assuming that the outer diameter of the spiral blades is 1.5 to 2.5 times the outer diameter of the steel pipe, the bearing capacity of the small-diameter steel pipe pile is considered to be determined by the sum of the supporting pressure of the soil in accordance with the area of the spiral blades and the shear force between the main body of the steel pipe and the surrounding soil that adheres to the main body of the steel pipe. The reason why the outer diameter is set in the above-described range is that when the outer diameter of the spiral blades is too large or too small, the rotational torque is increased and the pipe wall thickness needs to be increased (see page 3, column 5, line 6 to page 3, column 5, line 24 of Patent Literature 3).
[0014] As described above, according to Patent Literature 3, the intervals and the blade diameter of the spiral blades are individually designed, and values thereof are determined mainly in consideration of workability.
[0015] However, even for the steel pipe pile with multiple steps of blades that does not need to extend to the hard support layer, it is important to provide a large supporting force. This has not been studied in the related art.
[0016] In addition, Patent Literature 3 does not describe any specific method for attaching the spiral blades. When multiple steps of blades are provided, all blades are generally similarly attached by welding to facilitate manufacture.
[0017] However, an increase in the number of blades leads to an increase in, for example, the costs for attaching the blades.
[0018] The present invention has been made to solve the above-described problems, and an object of the present invention is to provide a steel pipe pile having multiple steps of blades and capable of most effectively exerting a supporting force.
[0019] Another object is to provide a steel pipe pile that has blades with optimum thicknesses and/or fixture strengths and that can be manufactured with reduced costs.

Solution to Problem

[0020] In general, the supporting force of a steel pipe pile having multiple steps of blades is provided by skin friction and supporting pressure provided by each blade. The skin friction is large when the intervals between the blades are small, and its maximum is skin friction corresponding to a cylindrical peripheral surface having a diameter equal to the outer diameter of the blades. The skin friction is small when the intervals between the blades are large, and its minimum is skin friction corresponding to a cylindrical peripheral surface having a diameter equal to the diameter of the pile body.
[0021] The supporting pressure is low when the intervals between the blades are small, and is high when the intervals between the blades are large.
[0022] Studies conducted by the inventors in this regard have shown that by setting the intervals between the multiple steps of blades and a projecting length of the blades to be in a certain relationship, the balance between the skin friction and the supporting pressure can be improved and, as a result, the supporting force of the steel pipe pile can be increased.
[0023] The present invention is based on the above-described findings and has the features described below.
[0024] A steel pipe pile may have a closed end or an open end irrespective of whether the steel pipe pile focuses more on the skin friction or on the supporting force at the end.
[0025] The closed end is advantageous in that a large supporting force is provided by the end portion and that the supporting force is increased because an amount of soil equal to the volume of the pile is compressed into the surrounding ground to increase the density of the ground. However, the closed end is disadvantageous in that the workability is reduced and a large machine is required.
[0026] Therefore, whether to select the closed end or the open end is determined in consideration of the balance between the supporting force and workability. In the present invention, the open end is selected.

(1) An open-ended steel pipe pile comprising a pile body composed of a steel pipe with an outer diameter of ϕ800 mm or less and a plurality steps of blades fixed by welding to the pile body to project from an outer periphery of the pile body, wherein a relationship of $10 \leq h_k/w_k \leq 30$ is satisfied, where k is an integer of 1 or more, w_k is a projecting

length of a $(k+1)^{th}$ blade of the plurality steps of blades counted from bottom, and h_k is an interval between the $(k+1)^{th}$ blade and another one of the plurality steps of blades that is downwardly adjacent to the $(k+1)^{th}$.
(2) The steel pipe pile according to (1), wherein an fixture strength of a lowermost one of the plurality steps of blades is greater than an fixture strength of the rest of the plurality steps of blades.
(3) The steel pipe pile according to (1) or (2), wherein a thickness of a lowermost one of the plurality steps of blades is greater than a thickness of the rest of the plurality steps of blades.
(4) The steel pipe pile according to any one of (1) to (3), wherein a projecting length of a lowermost one of the plurality steps of blades is longer than a projecting length of the rest of the plurality steps of blades.

Advantageous Effects of Invention

[0027] According to the present invention, the projecting length w_k of each blade of the plurality steps of blades other than the lowermost blade and the interval h_k between that blade and another one of the plurality steps of blades that is downwardly adjacent thereto satisfy $10 \leq h_k/w_k \leq 30$ (where k is an integer of 1 or more). Accordingly, the steel pipe pile having multiple steps of blades is capable of most effectively exerting the supporting force.
[0028] In addition, according to the present invention, the fixture strength or the thickness of only the lowermost blade is increased. In other words, the fixture strengths or the thicknesses of the rest of the plurality steps of blades is reduced. In such a case, the costs of the blades can be reduced without affecting the supporting force and the workability.

Brief Description of Drawings

[0029]

[Fig. 1] Fig. 1 illustrates a steel pipe pile according to an embodiment of the present invention.
[Fig. 2] Fig. 2 is a graph showing the cross-sectional area and the circumference of the pile with respect to the pile diameter.
[Fig. 3] Fig. 3 illustrates a steel pipe pile according to another embodiment of the present invention (No. 1).
[Fig. 4] Fig. 4 illustrates a steel pipe pile according to another embodiment of the present invention (No. 2).
[Fig. 5] Fig. 5 illustrates a steel pipe pile according to another embodiment of the present invention (No. 3).
[Fig. 6] Fig. 6 is a graph showing the test results of Example 1.
[Fig. 7] Fig. 7 is a graph showing the test results of

Example 2.

