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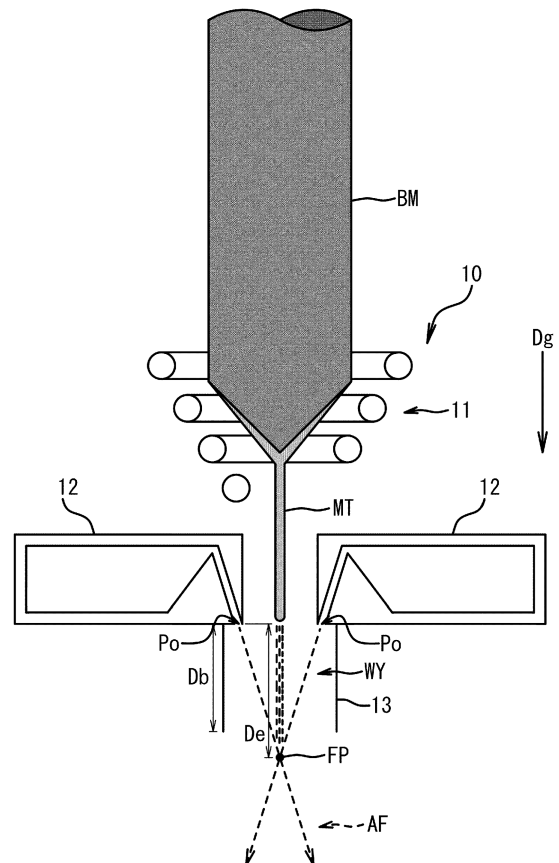
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(54) **GAS ATOMIZATION DEVICE AND GAS ATOMIZATION METHOD**

(57) The object of the present invention is to provide a gas atomization device and a gas atomization method that are capable of continuously producing small particle size metal powder over a relatively long period of time while utilizing a suction tube or the like to form a flow path and while preventing adhesion of unsolidified metal powder. The gas atomization device 10 according to the present invention includes a gas nozzle 12, a molten metal supply unit 11, and a flow path WY. The gas nozzle ejects gas from the ejection ports toward a focal point FP. The molten metal supply unit supplies molten metal from above the focal point in the vertical direction toward the focal point. The flow path extends downward from the lower end of the gas nozzle so as to surround the ejection ports in a plan view. The vertical distance D_e from the gas ejection ports to the focal point is longer than the vertical distance D_b from the gas ejection ports to the lower end of the flow path.

Fig. 2



Description

TECHNICAL FIELD

[0001] The present invention relates to a gas atomization device and a gas atomization method.

BACKGROUND ART

[0002] In recent years, the free-fall gas atomization method has become widely known as a method for producing metal powder such as titanium and zirconium, which have high melting points and exhibit high activity at high temperatures. Note that the "free-fall gas atomization method" referred to here is a method of producing metal powder by melting metal using induction heating or the like to form a molten metal, and then spraying an inert gas or air into the molten metal at high speed (e.g., see Patent Document 1).

[0003] Incidentally, the particle size of metal powder produced by gas atomization depends greatly on the flow rate of the gas ejected from a gas nozzle. As a method for increasing the gas flow rate to produce fine-particle powder, a method utilizing the ejector effect has been proposed (e.g., see Non-Patent Documents 1 and 2). In this method, a flow path is provided in the direction of ejection from the gas ejection port using a suction tube or the like, and the pressure can be reduced by the ejector effect; in addition, the ejector effect can be enhanced by reducing the diameter of the flow path, thus allowing for producing fine-particle powder.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0004] Patent Document 1: Japanese Patent Publication No. 2002-241807

NON-PATENT DOCUMENTS

[0005]

Non-Patent Document 1: Toru Takeda and Kazumi Minagawa, "Decompressed Gas Atomization of Bronze," Abstracts of Lectures by the Japan Society of Powder and Powder Metallurgy, 1990, pp. 28-29
Non-Patent Document 2: Tadanori Kojima, Yoshihiro Matsuoka, "Study on Interference of Underexpanded Jets," Transactions of the Society of Mechanical Engineers, No. 88-0469B, 1989, pp. 188-193

