



(11)

EP 4 049 764 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:

31.08.2022 Bulletin 2022/35

(21) Application number: **20880100.1**

(22) Date of filing: **14.10.2020**

(51) International Patent Classification (IPC):

B05D 1/02 ^(2006.01) **B05D 3/00** ^(2006.01)
B05D 7/00 ^(2006.01) **B21B 45/02** ^(2006.01)
C21D 1/00 ^(2006.01) **C21D 1/18** ^(2006.01)
C21D 1/667 ^(2006.01)

(52) Cooperative Patent Classification (CPC):

B05D 1/02; B05D 3/00; B05D 7/00; B21B 45/02;
C21D 1/00; C21D 1/18; C21D 1/667

(86) International application number:

PCT/JP2020/038820

(87) International publication number:

WO 2021/079806 (29.04.2021 Gazette 2021/17)

(84) Designated Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR

Designated Extension States:

BA ME

Designated Validation States:

KH MA MD TN

(30) Priority: **21.10.2019 JP 2019191869**

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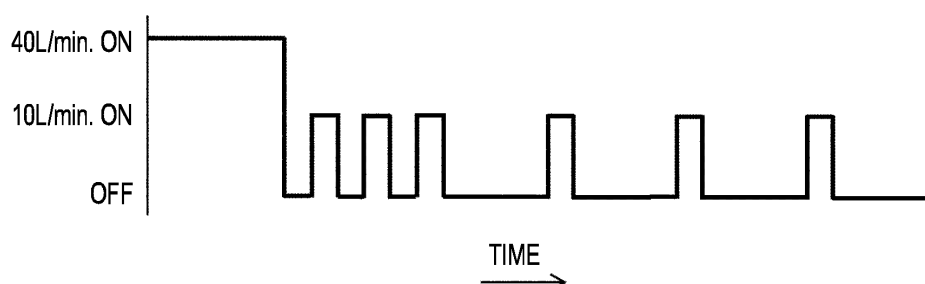
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(54) **COOLING METHOD AND COOLING DEVICE FOR MEMBER TO BE COOLED**

(57) The present invention relates to a method for cooling a member to be cooled by using a cooling device, the cooling device including: a plurality of spray nozzles, each of which sprays a droplet group onto a heated member to be cooled to cool the member to be cooled; a spray adjustment unit; and a control unit configured to control spray of droplets. The control unit sprays the droplet

group in a pulse shape and repeats pulse spray according to a set value, and controls the spray of the droplet group. The droplet group is repeatedly sprayed in the pulse shape onto the heated member to be cooled to cool the member to be cooled, and at least one of a magnitude of a pulse, a pulse width, and a pulse interval is changed over time.

FIG. 7



Description

TECHNICAL FIELD

[0001] The present invention relates to a method for cooling a member to be cooled, which cools the member to be cooled heated to a high temperature by spraying a droplet group, and a cooling device therefor.

BACKGROUND ART

[0002] Oil quenching of a steel material has a cooling characteristic in which a high temperature region that is a ferrite precipitation temperature region is rapidly cooled and a low temperature region in which martensitic transformation occurs is slowly cooled, and has an advantage in that quenching cracking can be prevented while quality of the steel material can be ensured. On the other hand, oil quenching has disadvantages such as a risk of fire and deterioration of a working environment due to oil smoke. Therefore, a cooling method instead of oil quenching has been studied, and a method by spray cooling has been proposed. Spray cooling is a method of cooling an object to be cooled by sensible heat and latent heat transfer using atomized droplet groups.

[0003] It has already been reported in many documents that cooling of an object to be cooled such as a steel material is controlled by increasing or decreasing a spray flow rate during spray cooling.

[0004] For example, in PTL 1, a spray flow rate can be adjusted by providing a plurality of spray nozzles and changing the number of spray nozzles used during cooling.

CITATION LIST

PATENT LITERATURE

[0005] PTL 1: JP-A-H6-322449

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0006] In oil quenching, a cooling state in which a cooling rate is changed at a boundary of about 500°C while a temperature decreases from 700°C to 400°C, that is, a cooling state in which a cooling rate of 50°C/min. or higher from 700°C to 500°C is changed to about 10°C/min. from 500°C to 400°C at a temperature at a position where a depth from a surface of a steel material 100 is 10 mm is obtained, and the same cooling state is required as a cooling method in place of the oil quenching even when spray of a droplet group is used. However, when it is attempted to obtain this state simply by reducing a spray flow rate of the spray from each nozzle, there is a problem that at a spray flow rate (L/m² · min.) per unit area (1m²) of smaller than a certain amount, the at-

omized droplet group is evaporated before reaching a high temperature surface of the steel material, and a cooling similar to air cooling is obtained, and characteristics of the oil quenching cannot be obtained.

[0007] The present invention has been made in view of the above circumstances, and an object thereof is to provide a method for cooling a member to be cooled, which enables a desired cooling state to be obtained by pulsing spray of a droplet group, and a cooling device therefor.

SOLUTION TO PROBLEM

[0008] That is, in a cooling method for cooling a heated member to be cooled of the present invention, a first aspect is a cooling method for cooling a heated member to be cooled by spraying a droplet group onto the member to be cooled, characterized by including:

performing pulse spray by spraying the droplet group in a pulse shape and repeating the pulse spray, and changing at least one of a magnitude of a pulse, a pulse width, and a pulse interval over time.

[0009] The invention of a method for cooling the member to be cooled according to a second aspect is, in the invention of the above aspect, characterized by including adjusting cooling performance over time in accordance with the change.

[0010] The invention of a method for cooling the member to be cooled according to a third aspect is, in the invention of the above aspect(s), characterized in that the adjusting of the cooling performance includes determining an average spray flow rate per unit area (1m²) of the droplet group per predetermined time.

[0011] The invention of a method for cooling the member to be cooled according to a fourth aspect is, in the invention of the above aspect(s), characterized by including setting the magnitude of the pulse to be equal to or larger than a spray flow rate per unit area (1m²) at which the droplet group can reach a surface of the member to be cooled.

