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(71) Applicant: **Krosakiharima Corporation**
Kitakyushu-shi, Fukuoka 806-8586 (JP)

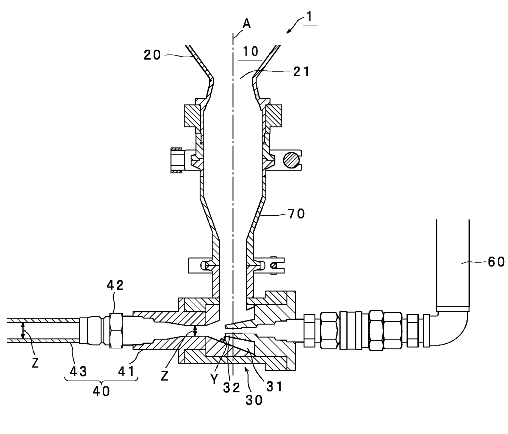
(72) Inventors:
- **YOSHIDA, Shogo**
  Kitakyushu-shi, Fukuoka 806-8586 (JP)
- **HONDA, Kazuhiro**
  Kitakyushu-shi, Fukuoka 806-8586 (JP)
- **HASHIMOTO, Shinya**
  Kitakyushu-shi, Fukuoka 806-8586 (JP)
- **TAKAKI, Tatsuya**
  Kitakyushu-shi, Fukuoka 806-8586 (JP)
- **YAMAGUCHI, Terufumi**
  Kitakyushu-shi, Fukuoka 806-8586 (JP)

(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstrasse 3
81675 München (DE)

(54) SPRAYING APPARATUS AND SPRAYING MATERIAL

(57) The present invention is intended to enable a spraying apparatus equipped with an ejector to suppress a decrease in ejector effect to ensure a given powder spray amount. A spraying apparatus 1 according to the present invention comprises: storage means 20 to store a powder 10; an ejector 30; a transport conduit 40 configured to transport therethrough a mixture formed by the ejector; and spray means to spray the mixture transported through the transport conduit 40. The ejector 30 comprises: a container part 31 having an internal space which is in communication with a dispensing port 21 of the storage means 20; and an ejection nozzle 32 configured to eject a pressurized carrier gas from the tip thereof into the internal space, wherein the tip of the ejection nozzle 32 is located closer to the transport conduit 40 than a vertical center line A passing through the center of the dispensing port 21, and the shortest distance Y from the tip of the ejection nozzle 32 to an inner surface of the container part 31 falls within a range satisfying the following formula: $2X \leq Y \leq 4.19 \ln(X) + 26.74$, where X represents the maximum particle size of the powder. The maximum particle size of the powder 10 is 0.03 mm to 5 mm.

Fig. 2



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Description

TECHNICAL FIELD

[0001] The present invention relates to a spraying apparatus for spraying a powder, and a spraying material as a powder used for the spraying device.

BACKGROUND ART

[0002] As a spraying apparatus for spraying a powder, there has been known a spraying apparatus equipped with an ejector configured to mix a powder and a carrier gas to form a mixture (e.g. Patent Documents 1 and 2).
[0003] In such a spraying apparatus, a suction flow is generated in an internal space of a container part of the ejector by the flow of pressurized carrier gas ejected from the tip of an ejection nozzle. Then, a powder dispensed to the internal space of the container part by the suction flow is transported to a transport conduit, and sprayed from spray means.

CITATION LIST

[Patent Document]

[0004]

Parent Document 1: JP 2007-275816 A

Patent Document 2: JP 5814699 B

SUMMARY OF INVENTION

[Technical Problem]

[0005] The present inventors conducted a number of spray tests using such a spraying apparatus. As a result, the present inventors have found that as the particle size of a powder as a spraying material becomes larger, a problem that the powder is clogged between the tip of the ejection nozzle and an inner surface of the container part of the ejector in the internal space of the container part, resulting in failing to obtain a sufficient suction flow, i.e., a sufficient ejector effect, is more likely to occur. If a sufficient ejector effect is not obtained, the suction amount of the powder in the ejector decreases, and consequently a powder spray amount from the spray means decreases, resulting in failing to ensure a given powder spray amount.
[0006] A problem to be solved by the present invention is to enable a spraying apparatus equipped with an ejector to suppress a decrease in ejector effect to ensure a given powder spray amount.