DISCLOSURE OF INVENTION

TECHNICAL PROBLEM

[0006] However, making the diameter of the flow path described above too small causes unsolidified metal powder to adhere to the inner walls of the suction tube, or the like, clogging the flow path; this would necessitate halting metal powder production, making continuous metal powder manufacturing extremely difficult. In particular, in a case of producing metal powder, such as titanium and titanium alloys, that exhibit high activity at high temperatures, adhesion of unsolidified metal powder is likely to occur, making it extremely difficult to reduce the diameter of the metal powder using a suction tube or the like.

[0007] An object of the present invention is to provide a gas atomization device and a gas atomization method that are capable of continuously producing small particle size metal powder over a relatively long period of time while utilizing a suction tube or the like to form a flow path and while preventing adhesion of unsolidified metal powder.

SOLUTION TO PROBLEM

[0008] A gas atomization device according to a first aspect of the present invention includes a gas nozzle, a molten metal supply unit, and a flow path. The gas nozzle has a plurality of ejection ports. The gas nozzle ejects gas from the ejection ports toward a focal point. The molten metal supply unit supplies molten metal from above the focal point in a vertical direction toward the focal point. The flow path extends downward from a lower end of the gas nozzle so as to surround the ejection ports in a plan view. Note that the diameter of this flow path is preferably within a range from 40 mm or more to 160 mm or less to prevent unsolidified metal powder from adhering to the wall surface of the flow path. The flow path can be formed by a tube, a block having a through hole, or the like. The vertical distance from the gas ejection port to the focal point

is longer than the vertical distance from the gas ejection port to the lower end of the flow path.

[0009] As a result of extensive research by the inventor of the present application, it has been confirmed that the above-mentioned gas atomization device is less likely to cause adhesion of unsolidified metal powder, and is capable of continuously producing small particle size metal powder over a relatively long period of time.

[0010] In a gas atomization method according to a second aspect of the present invention, in a gas atomization device including: a gas nozzle having a plurality of ejection ports and ejecting gas from the ejection ports toward a focal point, a molten metal supply unit supplying molten metal from above the focal point in a vertical direction toward the focal point; and a flow path extending downward from a lower end of the gas nozzle so as to surround the ejection ports in a plan view, gas atomization is performed with a vertical distance from the gas ejection port to the focal point set longer than a vertical distance from the gas ejection port to the lower end of the flow path. Note that the diameter of the flow path is preferably within a range from 40 mm or more to 160 mm or less to prevent unsolidified metal powder from adhering to the wall surface of the flow path. The flow path can be formed by a tube, a block having a through hole, or the like.

[0011] As a result of intensive research by the present inventor, it has been confirmed that using the above-mentioned gas atomization method makes adhesion of unsolidified metal powder less likely to occur, and small particle size metal powder can be produced continuously over a relatively long period of time.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

FIG. 1 is a schematic diagram of a metal powder manufacturing device according to an embodiment of the present invention.

FIG. 2 is a schematic diagram of a gas atomization device that constitutes the metal powder manufacturing device according to the embodiment of the present invention.

REFERENCE SIGNS LIST

[0013]

- 10 Gas atomization device
- 11 High-frequency induction coil (molten metal supply unit)
- 12 Gas nozzle
- Db Vertical distance from gas ejection ports to the lower end of the flow path
- De Vertical distance from the gas ports to the focal point
- FP focal point
- Po Ejection port
- WY flow path

DESCRIPTION OF EMBODIMENTS

[0014] A metal powder manufacturing device according to an embodiment of the present invention will be now described in detail with reference to the drawings.

[0015] As shown in FIG. 1, a metal powder manufacturing device 1 according to an embodiment of the present invention mainly includes a raw material supply unit 2, a gas atomization device 10, a gas receiving container 3, and a recovery container 4. These components will be described in detail below.