Description of Embodiments

[0030] A steel pipe pile according to an embodiment of the present invention will now be described with reference to the drawings.
[0031] As illustrated in Fig. 1, a steel pipe pile 1 according to the present embodiment is an open-end steel pipe pile including a pile body 3 formed of a steel pipe having an outer diameter D of ϕ800 mm or less and a plurality steps of blades 50 to 53 fixed by welding to the pile body 3 so as to project from an outer periphery of the pile body 3. The blades 50 to 53 respectively have projecting lengths w_0 to w_3. When the intervals from the second to fourth blades 51 to 53 among the blades 50 to 53 counted from bottom to the blades 50 to 52 downwardly adjacent to the second to fourth blades 51 to 53 are h_1 to h_3, $10 \leq h_k/w_k \leq 30$ (where k = 1, 2, and 3) is satisfied.
[0032] The constituent features will now be described.

<Steel Pipe>

[0033] It is assumed that the steel pipe has an outer diameter of ϕ100 mm to ϕ800 mm, which is a general outer diameter of a friction pile.
[0034] The reason why the lower limit of the outer diameter of the steel pipe is ϕ100 mm is that if the outer diameter is less than 100 mm, even when the blade diameter is as large as 2.5 times the outer diameter of the steel pipe, the projecting length of the blade 50 is 75 mm or less and it is difficult to attach the blade 50.
[0035] The reason why the upper limit of the outer diameter of the steel pipe is ϕ800 mm is as follows.
[0036] When the pile diameter increases, the cross-sectional area of the pile increases in proportion to the square of the diameter. Therefore, the allowable vertical axial force of the pile also increases in proportion to the square of the diameter. The skin friction of the pile is proportional to the pile diameter. Therefore, as the pile diameter increases, the difference between the skin friction and the allowable axial force of the pile increases. This will be further described with

reference to the graph of Fig. 2.

[0037] Fig. 2 is a graph showing the cross-sectional area and the circumference of the pile with respect to the pile diameter. The horizontal axis represents the pile diameter (mm). The left vertical axis represents the cross-sectional area (mm^2) of the pile, and the right vertical axis represents the circumference (mm) of the pile. To calculate the cross-sectional area of the pile, it is assumed that the wall thickness is 1.3% of the pile diameter and that the minimum wall thickness is 9 mm. More specifically, it is assumed that the wall thickness is 9 mm when the pile diameter is ϕ600 or less, and is 1.3% of the pile diameter when the pile diameter is ϕ700 or more.

[0038] Referring to Fig. 2, as the pile diameter is increased beyond ϕ800 mm, the curves of the cross-sectional area and the circumference start to deviate from each other, which means that it is not economically reasonable.

<Blades>

[0039] In the present embodiment, as illustrated in Fig. 1, the blades 50 to 53 that project from the outer peripheral surface of the pile body 3 by the projecting lengths w_0 to w_3 are fixed with the intervals of h_1 to h_3 therebetween. The projecting lengths w_0 to w_3 of the blades 50 to 53 are all equal to each other ($w_0 = w_1 = w_2 = w_3$), and the intervals h_1 to h_3 between the blades 50 to 53 are also equal to each other ($h_1 = h_2 = h_3$).

[0040] The blades 50 to 53 illustrated in Fig. 1 are spiral blades, and are shaped such that one revolution of the blades 50 to 53 causes an upward displacement corresponding to one pitch (p_0 to p_3) thereof. In the present embodiment, the blades 50 to 53 all have the same shape and the same pitch ($p_0 = p_1 = p_2 = p_3$).

[0041] The shapes of the blades 50 to 53 are not limited to this. For example, as illustrated in Fig. 3, the blades 50 to 53 may instead be arranged such that bottom end portions thereof are at different positions in the circumferential direction of the pile body 3. In the example illustrated in Fig. 3, the positions of the bottom ends of the blades 50 to 53 are shifted from each other by 180°. This is preferred because the linearity of movement during installation can be increased.

[0042] It is not necessary that the pitches p_0 to p_3 of the blades 50 to 53 be equal to each other. However, when the pitches p_0 to p_3 of the blades 50 to 53 are equal to each other, the following advantages can be obtained.

[0043] During installation of the steel pipe pile 1 having the multiple steps of blades 50 to 53, the pile is rotated so that a large propulsive force is generated at the lowermost blade 50. This force serves to insert the pile into the ground.

[0044] As the pile is rotationally inserted, the blades 51 to 53 other than the lowermost blade 50 are also inserted into the ground. When the pitches of the blades 51 to 53 other than the lowermost blade 50 are equal to the pitch of the lowermost blade 50, the lowermost blade 50 and the other blades 51 to 53 can be inserted at the same rate per revolution. Accordingly, as the lowermost blade 50 is inserted, the blades 51 to 53 other than the lowermost blade 50 can also be smoothly inserted into the ground, and disturbance of the ground does not occur.

[0045] It is generally known that disturbance of the ground leads to a large reduction in the supporting force of the pile. When the blades 50 to 53 all have the same pitch, the steel pipe pile 1 having the multiple steps of blades can be inserted into the ground without causing disturbance of the ground. Therefore, a large supporting force can be exerted.

[0046] The number of blades 50 to 53 is not particularly limited as long as a plurality steps of blades are provided. For example, in the example illustrated in Fig. 1, the four blades 50 to 53 are attached over the entire length of the pile. Alternatively, however, as in the example illustrated in Fig. 4, the structure may instead be such that no blades are arranged on a portion to be disposed in a weak layer in which the expected skin friction is very small, and that two blades 50 and 51 are provided only on a portion to be disposed in a lower layer in which the expected skin friction is large.

