



(11)

EP 4 582 565 A1

(12)

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

(43) Date of publication:
09.07.2025 Bulletin 2025/28

(21) Application number: **23859907.0**

(22) Date of filing: **25.07.2023**

(51) International Patent Classification (IPC):
C21D 8/12 (2006.01) **C22C 30/00** (2006.01)
C22C 19/07 (2006.01) **C22C 38/00** (2006.01)
C22F 1/00 (2006.01) **C22F 1/10** (2006.01)

(52) Cooperative Patent Classification (CPC):
C21D 8/12; C22C 19/07; C22C 30/00; C22C 38/00;
C22F 1/10; C22F 1/00

(86) International application number:
PCT/JP2023/027225

(87) International publication number:
WO 2024/048138 (07.03.2024 Gazette 2024/10)

(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 ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **31.08.2022 JP 2022138727**

(71) Applicant: **Proterial, Ltd.**
Tokyo 135-0061 (JP)

(72) Inventors:
• **KATO, Daiki**
Tokyo 135-0061 (JP)
• **UESAKA, Shujiro**
Tokyo 135-0061 (JP)

(74) Representative: **Winter, Brandl - Partnerschaft**
mbB
Alois-Steinecker-Straße 22
85354 Freising (DE)

(54) **METHOD FOR PRODUCING FE-CO-BASED ALLOY ROD, AND FE-CO-BASED ALLOY ROD**

(57) The present invention provides: an Fe-Co-based alloy rod which is capable of suppressing variation in the magnetic characteristics of a long rod; and a method for producing this Fe-Co-based alloy rod. A method for producing an Fe-Co-based alloy rod, the method comprising a hot rolling step in which an Fe-Co-based alloy billet is subjected to hot rolling so as to obtain a hot rolled rod that has a length of 2 m or more, and a heating straightening step in which a tensile stress is applied to the hot rolled rod so that the area reduction ratio of the rod is 2.0% to 8.0%, while heating the hot rolled rod to 500°C to 900°C, without having a solution heat treatment between the hot rolling step and the heating straightening step; and an Fe-Co-based alloy rod.

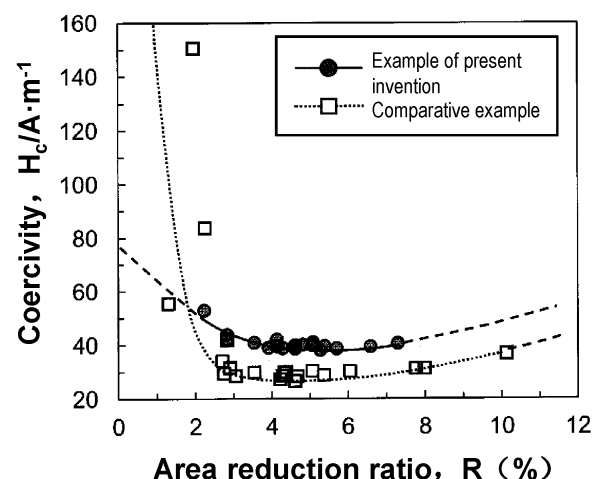


FIG. 5

Description

Technical Field

5 **[0001]** The present invention relates to a method for producing an Fe-Co-based alloy rod and an Fe-Co-based alloy rod.

Related Art

10 **[0002]** Fe-Co-based alloy rods, represented by Permendur, are known as alloys to have excellent magnetic properties are used in various products such as sensors, cylindrical magnetic shields, electromagnetic valves, and magnetic cores. As a method for producing the Fe-Co-based alloy rods, for example, Patent Document 1 describes that an ingot is heated to 1000°C to 1100°C, hot-worked into a billet of about $\phi 90$ mm, removing surface defects by lathe, then heated again to 1000°C to 1100°C, and hot-rolled to produce a material (rod) of about $\phi 6$ to $\phi 9$ mm.

15 **[0003]** Moreover, in Patent Document 2, the applicant of the present invention proposes an Fe-Co-based alloy rod, which can stably obtain excellent magnetic properties and has 20% or more crystal grains having a GOS (Grain Orientation Spread) value of 0.5° or more in area ratio; and a method for producing the Fe-Co-based alloy rod, which includes a heating and straightening step that applies tensile stress while heating the hot-rolled material to a temperature of 500 to 900°C.