(1) Raw material supply unit

[0016] The raw material supply unit 2 supplies a rod-shaped metal raw material BM to the gas atomization device 10. The term "metal" as used herein includes not only pure metals but also alloys.

(2) Gas atomization device

[0017] The gas atomization device 10 is a free-fall gas atomization device that produces metal powder from rod-shaped metal raw material supplied from the raw material supply unit 2, and as shown in FIGS. 1 and 2, mainly includes a high-frequency induction coil 11, a gas nozzle 12, and a suction tube 13. These components will be described in detail below.

(2-1) High-frequency induction coil

[0018] The high-frequency induction coil 11 heats and melts the rod-shaped metal raw material supplied from the raw material supply unit 2 to form a molten metal. Note that the rod-shaped metal raw material is passed through the center of the high-frequency induction coil 11.

(2-2) Gas nozzle

[0019] The gas nozzle 12 is a substantially annular member, and is disposed so as to surround the periphery of a lower extension of the axis of the high-frequency induction coil 11. As shown in FIGS. 1 and 2, a plurality of gas ejection ports Po are formed in the gas nozzle 12. As shown in FIGS. 1 and 2, the gas ejection ports Po are arranged at equal intervals along a horizontal plane. Although only two gas ejection ports Po are shown in FIGS. 1 and 2, the number of gas ejection ports Po may be three or more. Further, as shown in FIG. 2, the focal point FP of the gas ejection direction from these ejection ports Po is located below the lower end of the suction tube 13, that is, inside the gas receiving container 3. In other words, in the gas atomization device 10 of the present embodiment, the vertical distance De from the gas ejection ports Po to the focal point FP is designed to be longer than the vertical distance Db from the gas ejection ports Po to the lower end of the suction tube 13, that is, the lower end of the flow path WY. These gas nozzles 12 eject an inert gas (e.g., a rare gas such as argon) onto the molten metal supplied from the high-frequency induction coil 11 to atomize it.

(2-3) Suction tube

[0020] As shown in FIGS. 1 and 2, the suction tube 13 has a straight tube shape and extends downward from the lower end of the gas nozzle 12. Further, the suction tube 13 is disposed so as to surround the ejection ports Po in a plan view. Further, the axis of the suction tube 13 lies on the same straight line as the axis of the high-frequency induction coil 11. Furthermore, the inner diameter of the suction tube is preferably within a range from 40 mm or more to 160 mm or less to prevent unsolidified metal powder from adhering to the inner surface of the suction tube.

(3) Gas receiving container

[0021] The gas receiving container 3 serves to retain within the system the gas ejected from the gas nozzle 12 and the metal powder generated therein. As described above, the focal point FP of the ejection ports Po exists inside the gas receiving container 3.

(4) Recovery container

[0022] The recovery container 4 serves to recover the metal powder produced by the gas atomization device 10. Note that a suction tube is provided on the upper side of the recovery container 4, and this suction tube is connected to a vacuum pump (not shown). In other words, the gas ejected from the gas nozzle 12 is pulled by the vacuum pump, and as a result, a gas flow always directed toward the recovery container 4 is formed.

<Flow of metal powder production by the metal powder production device according to the present embodiment>

[0023] Rod-shaped metal raw material BM is continuously supplied through the raw material supply unit 2 so that the tip of the rod-shaped metal raw material BM always faces the high-frequency induction coil 11 without contacting it, and the high-frequency induction coil 11 gradually melts the lower tip of the rod-shaped metal raw material BM to turn it into molten metal, and then the flowing molten metal is dropped into the gas receiving container 3 through the center of the gas nozzle 12. Then, when the molten metal passes through the inert gas flow AF ejected from the plurality of ejection ports Po of the gas nozzle 12, it is atomized and disperses into the interior of the gas receiving container 3. The metal powder is then collected in the recovery container 4 connected to the bottom of the gas receiving container 3 by a tube. The metal powder collected in the recovery container 4 is then sieved in the next step to be classified and separated into particle size ranges suited to the intended use.