[0047] Thus, it is not necessary that the blades be provided over the entire length of the pile body 3. In addition, it is also not necessary that the projecting lengths of the blades and the intervals between the blades be equal to each other. When the blades are provided only on a portion of the pile body 3 to be disposed in a ground layer in which the expected skin friction is large and when the projecting lengths of the blades and the intervals between the blades are set as appropriate, the manufacturing costs of the steel pipe pile 1 can be reduced.

[0048] Each blade is not limited to a spiral blade formed of a single steel plate. For example, as illustrated in Fig. 5, each blade may instead be a pseudo spiral blade obtained by attaching two flat plates 5a such that the flat plates 5a are inclined in opposite directions. The use of the flat plates 5a is preferred because it is not necessary to perform press forming on steel plates and the costs can be reduced.

[0049] With regard to blade diameters Dw_0 to Dw_3, as the sizes of the blades 50 to 53 are increased, the skin friction can be increased, but the workability is reduced and a larger machine is required. In addition, the force applied to the blades 50 to 53 is increased, and therefore the welding specifications of the blades 50 to 53 need to be changed and the thicknesses of the blades 50 to 53 need to be increased. As a result, the costs are significantly increased. Accordingly, preferably, the blade diameter Dw_0 of the lowermost blade 50 is 2.0 to 2.5 times the outer diameter D of the pile body 3, and the blade diameters Dw_1 to Dw_3 of the blades 51 to 53 other than the lowermost blade 50 are 2.0 times the outer diameter D of the pile body 3 or less.

[0050] With regard to the projecting lengths w_0 to w_3 of the blades 50 to 53, in the example illustrated in Fig. 1, the projecting lengths w_0 to w_3 of the blades 50 to 53 including the lowermost blade 50 are all set to the same length.

However, in the present invention, it is not necessary that the projecting lengths of the blades 50 to 53 all be set to the same length.

[0051] For example, the projecting length w_0 of the lowermost blade 50 may be longer than the projecting lengths w_1 to w_3 of the other blades 51 to 53. This is preferred in that the propulsive force of the steel pipe pile 1 can be increased and the workability can be improved. Alternatively, the projecting lengths of the blades to be disposed in a weak layer in the ground may be set to lengths shorter than the projecting lengths of other blades.

[0052] In addition, as described below, the lowermost blade 50 exerts a large supporting force. Therefore, the thickness of the lowermost blade 50 is preferably set to a thickness greater than those of the other blades 51 to 53. In other words, the thickness of the lowermost blade 50 may be set based on the relationship between the thickness and the supporting force to be exerted by the lowermost blade 50, and the thicknesses of the other blades 51 to 53 may be set to thicknesses less than that of the lowermost blade 50. Thus, the costs can be reduced.

[0053] In addition, to improve the insertion performance at the start of installation, the lowermost blade 50 is preferably attached at a position that is 1 m or less from the end of the pile body 3 and that is as close to the end of the pile as possible within a range in which welding can be appropriately performed. More specifically, a distance x from the end of the pile body 3 to the lowermost blade 50 is preferably as small as possible within the range of $x \leq 1$ m to ensure good workability of the steel pipe pile 1 (see Fig. 1).

<Relationship Between h and w>

[0054] The projecting lengths w_1 to w_3 of the blades 51 to 53 other than the lowermost blade 50 among the blades 50 to 53 and the intervals h_1 to h_3 from the blades 51 to 53 to the blades 50 to 52 that are downwardly adjacent to the blades 51 to 53 satisfy $10 \leq h_k/w_k \leq 30$ (k is an integer of 1 or more).

[0055] The reason for this will now be described.

[0056] The supporting force of the steel pipe pile 1 having the multiple steps of blades 50 to 53 is the sum of the skin friction and the supporting pressures of the blades 50 to 53. The skin friction increases as the area increases, and therefore increases as the circumference along which the skin friction is exerted increases. The supporting pressures of the blades 50 to 53 increase as the areas of the projecting portions of the blades 50 to 53 increase.

[0057] The supporting force (sum of the skin friction and the supporting pressures) obtained in a certain section of the steel pipe pile 1 will now be discussed. When the interval h_k between the blades is significantly large, for example, when $h_k/w_k > 30$, the surface area at which the skin friction is exerted is the surface area of the pile body 3. Although a high supporting pressure is provided by each blade, the total supporting pressure provided by all of the blades is not very high because the number of blades is small when the intervals between the blades is large.

[0058] When the interval h_k between the blades is significantly small, for example, when $h_k/w_k < 10$, the supporting pressures of the blades interfere with each other. Therefore, the supporting pressure is reduced, and the skin friction is also adversely affected. As a result, the total supporting force is significantly reduced.

[0059] As described above, the supporting force of the pile depends on the relationship between the intervals h_1 to h_3 between the blades 50 to 53 and the projecting lengths w_1 to w_3 of the blades. By setting h_k/w_k (where k = 1, 2, 3) to an appropriate value, the supporting force of the steel pipe pile 1 including the multiple steps of blades 50 to 53 can be increased.

[0060] Studies conducted by the inventors in this regard have shown that when h_k/w_k is in the range of $10 \leq h_k/w_k \leq 30$, the exerted supporting force is greater than a supporting force of a steel pipe pile including a pile body 3 with a diameter equal to the blade diameter and having no blades.

[0061] This is demonstrated in Example 1 described below.

<Method for Fixing Blades>

[0062] The blades 50 to 53 are attached to the pile body 3 by welding. The fixture strength of the lowermost blade 50 is preferably set to a strength greater than the fixture strengths of the other blades 51 to 53.

[0063] The reason for this will now be described.