[Solution to Technical Problem]

[0007] Based on the knowledge that, in a spraying apparatus equipped with an ejector, the biggest factor causing a decrease in ejector effect is a phenomenon that the powder is clogged between the tip of the ejection nozzle and the inner surface of the container part of the ejector in the internal space of the container part, as described above, the present inventors have conducted a number of spray tests with a focus on a relationship between a distance from the tip of the ejection nozzle to the inner surface of the container part, and the maximum particle size of the powder as the spraying material. As a result, the present inventors have found that a decrease in ejector effect can be suppressed by setting the shortest distance Y from the tip of the ejection nozzle to the inner surface of the container part to fall within a range satisfying the following formula: $2X \leq Y \leq 4.19 \ln(X) + 26.74$, where X represents the maximum particle size of the powder.
[0008] Specifically, according to a first aspect of the present invention, the following spraying apparatus is provided.
[0009] A spraying apparatus for spraying a mixture of a powder whose maximum particle size is 0.03 mm to 5 mm, and a carrier gas, comprising: storage means to store the powder, the storage means having a dispensing port for dispensing the powder; an ejector configured to suck the powder by a flow of pressurized carrier gas, and mix the carrier gas and the powder to form the mixture; a transport conduit configured to transport therethrough the mixture formed by the ejector; and spray means to spray the mixture transported through the transport conduit; wherein the ejector comprises: a container part having an internal space which is in communication with the dispensing port; and an ejection nozzle configured to eject the pressurized carrier gas from the tip thereof into the internal space; wherein the tip of the ejection nozzle is located closer to the transport conduit than a vertical center line passing through a center of the dispensing port, and a shortest distance Y

from the tip of the ejection nozzle to an inner surface of the container part falls within a range satisfying the following formula: $2X \leq Y \leq 4.19 \ln(X) + 26.74$, where X represents the maximum particle size of the powder.

[0010] According to a second aspect of the present invention, there is provided a spraying material used as the powder in the spraying apparatus according to the first aspect of the present invention, wherein the spraying material has a compressibility of 32% or less.

[Advantageous Effects of Invention]

[0011] The present invention can enable a spraying apparatus equipped with an ejector to suppress a decrease in ejector effect to ensure a given powder spray amount.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

FIG. 1 is a side view of a spraying apparatus according to one embodiment of the present invention.
FIG. 2 is a vertical sectional view of a relevant part of the spraying apparatus in FIG. 1.
FIG. 3 is a graph in which evaluation results about powder spray amount are plotted, wherein the maximum particle size X of a powder is taken on the X-axis, and the shortest distance Y is taken on the Y-axis.

DESCRIPTION OF EMBODIMENTS

[0013] FIG. 1 shows the overall configuration of a spraying apparatus 1 according to one embodiment of the present invention, in the form of a side view. Further, FIG. 2 shows a relevant part of the spraying apparatus 1, in the form of a vertical sectional view.

[0014] The spraying apparatus 1 comprises: a hopper 20 as storage means to store a powder 10 as a spraying material; an ejector 30; a transport conduit 40; and spray means 50.

[0015] The composition of the powder 10 is determined according to the type of spraying construction by the spraying apparatus 1, i.e., the type of spraying material. For example, in the case of a spraying material for thermal spraying construction, as in the Patent Documents 1 and 2, the powder 10 is composed to mainly include a combustible powder and a refractory powder. On the other hand, in a case where the spraying material is a spraying material for dry spraying construction, the powder 10 is composed to mainly include a refractory powder. Further, in a case where the spraying material is a spray material for dry sealing construction, the powder 10 is composed to mainly comprise a refractory powder and a glass frit powder. In addition to the above-mentioned main powder(s), the powder 10 may further comprise a powder as an additive, such as a binder, a dispersant, or a quick setting agent, as needed.

[0016] In any case, the maximum particle size of the powder 10 is 0.03 mm to 5 mm. That is, the powder 10 has a particle size composition in which all particles thereof pass through a sieve having an opening size of 5 mm, and at least part of the particles do not pass through a sieve having an opening size of 0.03 mm.