[0012] The invention of a method for cooling the member to be cooled according to a fifth aspect is, in the invention of the above aspect(s), characterized by including at least an initial first step of maximizing the cooling performance, a second step of making the cooling performance relatively lower than that in the first step after the first step, and a third step of making the cooling performance relatively lower than that in the second step after the second step,

wherein in the first step, the magnitude of the pulse and the pulse width are set to a magnitude of a first pulse and a first pulse width that are relatively largest, in the second step, the magnitude of the pulse is set to a magnitude of a second pulse that is smaller than the magnitude of the first pulse, the pulse width is set to a second pulse width that is smaller than the first pulse width, and the pulse interval is set to a second pulse interval, and in the third step, the magnitude of the pulse and the pulse width are

set to a magnitude of a third pulse and a third pulse width that are equal to or smaller than the magnitude of the second pulse and equal to or smaller than the second pulse width, respectively, and the pulse interval is set to a third pulse interval that is equal to or larger than the second pulse interval.

[0013] The invention of a method for cooling the member to be cooled according to a sixth aspect is, in the invention of the above aspect(s), characterized by including spraying the droplet group by a single-fluid nozzle.

[0014] The invention of a method for cooling the member to be cooled according to a seventh aspect is, in the invention of the above aspect(s), characterized in that the member to be cooled is a steel material having a thickness of 200 mm or larger.

[0015] The invention of a method for cooling the member to be cooled according to an eighth aspect is, in the invention of the above aspect(s), characterized in that cooling by the droplet group obtains a cooling state equivalent to cooling by oil cooling.

[0016] In a cooling device for a member to be cooled of the present invention, a first aspect is characterized by including:

a plurality of spray nozzles, each of which sprays a droplet group onto a heated member to be cooled to cool the member to be cooled;

a spray adjustment unit configured to adjust a spray amount of the droplet group sprayed from the spray nozzle; and

a control unit configured to control spray of the droplet group from the spray nozzle, wherein the control unit is configured to perform pulse spray by spraying the droplet group in a pulse shape and repeat pulse spray according to a set value, and to control the spray of the droplet group by changing at least one of a magnitude of a pulse, a pulse width, and a pulse interval over time.

[0017] The invention of a cooling device for the member to be cooled according to a second aspect is, in the invention according to the above aspect, characterized in that the spray nozzle has a plurality of types.

[0018] The invention of a cooling device for the member to be cooled according to a third aspect is, in the invention according to the above aspect(s), characterized in that the spray adjustment unit is configured to switch a type of the spray nozzle to be used.

[0019] The invention of a cooling device for the member to be cooled according to a fourth aspect is, in the invention according to the above aspect(s), characterized in that the control unit is configured to measure a temperature of the member to be cooled that is being cooled and to adjust a spray flow rate of the droplet group based on the measurement result.

[0020] The invention of a cooling device for the member to be cooled according to a fifth aspect is, in the invention according to the above aspect(s), characterized

in that the spray nozzle is a single-fluid nozzle.

[0021] A magnitude of a pulse indicates a height of the pulse, and in the present application, indicates a spray flow rate of a droplet group. A pulse width indicates a width of the pulse, and in the present application, indicates time for spraying the droplet group. A pulse interval indicates an interval between pulses, and in the present application, indicates time from an end of spray to a start of the next spray.

ADVANTAGEOUS EFFECTS OF INVENTION

[0022] That is, according to the present invention, a member to be cooled can be cooled in a desired cooling state by using pulse spray of a droplet group.

For example, in quenching of a steel material, an average spray flow rate per unit area (1m^2) per certain time can be determined by freely determining pulse time and a pulse interval during cooling by pulse width modulation control.

[0023] Accordingly, for example, when a temperature at a position where a depth from a surface of the steel material 100 is 10 mm is 700°C to 500°C , cooling is performed by continuous spray at a relatively large spray flow rate per unit area (1m^2) at which a large number of droplet groups can reach a high temperature surface of the steel material.

[0024] In addition, when a temperature at the position where the depth from the surface of the steel material 100 is 10 mm is 500°C to 400°C , spray is performed at a relatively small spray flow rate, a relatively small pulse width, and a relatively large pulse interval such that a small amount of droplet groups reach the high temperature surface of the steel material as compared with when the temperature at the position where the depth from the surface of the steel material 100 is 10 mm is 700°C to 500°C , and a relatively small average spray flow rate per unit area (1m^2) is obtained.

[0025] As a result, both a relatively high cooling rate from 700°C to 500°C and a relatively low cooling rate from 500°C to 400°C , which are characteristics of oil quenching, can be obtained by continuous spray and pulse spray.

BRIEF DESCRIPTION OF DRAWINGS

[0026]

[FIG. 1] FIG. 1 is a front view of a cooling device according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a plan view of the cooling device according to the embodiment of the present invention.

[FIG. 3] FIG. 3 is a diagram showing a measured value and an analysis result of a cooling state in oil cooling.

[FIG. 4] FIG. 4 shows a heat transfer coefficient dur-

ing the oil cooling obtained by inverse FEM analysis calculation.

[FIG. 5] FIG. 5(a) is a diagram showing a temporal change in a spray flow rate per unit area when cooling is performed by continuous spray required for cooling a steel material, and FIG. 5(b) is a diagram showing a temporal change in a spray flow rate in an embodiment when cooling is performed by continuous spray required for cooling the steel material. [FIG. 6] FIG. 6 is a diagram showing a temperature change of the steel material when the steel material is cooled by continuous spray while changing only a spray flow rate of a droplet group in cooling of the steel material.

[FIG. 7] FIG. 7 is a diagram in which the spray flow rate of the droplet group is changed with time by pulse spray of the droplet group.

[FIG. 8] FIG. 8 is a diagram showing a temperature change when the steel material is cooled by a cooling method according to the present embodiment and a temperature change when the steel material is cooled by oil quenching.

DESCRIPTION OF EMBODIMENT

[0027] Hereinafter, an embodiment of a cooling device according to the present invention will be described with reference to FIGS. 1 and 2.

[0028] A cooling device 1 includes a plurality of (for example, 48) spray nozzles 2 arranged around a steel material 100, and the spray nozzles 2 are arranged in vertical rows at four positions around the steel material 100. The steel material corresponds to a member to be cooled according to the present invention. The member to be cooled may be a metal member other than a steel material, another non-metal member, or the like.

[0029] Arrangement positions of the spray nozzles are not limited to the above, and positions or the number can be changed as appropriate according to a type, a shape, and the like of the member to be cooled.

[0030] A pipe 3 is connected to the spray nozzle 2, and the pipe 3 is connected to a spray adjustment unit 4. A water source (not shown) is connected to the spray adjustment unit 4, and water that forms a droplet group is supplied to the spray adjustment unit 4. The water source may include a water tank or the like and supply water by pressurizing the water by a pressurizing unit, or may be connected to a tap water path and used as a water source, or may be pressurized via a pressurizing unit at this time. In this embodiment, water is used as a material of a droplet portion, but a liquid other than water may be used in the present invention.