<Features of the gas atomization device according to the present embodiment>

[0024] In the gas atomization device 10 according to the present embodiment, the vertical distance De from the gas ejection ports Po to the focal point FP is longer than the vertical distance Db from the gas ejection ports Po to the lower end of the flow path WY. Thus, during the atomization of molten metal, adhesion of unsolidified metal powder is unlikely to occur, enabling the continuous production of fine-particle metal powder over a relatively long period.

<Modification>

[0025]

(A)

In the gas atomization device 10 according to the previous embodiment, only one approximately annular gas nozzle 12 is provided, and the plurality of gas ejection ports Po are formed in it; however, a plurality of block-shaped gas nozzles each having one gas ejection port Po may be arranged around the lower extension line of the axis of the high-frequency induction coil 11.

(B)

In the gas atomization device 10 according to the previous embodiment, the flow path WY is formed by the suction tube 13, but the flow path WY may be formed by a block body or the like having a through hole formed therein.

(C)

Although not specifically mentioned in the above embodiment, the suction tube 13 may not be a straight tube, but may have a shape that widens in diameter toward the lower end. In addition, a tube having an inner diameter larger than that of the suction tube 13 may be attached to the lower end of the suction tube 13, or a skirt portion that expands in diameter from the lower end of the suction tube 13 may be provided.

[0026] The present invention will be described in more detail below based on examples and comparative examples. Note that these examples do not limit the present invention.

WORKING EXAMPLE 1

[0027] In the gas atomization device 10 shown in FIGS. 1 and 2, the vertical distance Db from the gas ejection ports Po to the lower end of the suction tube 13 was set to 35 mm, the vertical distance De from the gas ejection ports Po to the focal point FP was set to 46 mm, and the inner diameter of the suction tube 13 was set to 160 mm; the Ti-6Al-4V alloy was atomized using the metal powder manufacturing device 1 shown in FIG. 1.

[0028] In this case, argon gas was used as the gas. As a result, Ti-6Al-4V alloy powder with an average particle size (D50) of 37.1 μ m could be continuously produced over a relatively long period of time (see Table 1).

WORKING EXAMPLE 2

[0029] The Ti-6Al-4V alloy was atomized under the same conditions as in WORKING EXAMPLE 1, except that the inner diameter of the suction tube 13 was changed to 50 mm. As a result, Ti-6Al-4V alloy powder with an average particle size (D50) of 31.4 μ m could be continuously produced over a relatively long period of time (see Table 1).

WORKING EXAMPLE 3

[0030] The Ti-6Al-4V alloy was atomized under the same conditions as in WORKING EXAMPLE 1, except that the vertical distance Db from the gas ejection ports Po to the lower end of the suction tube 13 was changed to 20 mm. As a result, Ti-6Al-4V alloy powder with an average particle size (D50) of 38.3 μ m could be continuously produced over a relatively long period of time (see Table 1).

WORKING EXAMPLE 4

[0031] The Ti-6Al-4V alloy was atomized under the same conditions as in WORKING EXAMPLE 1, except that the vertical distance Db from the gas ejection ports Po to the lower end of the suction tube 13 was changed to 20 mm and the inner diameter of the suction tube 13 was changed to 50 mm. As a result, Ti-6Al-4V alloy powder with an average particle size (D50) of 33.0 μ m could be continuously produced over a relatively long period of time (see Table 1).

(COMPARATIVE EXAMPLE 1)

[0032] The Ti-6Al-4V alloy was atomized under the same conditions as in WORKING EXAMPLE 1, except that the vertical distance Db from the gas ejection ports Po to the lower end of the suction tube 13 was changed to 70 mm. As a result, the suction tube 13 became clogged with unsolidified Ti-6Al-4V alloy powder in a relatively short time after the start of the process, making it impossible to continuously produce Ti-6Al-4V alloy powder (see Table 1).