[0017] In this embodiment, the spraying material stored in the hopper 20 can comprise fibers in addition to the powder 10. In this case, assume that such fibers are not a powder. Thus, the above-mentioned maximum particle size of the powder 10 is evaluated excluding the fibers.

[0018] In this embodiment, the powder 10 preferably has a compressibility of 32% or less. Here, the compressibility is determined by the following formula:

$$\text{Compressibility (\%)} = \{(\text{tapped (close-packed) bulk density} - \text{non-tapped (loose-packed) bulk density}) / \text{tapped bulk density}\} \times 100$$

[0019] It should be noted here that although the spraying material can comprise fibers in addition to the powder 10, the compressibility of the powder 10 is just the compressibility of the powder, and is evaluated excluding the fibers, as mentioned above.

[0020] Next, the equipment configuration of the spraying apparatus 1 will be described. The hopper 20 has a dispensing port 21 for dispensing the powder 10 to its bottom. The ejector 30 sucks the powder 10 from the dispensing port 21 by the flow of a pressurized carrier gas, and mixes the carrier gas and the powder 10 to form a mixture. The transport conduit 40 transports therethrough the mixture generated by the ejector. Then, the spray means 50 sprays the mixture transported through the transport conduit 40.

[0021] In this embodiment, the transport conduit 40 comprises a metal horizontal transfer pipe 41 connected to the exit side of the ejector 30, and a rubber hose 43 connected to the exit side of the horizontal transfer pipe 41 via a joint 42.

However, the horizontal transfer pipe 41 may be omitted, and the rubber hose 43 may be directly connected to the exit side of the ejector 30.

[0022] Next, the configuration of the ejector 30 will be described in detail. The ejector 30 comprises a container part 31 having an internal space which is in communication with the dispensing port 21 at the bottom of the hopper 20, and a tapered ejection nozzle 32 configured to eject a pressurized carrier gas from the tip thereof into the internal space of the container part 31. A carrier gas pressurized to a given pressure is supplied to the ejection nozzle 32 through a carrier gas supply conduit 60, and then the pressurized carrier gas is ejected from a nozzle hole at the tip of the ejection nozzle 32. More specifically, the ejector 30 generates a suction flow in the internal space of the container part 31 by the flow of the pressurized carrier gas ejected from the tip of the ejection nozzle 32. Then, the ejector 30 mixes the powder 10 sucked into the internal space of the container part 31 by the suction flow with the carrier gas to obtain a mixture, and transports the mixture to the transport conduit 40.

[0023] To explain the function of the ejector 30 in more detail, in the internal space of the container part 31, the pressurized carrier gas is ejected at a high speed from the nozzle hole at the tip of the tapered ejection nozzle 32, toward the exit side of the ejector 30, i.e., toward the base end side of the transport conduit 40, thereby allowing the internal space of the container part 31 to have a pressure lower than atmospheric pressure and thus generating a suction flow. On the other hand, the dispensing port 21 of the hopper 20 is in communication with the internal space of the container part 31 via a vertical transfer conduit 70. Thus, in the ejector 30, the powder 10 is sucked from the dispensing port 21 into the internal space of the container part 31 by the suction flow generated by the flow of the pressurized carrier gas, and the sucked powder 10 and the carrier gas ejected from the nozzle hole at the tip of the ejection nozzle 32 are mixed together in the internal space of the container part 31 to form a mixture, and the resulting mixture is transported to the transport conduit 40.

[0024] As appearing in FIG. 2, in the ejector 30, the tip of the ejection nozzle 32 is located closer to the transport conduit 40 than a vertical center line A passing through the center of the dispensing port 21. Further, the ejector 30 is configured such that the shortest distance Y from the tip of the ejection nozzle 32 to an inner surface of the container part 31 falls within a range satisfying the following formula: $2X \leq Y \leq 4.19 \ln(X) + 26.74$, where X represents the maximum particle size of the powder 10. In the spraying apparatus 1 according to this embodiment, the shortest distance Y is the length of a perpendicular line drawn from the underside of the tip of the ejection nozzle 32 toward the inner surface of the container part 31.

[0025] Although the details will be described in connection with Examples, it is possible to enable the spraying apparatus 1 to suppress a decrease in ejector effect to ensure a given powder spray amount by setting the above-mentioned shortest distance Y to fall within a range satisfying the following formula: $2X \leq Y \leq 4.19 \ln(X) + 26.74$.