[0031] A structure of the spray nozzle is not limited to a specific one as long as a desired droplet group can be obtained. The spray nozzle may include a plurality of types, and the spray adjustment unit can switch the type of the spray nozzle used during cooling.

[0032] A droplet desirably has an appropriate size, and

for example, a droplet diameter (diameter) of 100 μm or larger and 1500 μm or smaller is desirable. However, in the present invention, the size of the droplet is not limited to a specific size.

[0033] In this embodiment, a single-fluid nozzle is used as the spray nozzle 2. In the present invention, the spray nozzle is not limited to the single-fluid nozzle, and a two-fluid nozzle using air or the like can also be used. However, in the two-fluid nozzle, droplets spread over a wide range due to air blow, which may deteriorate a working environment and cause a problem in maintenance and management of peripheral facilities, and cost is increased in terms of capital investment. Therefore, in the present embodiment, the single-fluid nozzle is used as a desirable one.

[0034] In addition, in the present embodiment, the spray nozzles 2 are described as being connected to the same pipe 3, but a pipe may be used for each spray nozzle or for the spray nozzles of each specific group.

[0035] In addition, although the spray nozzle 2 has been described with the same reference numeral, the spray nozzle 2 may include different types of spray nozzles having different sizes, spray amounts, and the like of droplets. The spray nozzles of different types may have fixed installation positions, or the spray nozzles used during cooling may be switched between the same position and different positions so as to be used.

[0036] A control unit 5 is connected to the spray adjustment unit 4, and controls spray of the droplet group by the spray adjustment unit 4.

[0037] The spray adjustment unit 4 includes an on-off valve for turning ON/OFF the spray, a flow rate adjustment valve, and a flow meter (none of which are shown), and a measurement result of the flow meter is transmitted to the control unit 5. Further, a switching unit for switching the spray nozzle to which the water is supplied can be provided.

[0038] In the above configuration, pulse spray of the droplet group sprayed from the spray nozzle 2 can be performed by an operation of the on-off valve, and a pulse width and a pulse interval can be adjusted. In addition, a magnitude of a pulse can be adjusted by adjusting a flow rate of the flow rate adjustment valve.

[0039] Further, in a case where the switching unit is provided, the spray nozzle to be used can be changed by switching the pipe through which the water is supplied. The switching unit may be manually performed or may be performed under control of the control unit 5.

[0040] The control unit 5 includes a CPU, a program that operates on the CPU, a ROM that stores the program, a RAM that serves as a work area, and a storage unit that stores the program, operation parameters, and the like. In addition, an operation unit or the like that can set the magnitude of the pulse, the pulse width, the pulse interval, and the like over time may be provided. These parameters can be changed in the operation unit.

[0041] The control unit 5 can control on and off operations of the on-off valve, an opening degree of the flow

rate adjustment valve, a switching operation of the switching unit, and the like by controlling the spray adjustment unit 4.

[0042] A droplet group 10 sprayed from the spray nozzle 2 is sprayed onto the steel material 100 to cool the steel material 100.

[0043] Next, a cooling method using the cooling device 1 will be described.

[0044] First, the steel material 100 to be used for a test is prepared.

[0045] In this example, the steel material 100 is made of NiCrMo steel, has a columnar shape, and has a weight of 670 kg, a diameter of 300 mm, and a length of 1200 mm.

[0046] In the present invention, a size and the like of the member to be cooled serving as a target are not limited, but a steel material having a minimum weight of at least 100 kg or larger and a minimum dimension of at least a wall thickness (ϕ in a cylinder) of 200 mm or larger can be suitably used.

[0047] Next, based on a temperature measurement result during oil quenching from 860°C, a heat transfer coefficient during oil cooling is obtained from inverse calculation by finite element method (FEM) analysis. FIG. 3 shows the measured temperature change (exp.) and the temperature change (sim.) obtained by analysis, and FIG. 4 shows the obtained heat transfer coefficient. In FIG. 3, "D/4" represents a position where a depth from a surface is 1/4 of a diameter (D), "D/8" represents a position where a depth from the surface is 1/8 of the diameter (D), and "10 mm depth" represents a position where a depth from the surface is 10 mm. Further, a relationship between a flow rate of the droplet group and the heat transfer coefficient is obtained from literature values or the like, and FIG. 5(a) shows a result of obtaining a spray flow rate per unit area (1m^2) corresponding to the heat transfer coefficient during oil quenching for each temperature.

[0048] FIG. 5(a) is a diagram showing a temporal change in the spray flow rate per unit area when cooling is performed by continuous spray required for cooling the steel material. In order to obtain this state, it is necessary to adjust the spray flow rate, the pulse width, and the pulse interval according to a shape of the steel material, a spreading range of the droplet group, a positional relationship between a spray accuracy steel material and a cooling device, and the like, but FIG. 5(b) shows a result of calculating a spray flow rate in a case of spraying the steel material 100 having a surface area of approximately 1m^2 based on the flow rate per unit area shown in FIG. 5(a).

[0049] FIG. 6 shows a result of continuous spray of the droplet group onto the steel material heated to 800°C or higher under a condition in FIG. 5(b). In FIG. 6, a phenomenon in which a temperature decreases at a position at a depth of 10 mm from a surface of the steel material and once reaches about 500°C and then increases again is observed, and this indicates that there is a possibility

that the atomized droplet group is evaporated before reaching a high temperature surface of the steel material due to a temporal change in a steel material temperature and a spray condition. In FIG. 6, "D/8" represents a position where a depth from the surface is 1/8 of the diameter (D), and "10 mm dep." represents a position where a depth from the surface is 10 mm.

[0050] As described above, at a spray flow rate ($\text{L}/\text{m}^2 \cdot \text{min.}$) per unit area (1m^2) of smaller than a certain amount, the atomized droplet group is evaporated before reaching the high temperature surface of the steel material, and therefore the spray flow rate is increased in order to avoid this, and spray of the droplet group is pulsed so as to obtain an appropriate heat transfer coefficient.

[0051] Depending on a position and a shape of the steel material, when different spray flow rates are required at the same time, control of spray of each spray nozzle may be changed, or different types of spray nozzles may be used.

[0052] FIG. 7 shows a result of condition setting such that a spray flow rate the same as a flow rate change in the continuous spray in FIG. 5(b) is obtained by the pulse spray.