Citation List

20

Patent Literature

[0004]

25 Patent Document 1: Japanese Patent Application Laid-Open Publication No. H07-166239
Patent Document 2: International Publication No. WO 2021/182518

SUMMARY OF INVENTION

30 Technical Problem

[0005] The Fe-Co-based alloy rod described in Japanese Patent Application Laid-Open Publication No. 2 possesses excellent magnetic properties and is a highly useful invention. On the other hand, according to the investigation by the applicant of the present invention, it was confirmed that in the case of long rods of 2m or more, there are instances where
35 magnetic properties vary along the length direction of the rod. Obtaining stable magnetic properties throughout such long rods is not described in Patent Document 1 or Patent Document 2, leaving room for further investigation.

[0006] Therefore, the purpose of the present invention is to provide an Fe-Co-based alloy rod and the method for producing the same capable of suppressing variations in magnetic properties in long rods.

40 Solution to Problem

[0007] The present invention has been made in view of the above-mentioned problems.

[0008] In other words, one aspect of the present invention is a method for producing Fe-Co-based alloy rod, which includes a hot-rolling step of performing hot-rolling on an Fe-Co-based alloy billet to obtain a hot-rolled rod with a length of
45 2m or more; and a heating and straightening step of applying tensile stress while heating the hot-rolled rod to 500 to 900°C such that an area reduction ratio of the rod becomes 2.0 to 8.0%, in which no solution treatment is performed between the hot-rolling step and the heating and straightening step.

[0009] Another aspect of the present invention is an Fe-Co-based alloy rod having an average GOS (Grain Orientation Spread) of 0.3° or more and 1.5° or less, an average grain size number measured on an axial cross-section of the rod of 8.0
50 or more and 12.0 or less, and a length of 2m or more.

Effects of Invention

[0010] According to the present invention, it is possible to obtain an Fe-Co-based alloy rod in which variations in
55 magnetic properties are suppressed in long rods.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

[FIG. 1] A diagram showing the area reduction ratio of samples in example of the present invention.
 [FIG. 2] A diagram showing the area reduction ratio of samples in the comparative example.
 [FIG. 3] A diagram showing the coercivity distribution of samples in example of the present invention.
 [FIG. 4] A diagram showing the coercivity distribution of samples in the comparative example.
 [FIG. 5] A diagram showing the relationship between the area reduction ratio and coercivity in samples of example of the present invention and the comparative example.

DESCRIPTION OF THE EMBODIMENTS

[0012] The following describes embodiments of the present invention. First, the method for producing the Fe-Co-based alloy rod of the present invention is described. The Fe-Co-based alloy rod of the present invention is a straight rod including those with circular (including elliptical) or rectangular cross-sectional shapes. Unless otherwise specified, the rod in this embodiment is a round rod with a circular cross-sectional shape.

<Hot-rolled material composition>

[0013] First, in this embodiment, a hot-rolled material of Fe-Co-based alloy is prepared. In the present invention, Fe-Co-based alloy refers to an alloy material containing 95% or more of Fe+Co in mass%, and containing 25 to 60% of Co. This enables the achievement of high magnetic flux density.

[0014] Next, elements that may be contained in the Fe-Co-based alloy of the present invention are described. To improve workability and magnetic properties, the Fe-Co-based alloy of the present invention may contain one or two or more elements from V, Si, Mn, Al, Zr, B, Ni, Ta, Nb, W, Ti, Mo, and Cr, up to a total of 5.0% in mass%. In addition, impurity elements that are inevitably contained, such as C, S, P, and O, may be mentioned, and it is preferable to set the upper limit of each of these to 0.1%.

<Hot-rolling step>

[0015] In this embodiment, as an intermediate material for the Fe-Co-based alloy rod, hot-rolling is applied to a columnar Fe-Co-based alloy billet of approximately $\phi 90\text{mm}$ obtained from an Fe-Co-based alloy steel ingot having the aforementioned components, to obtain a hot-rolled rod. Since an oxide layer is formed on this intermediate material due to hot-rolling, a grinding step may be introduced to remove the oxide layer mechanically or chemically. In addition, the present invention targets hot-rolled rods with a length of 2m or more. The longer the hot-rolled rod, the higher the productivity in the heating and straightening step, but on the other hand, the longer it is, the more likely variations in magnetic properties occur along the length direction of the rod. According to the production method of the present invention, it is possible to suppress variations in magnetic properties even in such long rods. Considering the workability in subsequent steps, it is preferable to set the diameter of the hot-rolled rod to 5 to 20mm. For rods other than round rods, the area-circle equivalent diameter of the cross-section may be set to 5 to 20mm.