[0026] More specifically, if the shortest distance Y is less than 2X, the powder 10 is more likely to be clogged between the tip of the ejection nozzle 32 and the inner surface of the container part 31 in the internal space of the container part 31, resulting in failing to obtain a sufficient suction flow, i.e., a sufficient ejector effect. If a sufficient ejector effect is not obtained, the suction amount of the powder in the ejector 30 decreases, and consequently the powder spray amount from the spray means 50 decreases, resulting in failing to ensure a given powder spray amount.

[0027] On the other hand, if the shortest distance Y is greater than $4.19 \ln(X) + 26.74$, it becomes difficult to allow the internal space of the container part 31 to have a pressure lower than atmospheric pressure, resulting in failing to obtain a sufficient suction flow, i.e., a sufficient ejector effect. Thus, similarly to the case where the shortest distance Y is less than 2X, the suction amount of the powder 10 in the ejector 30 decreases, and consequently the powder spray amount from the spray means 50 decreases, resulting in failing to ensure a given powder spray amount.

[0028] Here, in order to generate a sufficient suction flow in the ejector 30, it is preferable to increase the flow rate of the carrier gas ejected from the tip of the ejection nozzle 32. For this purpose, the pressure of the carrier gas is preferably 0.1 MPa or more. The upper limit of the pressure of the carrier gas is not particularly limited, but is generally about 1.0 MPa.

[0029] The type of the carrier gas is determined according to the type of spraying construction by the spraying apparatus 1. For example, in the case of thermal spraying construction as in the Patent Documents 1 and 2, an oxygen gas can be typically used as the carrier gas. On the other hand, in the case of dry spraying construction or dry sealing construction, air can be typically used as the carrier gas.

[0030] With regard to the inner diameter Z of the transport conduit 40, when it becomes smaller, the powder 10 can be clogged in the transport conduit 40. On the other hand, when the inner diameter of the transport conduit 40 becomes larger, a transport pressure against the mixture comprising the powder 10 decreases, so that the powder 10 is likely to precipitate on the lower side of the transport conduit 40, and the uniformity of transport can be deteriorated. Thus, it is preferable that the inner diameter Z of the transport conduit 40 falls within a range satisfying the following formula: $2X \leq Z \leq 6X$.

[0031] As also shown in FIG. 2, the inner diameter Z of the transport conduit 40 is not necessarily constant in size. When the inner diameter Z of the transport conduit 40 is not constant in size, as in this embodiment, it is preferable to set all values of the inner diameter Z to fall within a range satisfying the following formula: $2X \leq Z \leq 6X$.

[0032] Further, it is preferable that an inner surface of the hopper 20 which is storage means to store the powder 10 is subjected to blasting. The blasting is surface processing of spraying small balls or balls with sharp angles, onto a to-be-processed surface (one surface of a steel material which corresponds to the inner surface of the hopper 20 in the present invention) to form fine roughness on the to-be-processed surface. The inner surface of the hopper 20 subjected to such blasting provides improved slippage of the powder 10 in the hopper 20, so that the powder 10 is uniformly dispensed from the dispensing port 21 of the hopper 20. This contributes to suppressing a decrease in ejector effect in the spraying apparatus 1.

[0033] Further, it is preferable that the compressibility of the powder 10 is preferably 32% or less, as mentioned above. A powder having a low compressibility is high in fluidity. Thus, by setting the compressibility of the powder 10 to 32% or less, clogging of the powder 10 becomes less likely to occur in the spraying apparatus 1, so that it becomes easier to ensure a given powder spray amount. The compressibility of the powder 10 can be adjusted by adjusting the particle size composition or the like. In other words, the particle size composition or the like of the powder 10 is adjusted such that the compressibility becomes 32% or less.

[0034] Here, with regard to the given powder spray amount, it is determined according to the maximum particle size or the like of the powder 10. For example, when the maximum particle size of the powder 10 is 1 mm to 5 mm, it may be set in the range of about 1 to 150 kg/h, and when the maximum particle size of the powder 10 is 0.03 mm to 1 mm, it may be set in the range of about 0.5 to 120 kg/h.