[0053] Now, it is assumed that a minimum spray flow rate per unit area (1m^2) at which the droplet group can collide with the high temperature surface of the steel material is $10\text{L}/\text{m}^2 \cdot \text{min.}$, and that all the droplet groups sprayed from the nozzles contribute to cooling. In this case, in the first 2 min., spray is performed at a flow rate of 40 L/min. per unit area (1m^2), the flow rate is reduced to 10 L/min. at the next stage, and at the same time, a ratio of a pulse width to a pulse interval is set to 1: 1 (Duty ratio: 1/2) by a timer or the like attached to an electromagnetic valve, and cooling is performed for 1 min.. Thereafter, a target spray flow rate is achieved by setting the ratio of the pulse width to the pulse interval to 1: 4 (Duty ratio: 1/5).

[0054] That is, in an initial first step of maximizing cooling performance, a flow rate of an amount the same as that of a total flow rate during continuous spray for 2 minutes at 35L to 40 L/min. is required, and a droplet group of a fixed amount, 40 L/min. in this example, is continuously sprayed for 2 minutes.

[0055] Next, in a second step in which the cooling performance is made relatively lower than that in the first step after the first step, a flow rate of an amount the same as that of a total flow rate during continuous spray for 1 minute at 4L to 5 L/min. is required, and a droplet group of 10 L/min. (corresponding to a magnitude of a pulse) is pulse-sprayed in a pulse shape at a pulse interval of 10 seconds and a pulse width of 10 seconds for 1 minute.

[0056] Further, in a third step in which the cooling performance is made relatively lower than that in the second step, a flow rate of an amount the same as that of a total flow rate during continuous spray for 30 minutes at 1.5 L to 2 L/min. is required, and a droplet group of 10 L/min. (corresponding to a magnitude of a pulse) is pulse-jetted

at a pulse interval of 40 seconds or longer and a pulse width of 10 seconds for 30 minutes or longer.

[0057] By the pulse spray, a phenomenon in which the droplet group is evaporated and does not reach the high temperature surface of the steel material can be avoided, and the steel material can be appropriately cooled.

[0058] FIG. 8 shows a result of a cooling test in which a spray flow rate per unit area is calculated in advance so as to be the flow rate shown in FIG. 7, a droplet group is pulsed and sprayed while monitoring an actual temperature change and adjusting the flow rate, and the steel material is cooled. The result substantially the same as a temperature change during cooling by oil quenching is obtained, and an appropriate cooling result is obtained by spraying the droplet group. In FIG. 8, "D/4" represents a position where a depth from the surface is 1/4 of the diameter (D), "D/8" represents a position where a depth from the surface is 1/8 of the diameter (D), and "10 mm depth" represents a position where a depth from the surface is 10 mm.

[0059] As described above, by calculating the target flow rate in advance and adjusting the flow rate while monitoring the actual temperature change, a cooling state equivalent to oil cooling can be obtained by the pulse spray. That is, in the above example, a cooling rate can be changed with a temperature range of about 500°C as a boundary.

[0060] In the above description, the pulse spray of the droplet group is performed for a purpose of making the cooling state equivalent to the oil cooling, but the present invention is not based on a premise of only this purpose, and in order to obtain a free cooling state, the pulse spray of the droplet group can be performed by changing at least one of the magnitude of the pulse, the pulse width, and the pulse interval over time.

[0061] In addition, in the above embodiment, the magnitude of the pulse, that is, the spray flow rate is set to zero at the minimum, but instead, the spray may be performed with a constant flow rate that is not zero as the minimum spray amount.

[0062] Although the present invention has been described based on the above embodiment, the scope of the present invention is not limited to the contents of the description of the above embodiment, and appropriate modifications of the present embodiment can be made without departing from the scope of the present invention.

INDUSTRIAL APPLICABILITY

[0063] According to the present invention, the member to be cooled can be cooled in a desired cooling state by using the pulse spray of the droplet group.

[0064] For example, in quenching of a steel material, a spray flow rate per unit area (1m^2) per certain time can be determined by freely determining pulse time and a pulse interval during cooling by pulse width modulation control, and thus an amount of droplets reaching a high temperature surface of the steel material per unit area

(1m^2) can be controlled, and a cooling state in which a cooling rate changes during cooling, such as oil quenching, can be obtained by cooling by pulse spray.

[0065] While the present invention has been described in detail with reference to the specific embodiment, it will be apparent to those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the present invention.

[0066] The present application is based on a Japanese Patent Application (Japanese Patent Application No. 2019-191869) filed on October 21, 2019, and the contents thereof are incorporated herein as reference.

REFERENCE SIGNS LIST

[0067]

1	Cooling device
2	Spray nozzle
3	Pipe
4	Spray adjustment unit
5	Control unit
10	Droplet group
100	Steel material

Claims

1. A cooling method for cooling a heated member to be cooled by spraying a droplet group onto the member to be cooled, the cooling method comprising: performing pulse spray by spraying the droplet group in a pulse shape and repeating the pulse spray, and changing at least one of a magnitude of a pulse, a pulse width, and a pulse interval over time.
2. The method for cooling the member to be cooled according to claim 1, comprising: adjusting cooling performance over time in accordance with the change.
3. The method for cooling the member to be cooled according to claim 2, wherein the adjusting of the cooling performance comprises determining an average spray flow rate per unit area (1m^2) of the droplet group per predetermined time.
4. The method for cooling the member to be cooled according to any one of claims 1 to 3, comprising: setting the magnitude of the pulse to be equal to or larger than a spray flow rate per unit area (1m^2) at which the droplet group can reach a surface of the member to be cooled.
5. The method for cooling the member to be cooled according to claim 2 or 3, comprising:

at least an initial first step of maximizing the cooling performance, a second step of making the cooling performance relatively lower than that in the first step after the first step, and a third step of making the cooling performance relatively lower than that in the second step after the second step, wherein in the first step, the magnitude of the pulse and the pulse width are set to a magnitude of a first pulse and a first pulse width that are relatively largest, in the second step, the magnitude of the pulse is set to a magnitude of a second pulse that is smaller than the magnitude of the first pulse, the pulse width is set to a second pulse width that is smaller than the first pulse width, and the pulse interval is set to a second pulse interval, and in the third step, the magnitude of the pulse and the pulse width are set to a magnitude of a third pulse and a third pulse width that are equal to or smaller than the magnitude of the second pulse and equal to or smaller than the second pulse width, respectively, and the pulse interval is set to a third pulse interval that is equal to or larger than the second pulse interval.