(COMPARATIVE EXAMPLE 2)

[0033] The Ti-6Al-4V alloy was atomized under the same conditions as in WORKING EXAMPLE 1, except that the vertical distance D_b from the gas ejection ports P_o to the lower end of the suction tube 13 was changed to 70 mm and the inner diameter of the suction tube 13 was changed to 50 mm. As a result, the suction tube 13 became clogged with unsolidified Ti-6Al-4V alloy powder in a relatively short time after the start of the process, making it impossible to continuously produce Ti-6Al-4V alloy powder (see Table 1).

[Table 1]

	Distance to the focal point (mm)	Distance to the lower end of the suction tube (mm)	Inner diameter of the suction tube (mm)	Average particle size D50 (μm)
WORKING EXAMPLE 1	46	35	160	37.1
WORKING EXAMPLE 2	46	35	50	31.4
WORKING EXAMPLE 3	46	20	160	38.3
WORKING EXAMPLE 4	46	20	50	33.0
COMPARATIVE EXAMPLE 1	46	70	160	---
COMPARATIVE EXAMPLE 2	46	70	50	---

(Summary)

[0034] In WORKING EXAMPLES 1 to 4, in which the vertical distance D_e from the gas ejection ports P_o to the focal point FP was longer than the vertical distance D_b from the gas ejection ports P_o to the lower end of the suction tube 13, small particle size Ti-6Al-4V alloy powder could be continuously produced over a relatively long period of time. Conversely, in COMPARATIVE EXAMPLES 1 and 2, in which the vertical distance D_e from the gas ejection ports P_o to the focal point FP was shorter than the vertical distance D_b from the gas ejection ports P_o to the lower end of the suction tube 13, the suction tube 13 became clogged with unsolidified Ti-6Al-4V alloy powder within a relatively short period of time after the start of the process, and continuous production of Ti-6Al-4V alloy powder was not possible.

Claims**1.** A gas atomization device comprising:

a gas nozzle having a plurality of ejection ports and ejecting gas from the ejection ports toward a focal point;
 a molten metal supply unit that supplies molten metal from above the focal point in a vertical direction toward the focal point; and
 a flow path extending downward from a lower end of the gas nozzle so as to surround the ejection ports in a plan view,
 wherein a vertical distance from the gas ejection port to the focal point is longer than a vertical distance from the gas ejection port to a lower end of the flow path.

2. The gas atomization device according to claim 1,
 wherein the diameter of the flow path is within a range from 40 mm or more to 160 mm or less.**3.** A gas atomization method comprising:

in a gas atomization device including: a gas nozzle having a plurality of ejection ports and ejecting gas from the ejection ports toward a focal point, a molten metal supply unit supplying molten metal from above the focal point in a vertical direction toward the focal point; and a flow path extending downward from a lower end of the gas nozzle so as to surround the ejection ports in a plan view,
 performing gas atomization with a vertical distance from the gas ejection port to the focal point set longer than a vertical distance from the gas ejection port to the lower end of the flow path.