EXAMPLES

[0035] In the spraying apparatus 1 illustrated in FIGS. 1 and 2, a spray test was conducted by changing the maximum particle size X of the powder 10 and the shortest distance Y, thereby checking whether or not a given powder spray amount can be secured. The results are shown in Table 1.

[0036] The spraying conditions other than the maximum particle size X of the powder and the shortest distance Y indicated in Table 1 are common to all Examples, and main ones of the spraying conditions are as follows. It should be noted here that the given powder spray amount is not common to all Examples, and the range thereof is about 2 to 30 kg/h.

- Powder composition: alumina-silica based material (alumina: 60% by mass)
- Powder compressibility: 25%
- Pressure of carrier gas: 0.3M P a
- Type of carrier gas: compressed air
- Spray test time: 0.5 h

[0037] In Table 1, with regard to the evaluation of the powder spray amount, an example where the given powder spray amount could be ensured until the spray test time expires was evaluated as ◦ (Good), and an example where the powder spray amount decreased before the spray test time expires, resulting in failing to ensure the given powder spray amount, was evaluated as × (NG).

TABLE 1

	Inventive Example 1	Comparative Example 1	Inventive Example 2	Comparative Example 2	Inventive Example 3	Comparative Example 3	Inventive Example 4	Comparative Example 4	Inventive Example 5	Comparative Example 5
Maximum Particle Size X of Powder (mm)	0,03		0,5		1		3		5	
Shortest Distance Y (mm)	0,1	0,04	1,2	0,06	2,1	1,5	8	5	11	9
Evaluation of Power Spray Amount	○	×	○	×	○	×	○	×	○	×

	Inventive Example 6	Comparative Example 6	Inventive Example 7	Comparative Example 7	Inventive Example 8	Comparative Example 8	Inventive Example 9	Comparative Example 9	Inventive Example 10	Comparative Example 10
Maximum Particle Size X of Powder (mm)	0,03		0,5		1		3		5	
Shortest Distance Y (mm)	10	15	22	25	26	28	30	34	32	35
Evaluation of Power Spray Amount	○	×	○	×	○	×	○	×	○	×

[0038] FIG. 3 shows a result of plotting of the evaluation results about powder spray amount, indicated in Table 1, wherein the maximum particle size X of the powder is taken on the X-axis, and the shortest distance Y is taken on the Y-axis. In FIG. 3, the straight line Y = 2 X is an approximation line indicating the boundary between Inventive Examples 1 to 5 and Comparative Examples 1 to 5 in the upper column of Table 1, and defines the lower limit of the shortest distance Y. On the other hand, in FIG. 3, the curve line Y = 4.19 ln(X) + 26.74 is an approximation line indicating the boundary between Inventive Examples 6-10 and Comparative Examples 6-10 in the lowercolumn of the Table 1, and defines the upper limit of the shortest distance Y That is, when the shortest distance Y falls within a range satisfying the following formula: $2X \leq Y \leq 4.19 \ln(X) + 26.74$, the evaluation result of the powder spray amount becomes ◦ (Good), which means that a decrease in ejector effect is suppressed.

LIST OF REFERENCE SIGNS

[0039]

1: spraying apparatus
10: powder
20: hopper (storage means)
21: dispensing port
30: ejector
31: container part
32: ejection nozzle
40: transport conduit
41: horizontal transfer pipe (transport conduit)
42: joint
43: rubber hose (transport conduit)
50: spray means
60: carrier gas supply conduit
70: vertical transfer conduit
A: vertical center line
Y: shortest distance
Z: inner diameter

Claims

1. A spraying apparatus for spraying a mixture of a powder whose maximum particle size is 0.03 mm to 5 mm, and a carrier gas, comprising:

storage means to store the powder, the storage means having a dispensing port for dispensing the powder;
an ejector configured to suck the powder by a flow of pressurized carrier gas, and mix the carrier gas and the powder to form the mixture;
a transport conduit configured to transport therethrough the mixture formed by the ejector; and
spray means to spray the mixture transported through the transport conduit;
wherein the ejector comprises:

a container part having an internal space which is in communication with the dispensing port; and
an ejection nozzle configured to eject the pressurized carrier gas from the tip thereof into the internal space;

wherein
the tip of the ejection nozzle is located closer to the transport conduit than a vertical center line passing through a center of the dispensing port, and
a shortest distance Y from the tip of the ejection nozzle to an inner surface of the container part falls within a range satisfying the following formula: $2X \leq Y \leq 4.19 \ln(X) + 26.74$, where X represents the maximum particle size of the powder.