6. The method for cooling the member to be cooled according to any one of claims 1 to 5, comprising spraying the droplet group by a single-fluid nozzle.

7. The method for cooling the member to be cooled according to any one of claims 1 to 6, wherein the member to be cooled is a steel material having a thickness of 200 mm or larger.

8. The method for cooling the member to be cooled according to any one of claims 1 to 7, wherein cooling by the droplet group obtains a cooling state equivalent to cooling by oil cooling.

9. A cooling device for a member to be cooled, the cooling device comprising:

a plurality of spray nozzles, each of which sprays a droplet group onto a heated member to be cooled to cool the member to be cooled;
a spray adjustment unit configured to adjust a spray amount of the droplet group sprayed from the spray nozzle; and
a control unit configured to control spray of the droplet group from the spray nozzle, wherein the control unit is configured to perform pulse spray by spraying the droplet group in a pulse shape and repeat pulse spray according to a set value, and to control the spray of the droplet group by changing at least one of a magnitude of a pulse, a pulse width, and a pulse interval over time.

10. The cooling device for the member to be cooled according to claim 9, wherein the spray nozzle has a plurality of types.

11. The cooling device for the member to be cooled according to claim 10, wherein the spray adjustment unit is configured to switch a type of the spray nozzle to be used.

12. The cooling device for the member to be cooled according to any one of claims 9 to 11, wherein the control unit is configured to measure a temperature of the member to be cooled that is being cooled and to adjust a spray flow rate of the droplet group based on the measurement result.

13. The cooling device for the member to be cooled according to any one of claims 9 to 12, wherein the spray nozzle is a single-fluid nozzle.