[0064] When a plurality steps of blades 50 to 53 are attached, the lowermost blade 50 generally exerts a greater supporting force than those exerted by the other blades 51 to 53, although this also depends on hardness of the ground. This is because although the blades 51 to 53 above the lowermost blade 50 mainly exert the supporting force based on the ground around the peripheral surface of the pile, the lowermost blade 50 exerts the supporting force based on not only the ground around the pile but also the ground below the bottom end of the pile.

[0065] The fact that the supporting force exerted by the lowermost blade 50 is greater than those exerted by the other blades 51 to 53 is demonstrated in Example 2 described below.

[0066] During the installation, the lowermost blade 50 moves into the ground while drilling the ground, and then the other blades 51 to 53 are inserted into the ground that has already been drilled once. Therefore, the lowermost blade

50 also receives a large resistance during installation.

[0067] The above discussion shows that in a pile having multiple steps of blades, the lowermost blade 50 bears a large load both during installation and exertion of the supporting force, and the other blades 51 to 53 bear smaller loads.

[0068] Accordingly, the welding specifications and the blade thickness may be set in consideration of the supporting force and the bearing capacity during installation only for the lowermost blade 50, and the welding specifications for the other blades 51 to 53 may be set based on a smaller bearing capacity. Thus, the weight of the weld metal and the steel material can be reduced without affecting the workability and the supporting force, and the costs can be reduced.

[0069] The welding specifications for the lowermost blade 50 may be changed from those for the other blades 51 to 53 by, for example, performing double side fillet welding on the lowermost blade 50 while performing single side fillet welding on the other blades 51 to 53.

[0070] The welding method is basically fillet welding, and the fixture strength is generally controlled based on the leg length. Accordingly, the fixture strength of the lowermost blade 50 may be increased by setting the welding leg length for the lowermost blade 50 to a length longer than those for the other blades 51 to 53 by 20% or more.

[0071] Alternatively, the lowermost blade 50 may be fixed by full penetration welding while the other blades 51 to 53 are fixed by double side fillet welding, single side fillet welding, or a combination of double side fillet welding and single side fillet welding.

[0072] As described above, according to the present embodiment, the projecting lengths w_1 to w_3 of the blades 51 to 53 other than the lowermost blade 50 among the blades 50 to 53 and the intervals h_1 to h_3 from the blades 51 to 53 to the blades 50 to 52 that are downwardly adjacent to the blades 51 to 53 satisfy $10 \leq h_k/w_k \leq 30$ (where k = 1, 2, 3). Accordingly, the steel pipe pile 1 having multiple steps of blades most effectively exerts the supporting force.

[0073] In addition, in the present embodiment, the fixture strength or the thickness of only the lowermost blade 50 is increased. In other words, the fixture strengths or the thicknesses of the other blades 51 to 53 are reduced. Thus, the costs of the blades can be reduced without affecting the supporting force and the workability.

[0074] In addition, the projecting lengths w_1 to w_3 of the blades 51 to 53 other than the lowermost blade 50 are equal to each other. Therefore, the design of the supporting force and the manufacture of the steel pipe pile 1 can be simplified, and the costs can be reduced.

Example 1

[0075] To demonstrate the effects of the present invention, a soil-layer test for determining a supporting force was carried out by using reduced-scale models having the same ratios as those of a real pile. Test piles used as the reduced-scale models each included a steel pipe having a diameter of 76.3 mm and a wall thickness of 2.8 mm, and the N-value of the soil layer was 20. The test results under the conditions shown in Table 1 were compared with each other.

[Table 1]

	Number of Blades	h_k/w_k
Comparative Example 1	5	6.3
Comparative Example 2	4	8.4
Invention Example 1	3	12.6
Invention Example 1	2	25.2

[0076] Fig. 6 illustrates the test results.

[0077] In Fig. 6, the horizontal axis represents the ratio (h_k/w_k) between the distance h between the blades and the projecting length w of the blades, and the vertical axis represents a coefficient of skin friction β (kN/m^2).

[0078] In general, the coefficient of skin friction of a steel pipe pile with no blades is assumed to be 2 (kN/m^2) irrespective of the diameter of the steel pipe. For comparison with this, a value corresponding to the coefficient of skin friction was calculated for the piles having multiple steps of blades. More specifically, a load was applied to each reduced-scale model, and the supporting force was measured. Then, a value obtained by dividing the supporting force by the surface area of a cylinder having a diameter equal to the blade diameter and a length equal to the length of the pile was plotted in the graph as a coefficient of skin friction.

[0079] As illustrated in Fig. 6, the coefficients of skin friction for Comparative Examples 1 and 2 are less than 2 (kN/m^2). In contrast, the coefficients of skin friction for Invention Examples 1 and 2, in which h_k/w_k is within the range of the present invention, are greater than 2 (kN/m^2), and are significantly greater than those for Comparative Examples 1 and 2.

[0080] This demonstrates that according to Invention Examples 1 and 2, in which h_k/w_k is within the range of the present invention, the coefficient of skin friction can be increased, in other words, the supporting force can be increased.

[0081] A full-scale test was carried out to confirm that the data of the above-described model test corresponds to that of full-scale piles. In the full-scale test, the pile diameter was 318.5 mm, the blade diameter was 1.5 times the pile diameter, that is, 477.75 mm, the interval h between the blades was 1200 mm, the projecting length w of the blades was 79.625 mm, and h_k/w_k was 15.1. The result of the full-scale test is plotted with a white circle in Fig. 6. The coefficient of skin friction is 4.762 kN/m^2, which substantially matches the data of the model test. This demonstrates that the data of the above-described model test corresponds to that of full-scale piles.

Example 2

[0082] A test was performed to confirm that the lowermost blade 50 exerts a greater supporting force than those exerted by the other blades 51 to 53. The test will now be described.