2. The spraying apparatus as claimed in claim 1, wherein the carrier gas has a pressure of 0.1 MPa or more.

3. The spraying apparatus as claimed in claim 1, wherein the transport conduit has an inner diameter Z falling within a range satisfying the following formula: $2X \leq Z \leq 6X$.

4. The spraying apparatus as claimed in claim 1, wherein the storage means has an inner surface subjected to blasting.

5. A spraying material used as the powder in the spraying apparatus as defined in any one of claims 1 to 4, wherein the spraying material has a compressibility of 32% or less.

Fig. 1

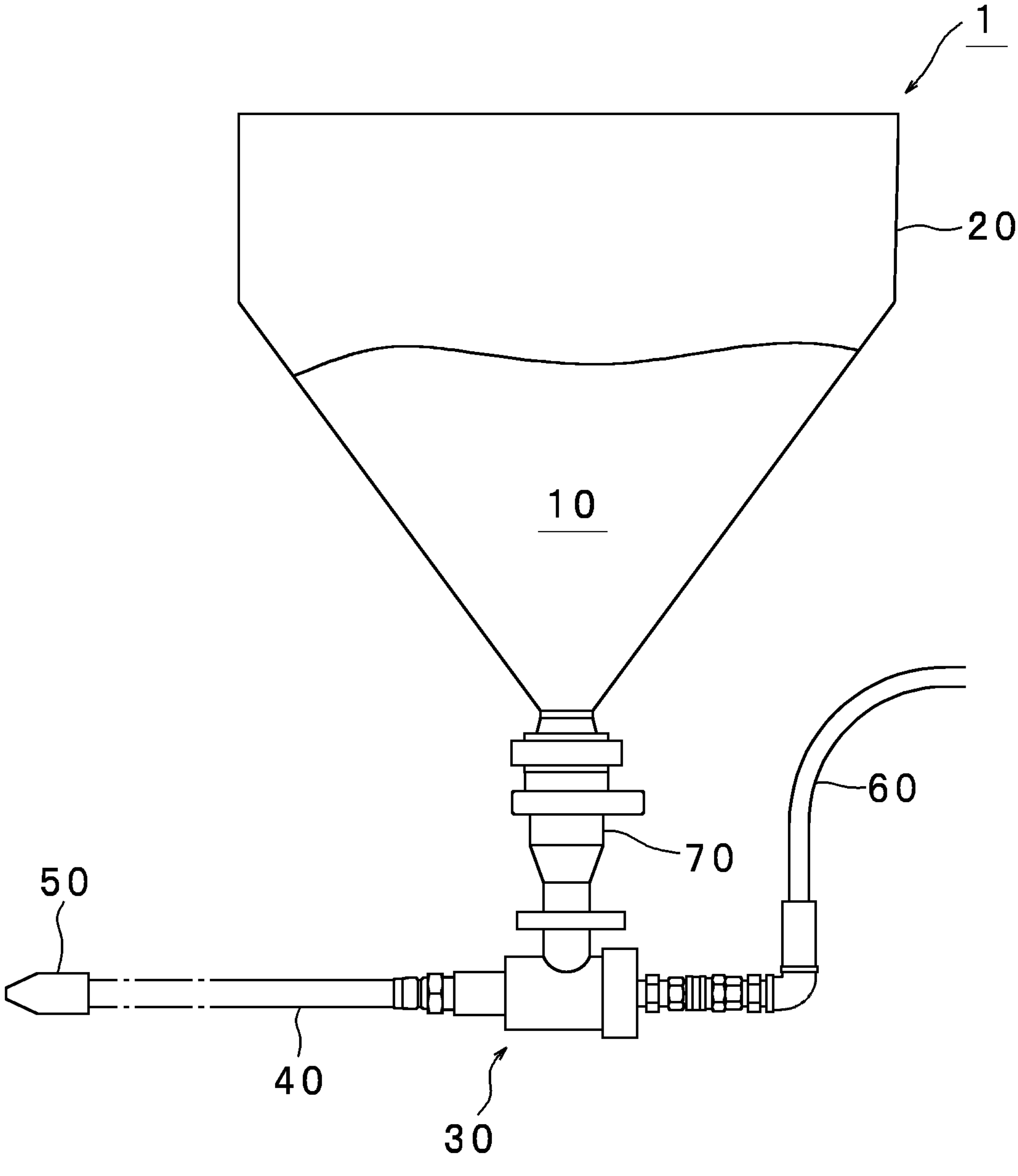


Fig. 2

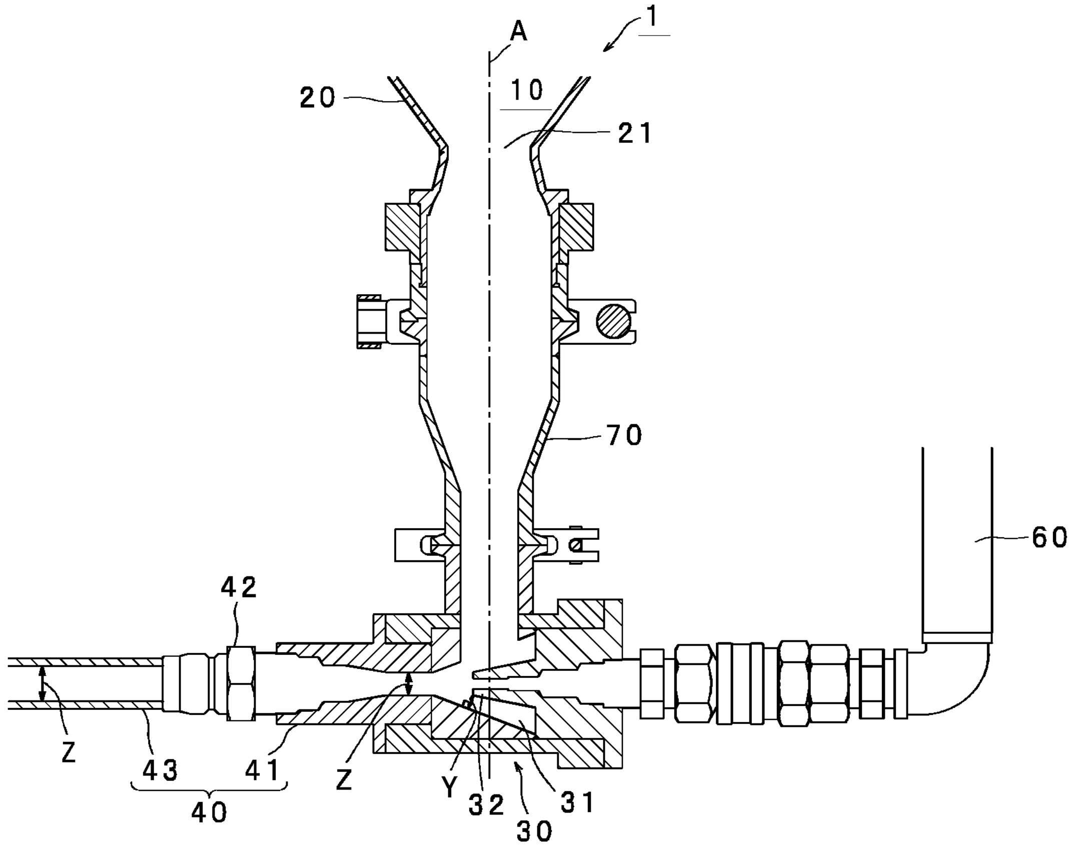
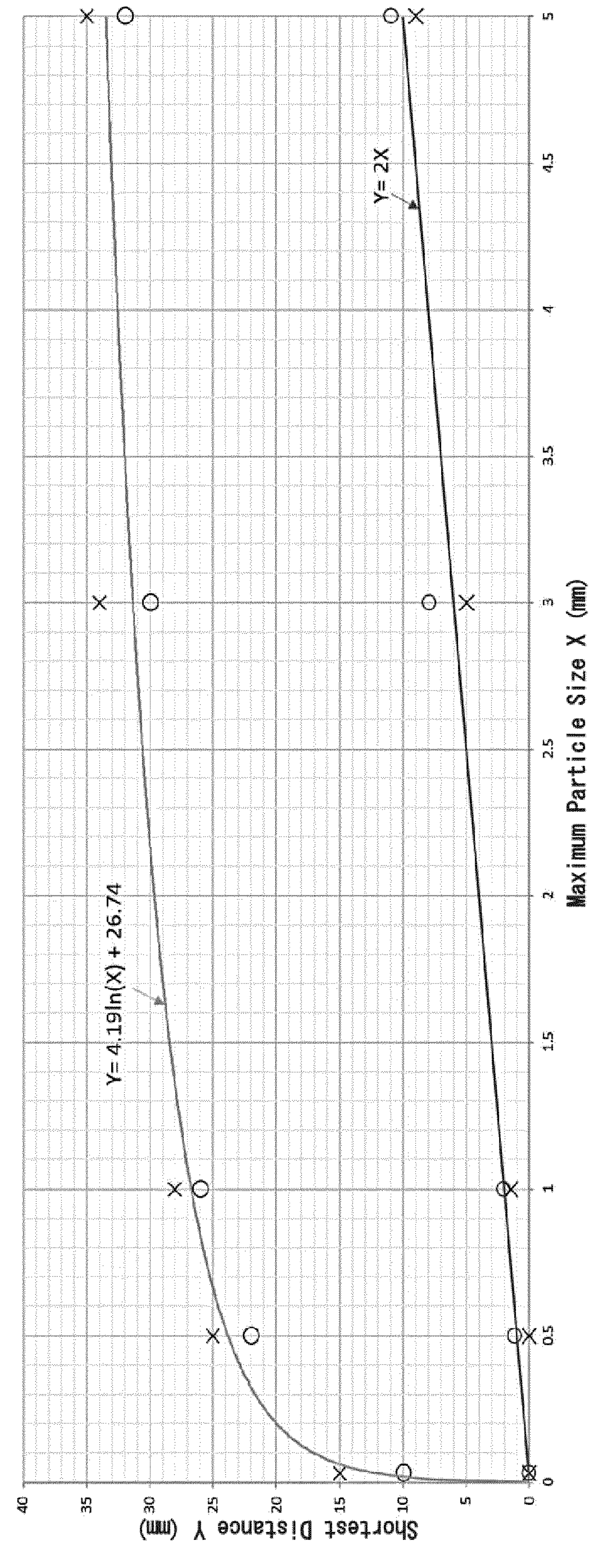