[0016] In this embodiment, solution treatment is not performed during the transition from the hot-rolling step to the heating and straightening step to be described later. In the case where solution treatment is performed, crystal grain growth progresses during the solution treatment, reducing grain boundaries that become recrystallization nucleation sites, making it difficult to promote recrystallization during magnetic annealing, and in low area reduction ratio parts with an area reduction ratio of 2.5% or less, a mixed grain structure containing unrecrystallized grains is formed, causing extreme deterioration of magnetic properties. Moreover, in the case where solution treatment is performed, bending may occur in the rod due to thermal contraction. When correcting the bending with press straightening to be described later, it becomes difficult to obtain a stable area reduction ratio due to work hardening caused by local strain. In the case where no solution treatment is performed, by suppressing crystal grain growth before the heating and straightening step, recrystallization during magnetic annealing can be promoted. This allows for stable magnetic properties with less variation in crystal grain diameter during magnetic annealing, even in regions with an area reduction ratio of 2.0 to 2.5%. Here, solution treatment refers to a step of heating the hot-rolled rod to a temperature exceeding the order-disorder transformation point (for example, 750 to 1050°C) followed by rapid cooling, and the area reduction ratio is the ratio calculated by dividing the difference in area before and after the heating and straightening step by the area before the heating and straightening step.

[0017] Before transitioning to the heating and straightening step to be described later, press straightening may be performed to adjust the shape of the rod within a range that does not deviate from the area reduction ratio range of the present invention. Press straightening allows for prompt implementation of the subsequent heating and straightening step.

Moreover, in the case where solution treatment is not performed as in the present invention, excessive bending tends not to occur, so it is preferable that press straightening with high processing rate is not performed. By not performing press straightening, a stable area reduction ratio can be obtained in the heating and straightening step.

<Heating and straightening step>

[0018] In this embodiment, a heating and straightening step is performed on the aforementioned hot-rolled material, applying tensile stress while heating. At this time, if the hot-rolled material is in the shape of a "rod", this tensile stress is applied by pulling the hot-rolled rod in its length direction. This step allows for obtaining a rod with excellent magnetic properties and straightness while imparting residual strain to the hot-rolled material. The heating temperature at this time is set to 500 to 900°C. In the case where the temperature is lower than 500°C, workability decreases, and there is a risk of the rod breaking when applying tensile stress. On the other hand, in the case where the heating temperature exceeds 900°C, it becomes impossible to impart desirable residual strain to the hot-rolled material. The preferable lower limit of the heating temperature in the heating and straightening step is 600°C, and more preferably 700°C. Moreover, the preferable upper limit of the heating temperature is 850°C, more preferably 830°C, and even more preferably 800°C. Further, in the case where the aforementioned solution treatment step is omitted, the preferable lower limit of the heating temperature is 700°C, more preferably 730°C, and even more preferably 740°C.

[0019] In this embodiment, it is characteristic to adjust the area reduction ratio of the rod in this heating and straightening step to 2.0 to 8.0%. This imparts strain to the rod, which acts as the driving force for obtaining coarse crystal grains, and makes it possible to obtain a rod with less variation in magnetic properties. This strain may be represented by the GOS average value to be described later. The preferable lower limit of the area reduction ratio is 2.2%, more preferably 2.5%, and the preferable upper limit of the area reduction ratio is 7.5%. The area reduction ratio of the present invention is calculated by measuring the diameter before the heating and straightening step and the diameter after the heating and straightening step using a micrometer, and the diameter is measured at multiple locations at equal intervals along the rod axial direction. In this embodiment, measurements are taken at 28 locations at equal intervals along the rod axial direction to obtain the area reduction ratio distribution within a single rod.

[0020] For this heating and straightening step, heating means such as electric heating or induction heating may be used. However, it is preferable to apply electric heating due to its advantages of being able to heat the material rapidly (for example, within 1 minute) and uniformly to a target temperature while obtaining the effect of easily aligning the easy magnetization axis of crystal grains in the hot-rolled material in a constant direction. Moreover, it is preferable to adjust the tensile load applied to the rod during the heating and straightening step to 4 to 90 kN in order to more reliably obtain the desired residual strain. Moreover, it is preferable to adjust the elongation to 3 to 10% of the total length before the heating and straightening step. The Fe-Co-based alloy rod obtained by the production method of the present invention can have an area reduction ratio of 2.0 to 8.0% by appropriately adjusting these values while omitting the solution treatment.