[0083] Similarly to Example 1, the test was a soil-layer test for determining a supporting force by using a reduced-scale model having the same ratios as those of a real pile. The N-value of the soil layer was 20. A test pile used as the reduced-scale model included a steel pipe having a diameter of 76.3 mm and a wall thickness of 2.8 mm. The number of blades was 3, and h/w was 12.6.

[0084] Fig. 7 shows the test results.

[0085] The vertical axis of the graph of Fig. 7 represents the load-bearing ratio obtained assuming that the load borne by all of the blades 50 to 53 in response to a downward vertical displacement applied to the pile head is 1. The horizontal axis represents the displacement of the pile head normalized by the blade diameter. The graph shows the load-bearing ratio of the lowermost blade 50 and the total load-bearing ratio of two upper blades.

[0086] The load applied when the displacement is 10% of the blade diameter, which is the pile diameter, is generally defined as the limit load. Accordingly, referring to the load-bearing ratios of the blades 5 at the pile head displacement corresponding to the limit load (0.1), the load-bearing ratio is 0.65 for the lowermost blade 5 and 0.35 for the two upper blades.

[0087] Thus, the load-bearing ratio of the lowermost blade 50 is large. This demonstrates that it is reasonable to increase the fixture strength or the thickness of only the lowermost blade 50 as described above.

Reference Signs List

[0088]

1 steel pipe pile
3 pile body
50 to 53 blades
5a flat plate
w_0 to w_3 projecting lengths
h_1 to h_3 intervals to downwardly adjacent blades
p_0 to p_4 pitches
D outer diameter of pile body
Dw_0 to Dw_3 outer diameters of blades

Claims

1. An open-ended steel pipe pile comprising a pile body composed of a steel pipe with an outer diameter of ϕ800 mm or less and a plurality steps of blades fixed by welding to the pile body to project from an outer periphery of the pile body,

wherein a relationship of $10 \leq h_k/w_k \leq 30$ is satisfied,
where k is an integer of 1 or more,
w_k is a projecting length of a $(k+1)^{th}$ blade of the plurality steps of blades counted from bottom, and
h_k is an interval between the $(k+1)^{th}$ blade and another one of the plurality steps of blades that is downwardly adjacent to the $(k+1)^{th}$.

2. The steel pipe pile according to Claim 1, wherein an fixture strength of a lowermost one of the plurality steps of blades is greater than an fixture strength of the rest of the plurality steps of blades.

3. The steel pipe pile according to Claim 1 or 2, wherein a thickness of a lowermost one of the plurality steps of blades is greater than a thickness of the rest of the plurality steps of blades.

4. The steel pipe pile according to any one of Claims 1 to 3, wherein a projecting length of a lowermost one of the plurality steps of blades is longer than a projecting length of the rest of the plurality steps of blades.