Fig. 1

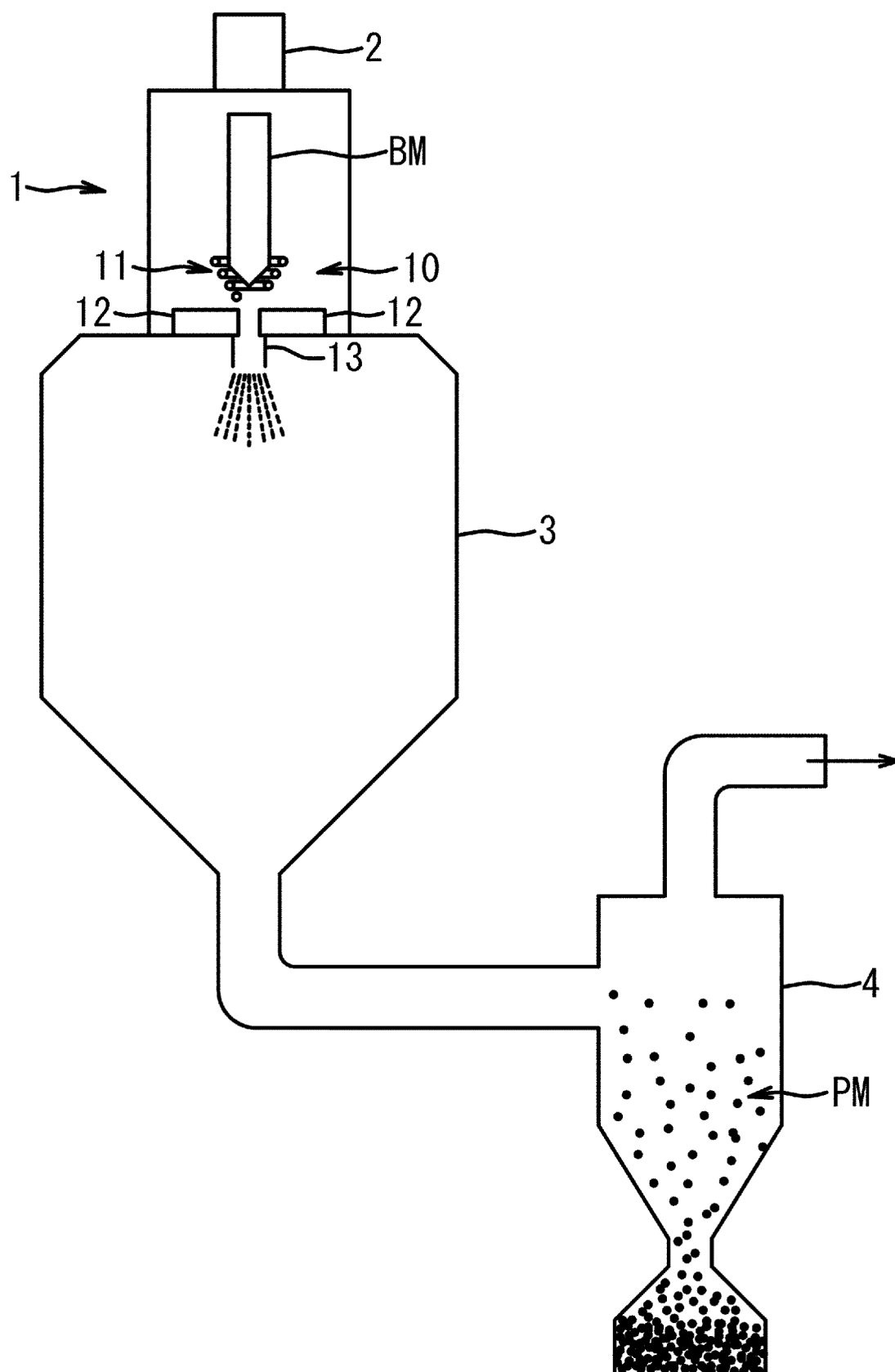
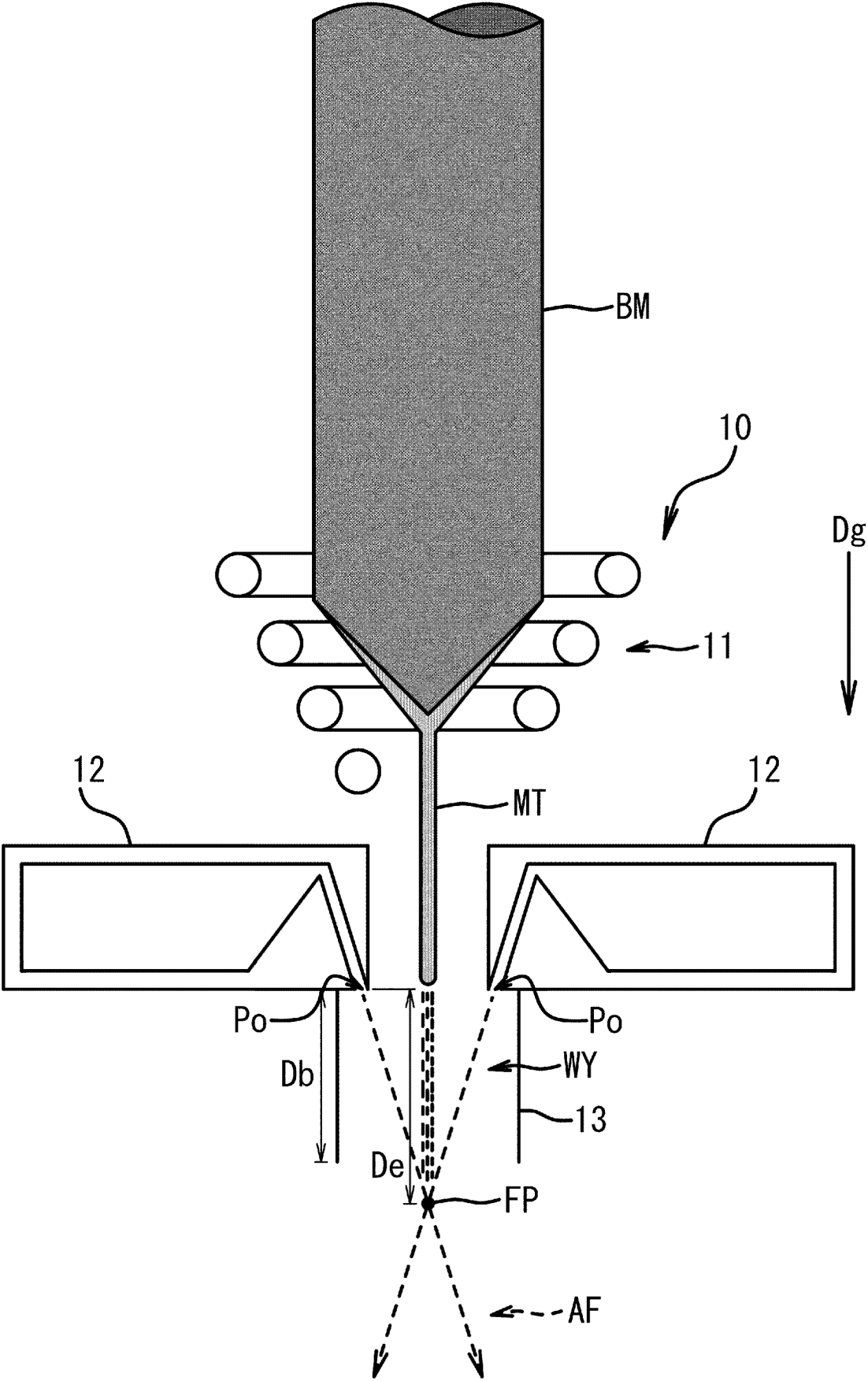


Fig. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/018507

A. CLASSIFICATION OF SUBJECT MATTER

B22F 9/08(2006.01)i

FI: B22F9/08 A

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)

B22F9/08

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 1971-2024

Registered utility model specifications of Japan 1996-2024

Published registered utility model applications of Japan 1994-2024

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 62-182211 A (SUMITOMO METAL INDUSTRIES, LTD.) 10 August 1987 (1987-08-10) entire text	1-3
A	KR 10-2308087 B1 (PARK, Yo-Seol) 01 October 2021 (2021-10-01) entire text	1-3

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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	62-182211	A	10 August 1987	(Family: none)	
KR	10-2308087	B1	01 October 2021	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2002241807 A [0004]

Non-patent literature cited in the description

- **TORU TAKEDA ; KAZUMI MINAGAWA.** Decompressed Gas Atomization of Bronze. *Abstracts of Lectures by the Japan Society of Powder and Powder Metallurgy*, 1990, 28-29 [0005]
- **TADANORI KOJIMA ; YOSHIHIRO MATSUOKA.** Study on Interference of Underexpanded Jets. *Transactions of the Society of Mechanical Engineers*, 1989 (88-0469B), 188-193 [0005]