FIG. 1

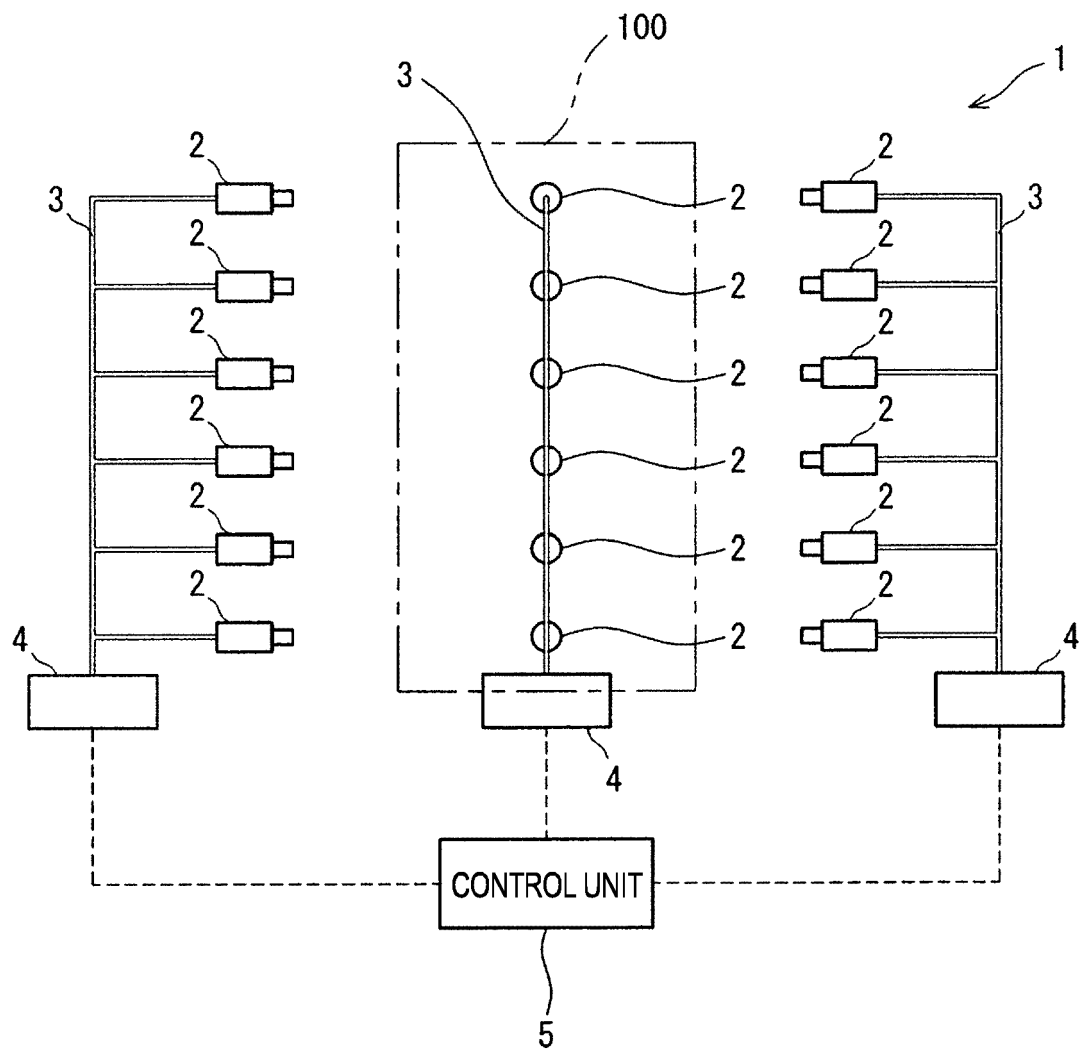


FIG. 2

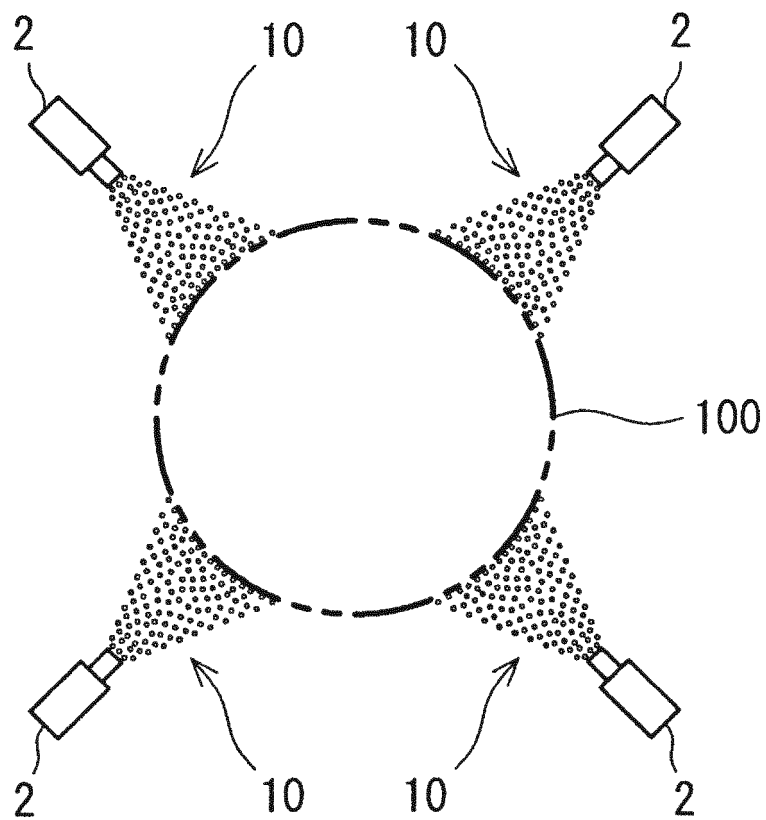


FIG. 3

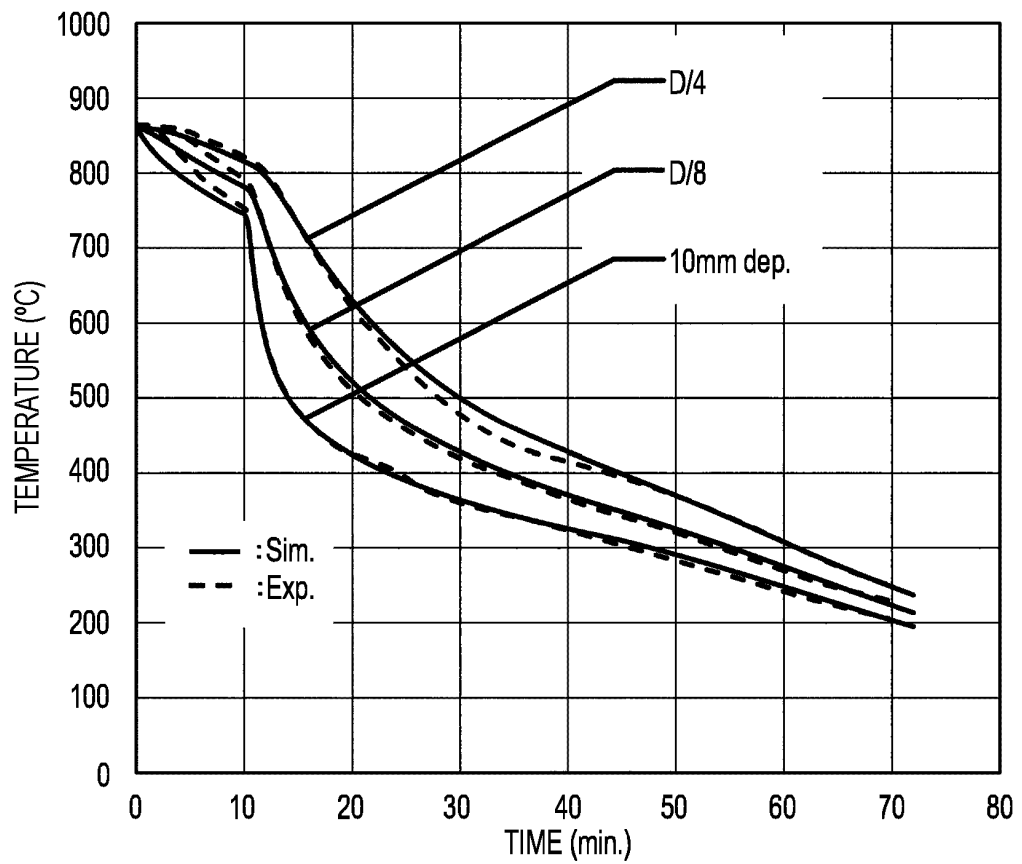
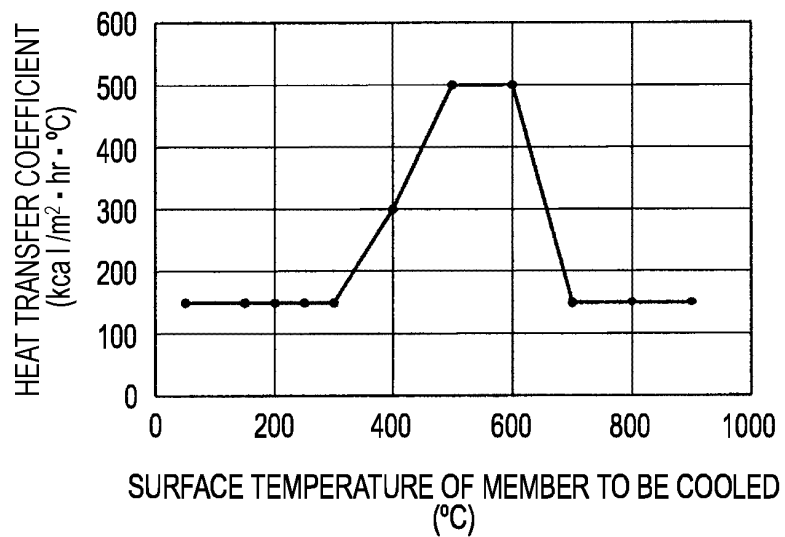