FIG. 1

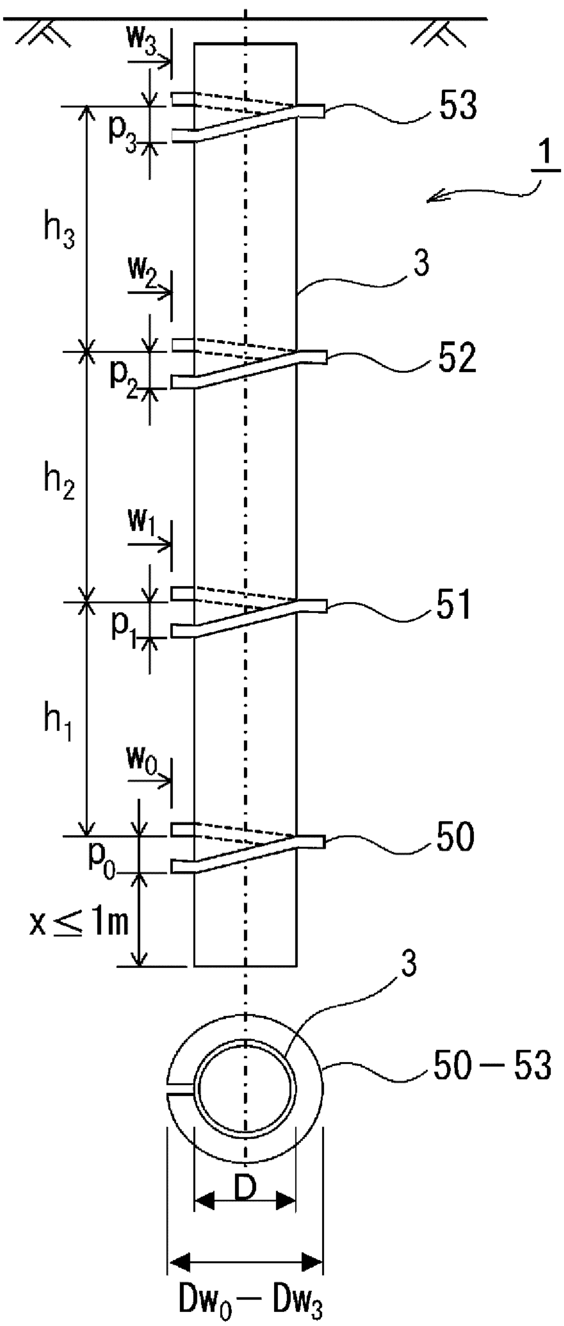
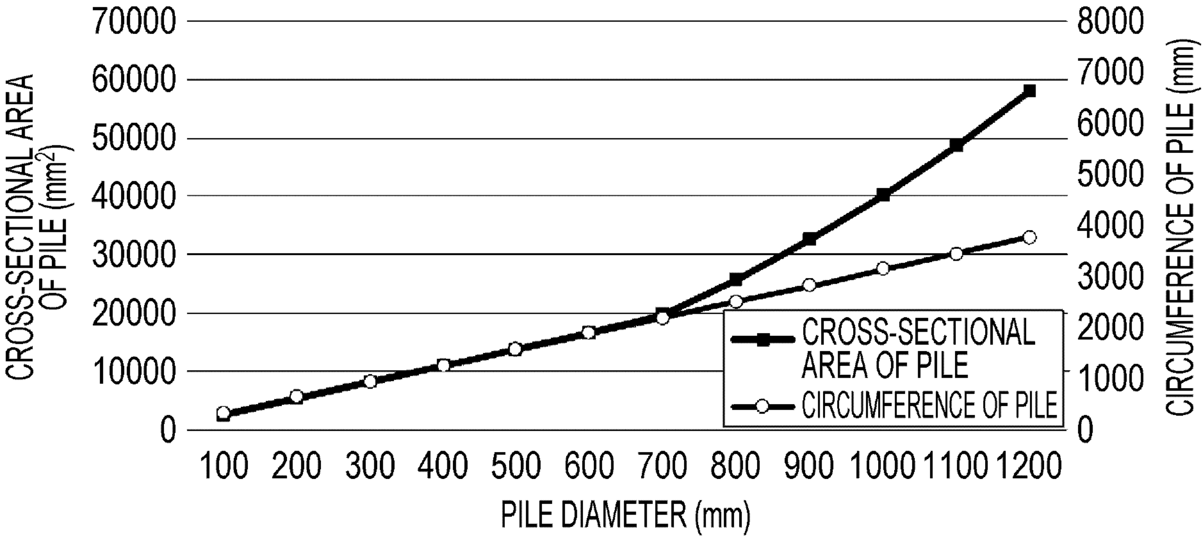
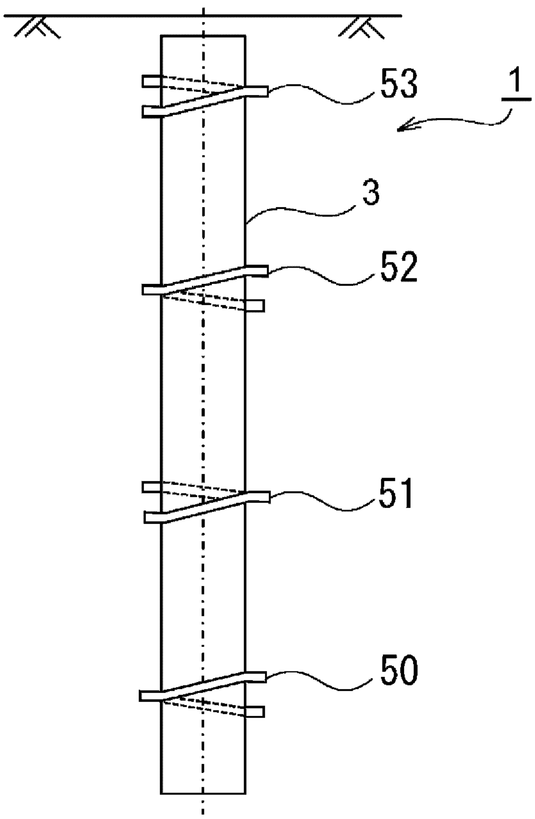


FIG. 2



CROSS-SECTIONAL AREA OF PILE (mm²)
70000
60000
50000
40000
30000
20000
10000
0
8000
7000
6000
5000
4000
3000
2000
1000
0
CIRCUMFERENCE OF PILE (mm)
CROSS-SECTIONAL AREA OF PILE
CIRCUMFERENCE OF PILE
100 200 300 400 500 600 700 800 900 1000 1100 1200
PILE DIAMETER (mm)