Fig.3


Y= 4.19ln(X) + 26.74
Y= 2X
Maximum Particle Size X (mm)
Shortest Distance Y (mm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/026020

A. CLASSIFICATION OF SUBJECT MATTER

B05B 7/14(2006.01)i; ***B05B 7/30***(2006.01)i
FI: B05B7/14; B05B7/30

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)

B05B1/00-17/08; B05D1/00-7/26; C23C4/00-6/00

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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.
A	JP 2013-43141 A (KUROSAKI HARIMA CORP) 04 March 2013 (2013-03-04) entire text	1-5
A	JP 2007-275816 A (NIPPON TOKUSHU ROZAI KK) 25 October 2007 (2007-10-25) entire text	1-5
A	JP 2018-70939 A (KUROSAKI HARIMA CORP) 10 May 2018 (2018-05-10) entire text	1-5
A	JP 2020-59899 A (KUROSAKI HARIMA CORP) 16 April 2020 (2020-04-16) entire text	1-5
A	JP 2009-18297 A (RICOH CO LTD) 29 January 2009 (2009-01-29) entire text	1-5
A	JP 2017-75381 A (SHINAGAWA REFRACTORIES CO) 20 April 2017 (2017-04-20) entire text	1-5

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"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
31 July 2023	**15 August 2023**

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

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/026020

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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JP 2018-70939 A	10 May 2018	(Family: none)	
JP 2020-59899 A	16 April 2020	(Family: none)	
JP 2009-18297 A	29 January 2009	US 2008/0305420 A1	
JP 2017-75381 A	20 April 2017	(Family: none)	

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

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- JP 2007275816 A **[0004]**
- JP 5814699 B **[0004]**