FIG. 4



HEAT TRANSFER COEFFICIENT DURING OIL COOLING
OBTAINED BY INVERSE FEM ANALYSIS CALCULATION

FIG. 5

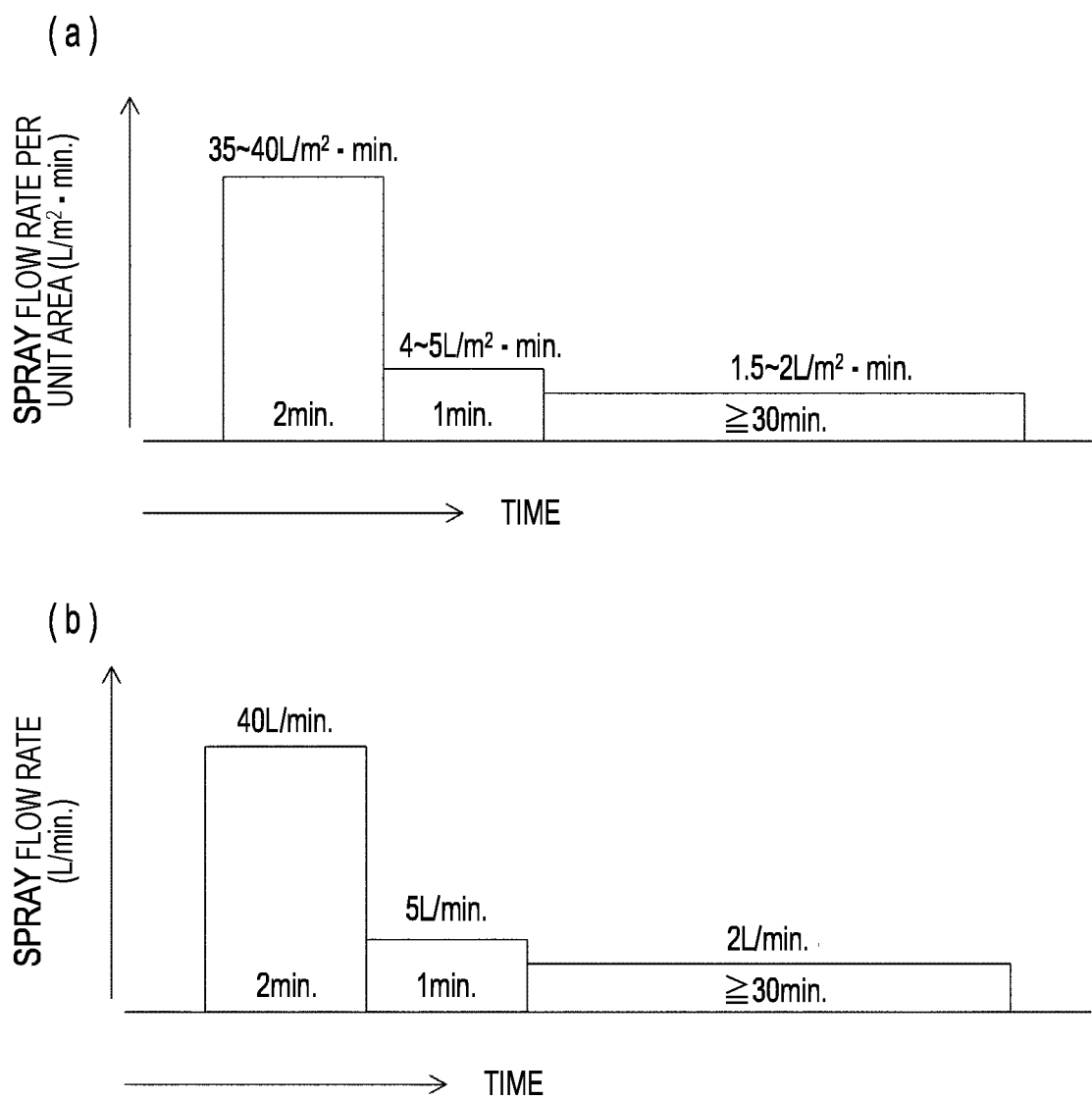


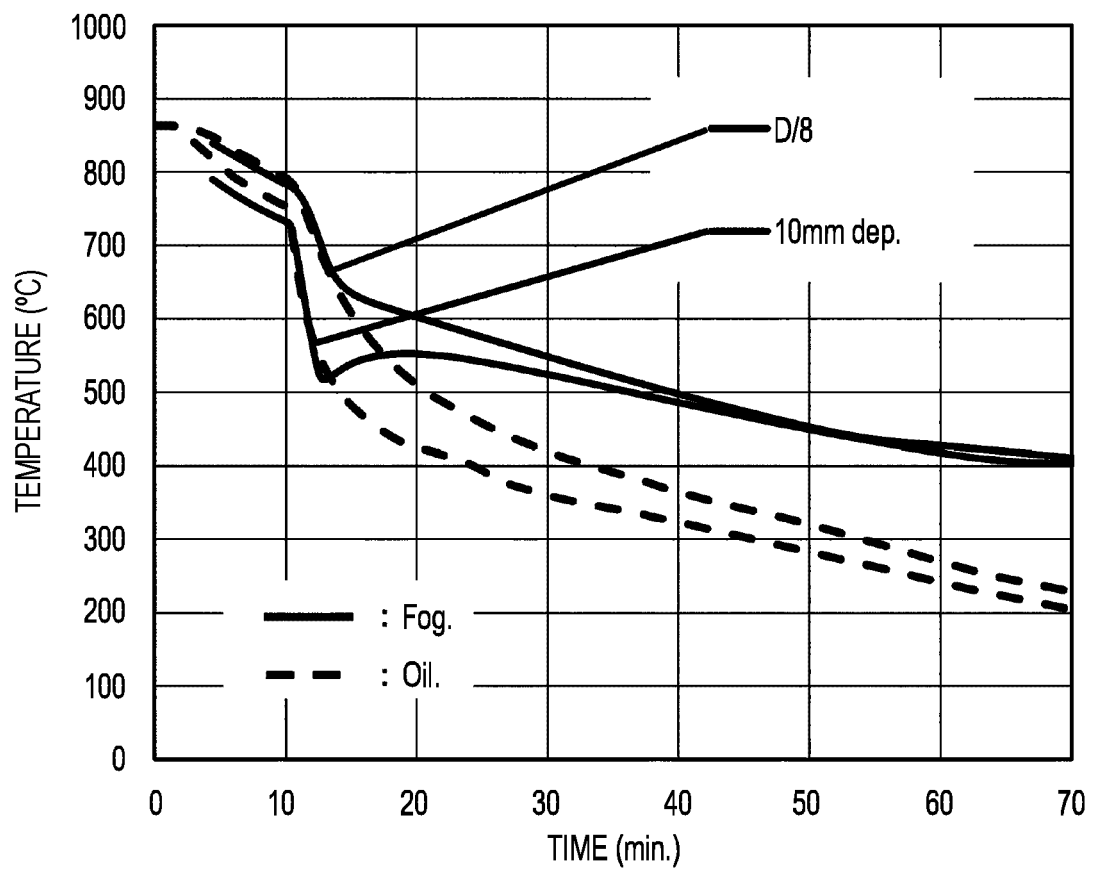
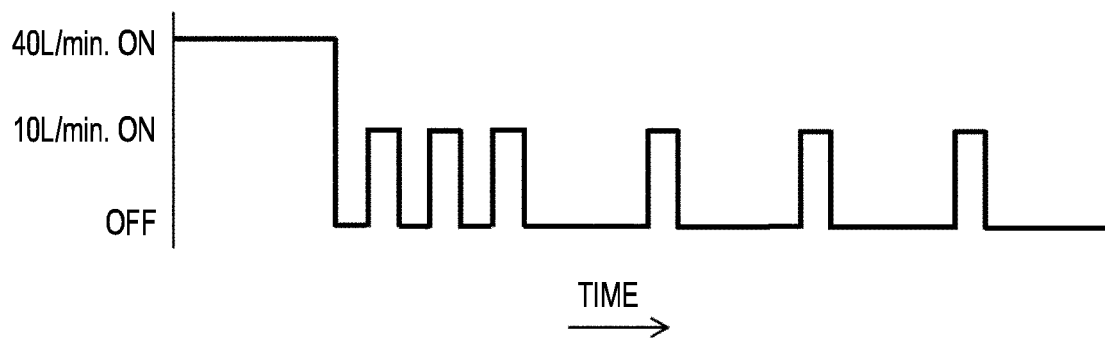
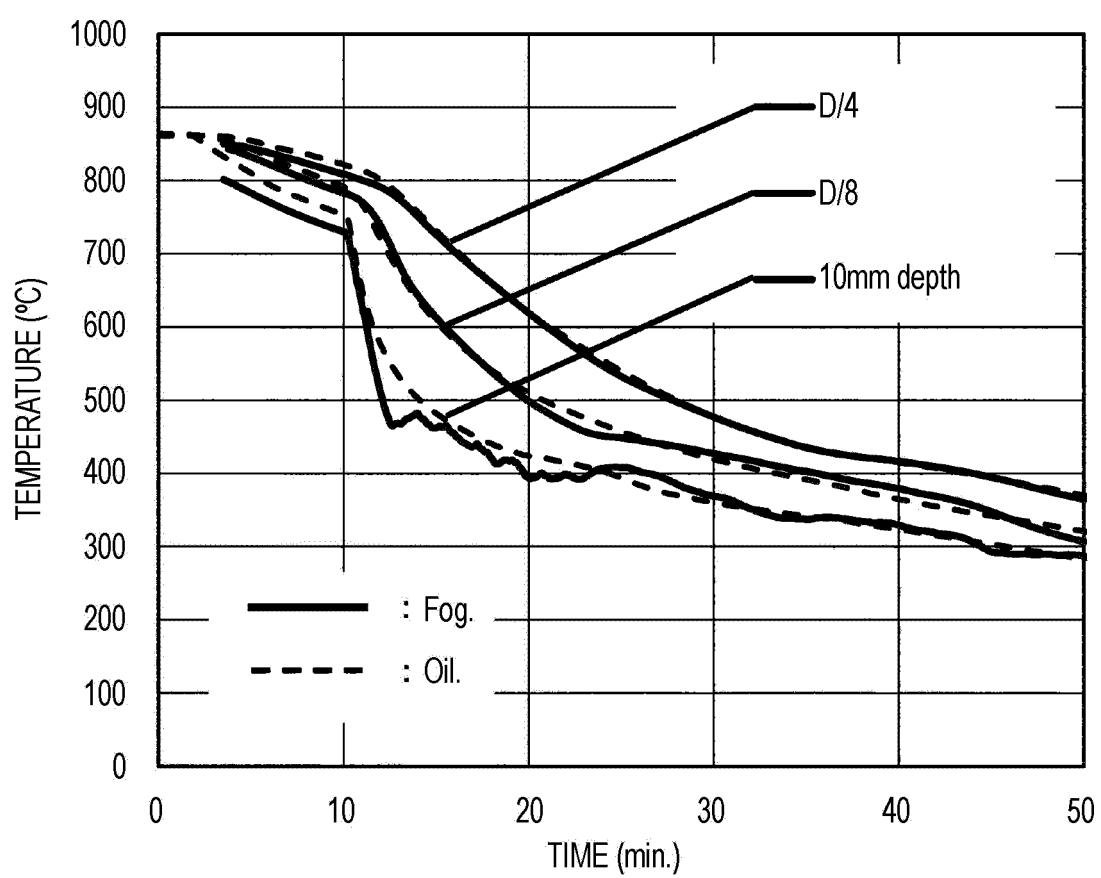
FIG. 6**FIG. 7**

FIG. 8



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/038820

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A. CLASSIFICATION OF SUBJECT MATTER

B05D 1/02 (2006.01) i; B05D 3/00 (2006.01) i; B05D 7/00 (2006.01) i; B21B 45/02 (2006.01) i; C21D 1/00 (2006.01) i; C21D 1/18 (2006.01) i; C21D 1/667 (2006.01) i

FI: C21D1/00 123Z; B05D7/00 K; B05D1/02 Z; B05D3/00 D; B21B45/02 320Z; C21D1/667; C21D1/18 F

According to International Patent Classification (IPC) or to both national classification and IPC

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B05D1/02; B05D3/00; B05D7/00; B21B45/02; C21D1/00; C21D1/18; C21D1/667

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 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2017/221671 A1 (HITACHI, LTD.) 28 December 2017 (2017-12-28) paragraphs [0001]-[0003], [0012]-[0017], [0025]-[0055], fig. 1-2	1-9, 13 10-12
Y	WO 2017/163732 A1 (IHI CORPORATION) 28 September 2017 (2017-09-28) paragraphs [0006], [0015]	10-11
Y	WO 2010/092659 A1 (IHI CORPORATION) 19 August 2010 (2010-08-19) paragraph [0049]	12
P, X	US 2020/0156133 A1 (TESLA, INC.) 21 May 2020 (2020-05-21) paragraphs [0039]-[0040], fig. 5A-6	1-13

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

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* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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

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Date of the actual completion of the international search
21 December 2020 (21.12.2020)

Date of mailing of the international search report
12 January 2021 (12.01.2021)

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Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2020/038820

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WO 2017/163732 A1	28 Sep. 2017	US 2018/0274049 A1	
		paragraphs [0007], [0023]	
		DE 112017001506 T5	
		CN 108779507 A	
WO 2010/092659 A1	19 Aug. 2010	JP 2014-141747 A	
		US 2011/0275024 A1	
		paragraph [0076]	
		DE 112009004328 B4	
		KR 10-2011-0102438 A	
		CN 102308008 A	
US 2020/0156133 A1	21 May 2020	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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- JP 2019191869 A [0066]