FIG. 3



53
1
3
52
51
50

FIG. 4

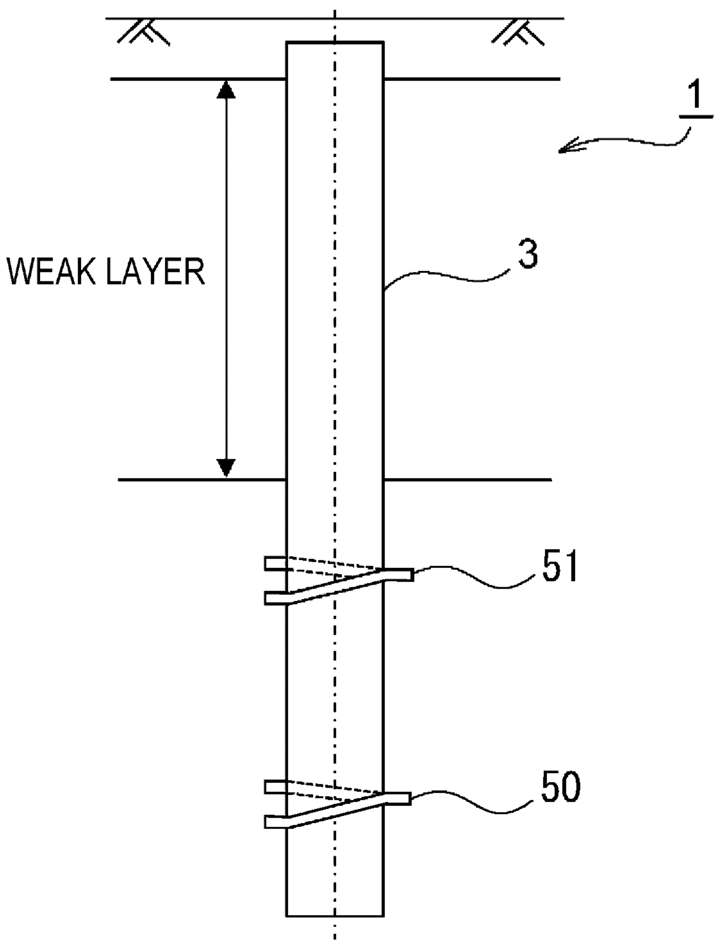


FIG. 5

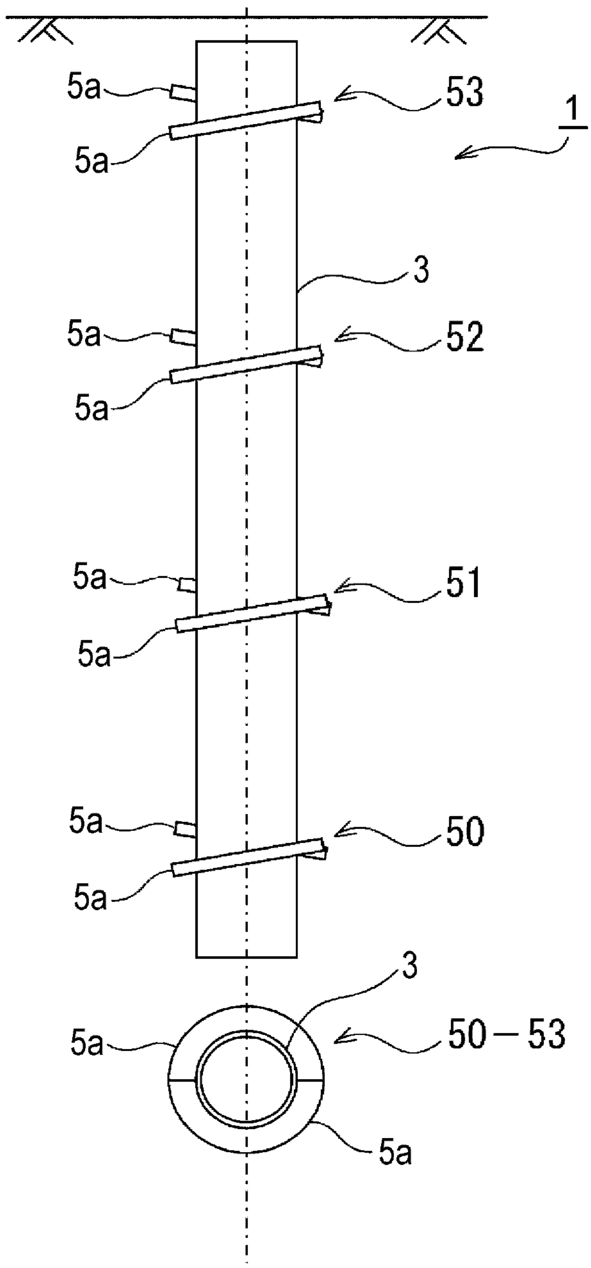
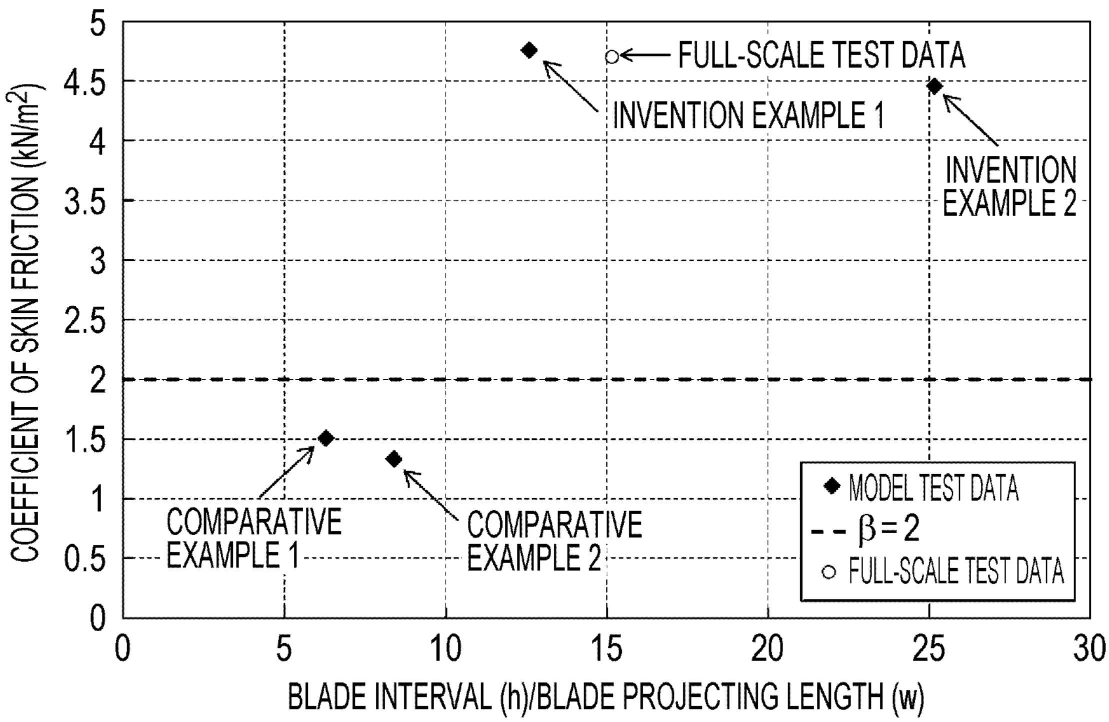
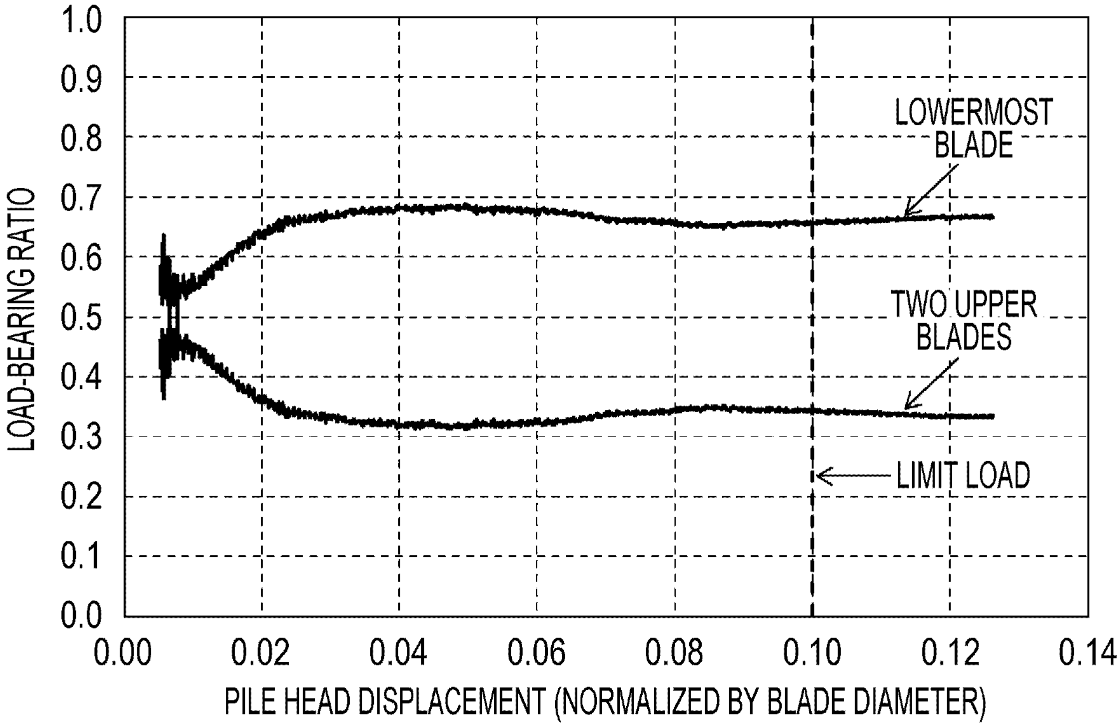


FIG. 6



COEFFICIENT OF SKIN FRICTION (kN/m2)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
BLADE INTERVAL (h)/BLADE PROJECTING LENGTH (w)
FULL-SCALE TEST DATA
INVENTION EXAMPLE 1
INVENTION EXAMPLE 2
COMPARATIVE EXAMPLE 1
COMPARATIVE EXAMPLE 2
MODEL TEST DATA
β=2
FULL-SCALE TEST DATA

FIG. 7



LOAD-BEARING RATIO
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
PILE HEAD DISPLACEMENT (NORMALIZED BY BLADE DIAMETER)
LOWERMOST BLADE
TWO UPPER BLADES
LIMIT LOAD

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/004344

A. CLASSIFICATION OF SUBJECT MATTER
E02D 5/28(2006.01)i; E02D 5/56(2006.01)i
FI: E02D5/28; E02D5/56
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
E02D5/28; E02D5/56

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2000-352048 A (KOKUDO KISO KK) 19 December 2000 (2000-12-19) paragraphs [0013]-[0015], fig. 1	1 2-4
Y	JP 1-142122 A (ASAHI KASEI INDUSTRY CO., LTD.) 05 June 1989 (1989-06-05) page 2, lower right column, line 17 to page 3, upper left column, line 15, fig. 1	1-4
Y	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 73954/1992 (Laid-open No. 34041/1994) (KOKUDO KISO KK) 06 May 1994 (1994-05-06) paragraph [0014], fig. 3-4	1-4
Y	JP 10-37182 A (NKK CORP.) 10 February 1998 (1998-02-10) paragraphs [0014]-[0020], [0026]-[0028], [0034], fig. 1, 7, 13-14	2-4

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 April 2021 (01.04.2021)	13 April 2021 (13.04.2021)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2021/004344

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2004-270440 A (MITANISEKISAN CO., LTD.) 30 September 2004 (2004-09-30) paragraphs [0030]-[0033], [0101], fig. 1-2	4
Y	JP 2014-122541 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 03 July 2014 (2014-07-03) paragraphs [0060]-[0061], fig. 11	4
A	JP 8-199568 A (NAKAMURA, Tamotsu) 06 August 1996 (1996-08-06) paragraph [0006], fig. 2	1-4
A	EP 2636797 A1 (KAPPAZETA S.P.A.) 11 September 2013 (2013-09-11) entire text all drawings	1-4
P, X P, A	JP 6749718 B1 (SANSEI INC.) 02 September 2020 (2020-09-02) paragraphs [0012]-[0015], fig. 1	1, 4 2-3

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/004344

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2000-352048 A	19 Dec. 2000	(Family: none)	
JP 1-142122 A	05 Jun. 1989	(Family: none)	
JP 6-34041 U1	06 May 1994	(Family: none)	
JP 10-37182 A	10 Feb. 1998	(Family: none)	
JP 2004-270440 A	30 Sep. 2004	(Family: none)	
JP 2014-122541 A	03 Jul. 2014	(Family: none)	
JP 8-199568 A	06 Aug. 1996	(Family: none)	
EP 2636797 A1	11 Sep. 2013	(Family: none)	
JP 6749718 B1	02 Sep. 2020	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 9324419 A **[0010]**
- JP 2009209674 A **[0010]**
- JP 1142122 A **[0010]**