[0021] Moreover, in the heating and straightening step using electric heating applied in the present invention, the chucking part is at an equal voltage and no current flows, so the temperature does not rise in the chucking part. Moreover, since the rod is mechanically constrained, almost no elongation occurs in the chucking part, which is a portion to be cut and removed in a later step. Therefore, in the present invention, the area reduction ratio within the range of up to 250 mm from the rod end, where the influence of the chucking part in the heating and straightening step is significant, is not considered. Alternatively, it may be said that in the method for producing the Fe-Co-based alloy rod of the present invention, it is sufficient if the area reduction ratio of 2.0 to 8.0% mentioned above is achieved over at least a continuous length of 2m of the rod.

[0022] In this embodiment, centerless grinding using, for example, a centerless grinder may be performed on the rod after completing the heating and straightening step. This allows for the removal of the black skin on the surface of the rod and further improves the roundness and tolerance accuracy of the shape. In the present invention, since the straightness of the rod is improved by the heating and straightening step, centerless grinding may be performed on long rods with a length of 2m or more without cutting them.

[0023] Next, the Fe-Co-based alloy rod of the present invention that may be obtained by production method of the present invention mentioned above will be described. The Fe-Co-based alloy rod of the present invention has an average Grain Orientation Spread (GOS) value of 0.3° to 1.5°. The preferable lower limit of the GOS average value is 0.5°, and the preferable upper limit of the GOS average value is 1.2°. The GOS value may be measured by the conventionally known "SEM-EBSD (scanned electron microscope-electron backscatter diffraction) method". Specifically, the GOS value of a crystal grain may be calculated by computing the average orientation difference between one point (pixel) constituting the crystal grain and all other points within the crystal grain, performing this operation for all points within the crystal grain, and then calculating the average value. Since the GOS value is determined for each crystal grain, two types of averages may be considered: the numerical average and the area average. The GOS average value referred to in the present invention indicates the area average. The area average is a value calculated by summing up the GOS of crystal grains present in the measurement field of view, weighted by the area ratio occupied by each crystal grain in the field of view. The GOS average

value may be used as an indicator of the strain imparted to the alloy by processing, so by setting the GOS average value to 0.3° to 1.5° , an appropriate strain that becomes the driving force for recrystallization to obtain coarse crystal grains is introduced into the rod, resulting in good magnetic properties. In the case where the GOS average value is less than 0.3° , the driving force for recrystallization is insufficient in the rod, leaving unrecrystallized grain regions that adversely affect the magnetic properties, and good magnetic properties cannot be obtained. Further, in the case where the GOS average value exceeds 1.5° , excessive tensile stress is applied to the rod, making it easier to reduce the area locally, which may result in disadvantages such as unstable magnetic properties throughout the rod. In addition, the cross-section for observing the GOS average value may be either the cross-section perpendicular to the axis or the axial cross-section; observation is also possible in the axial cross-section of the rod. It is preferable that the GOS average value is 0.3° to 1.5° in both cases when observed in the cross-section perpendicular to the axis and the axial cross-section of the rod.

[0024] The Fe-Co-based alloy rod of the present invention preferably has an average grain size number of 8.0 or more and 12.0 or less. This increases the grain boundaries or triple points that become recrystallization nucleation sites during magnetic annealing, making recrystallization more likely to occur, thus making it easier to exhibit stable magnetic properties. A more preferable lower limit of the average grain size number is 8.5, and a more preferable upper limit of the average grain size number is 11.5. An even more preferable lower limit of the average grain size number is 9.0, and an even more preferable upper limit of the average grain size number is 11.0. The average grain size number may be measured based on JIS (Japanese Industrial Standards) G 0551. Moreover, it may be measured in the axial cross-section of the rod. Alternatively, it may be measured in the cross-section perpendicular to the axis or the axial cross-section of the rod.

[0025] Further, in the Fe-Co-based alloy rod of the present invention, it is preferable that the aforementioned GOS average value and average grain size number are satisfied throughout the entire length of 2m or more. However, it may also be said that it is sufficient if these are satisfied in a continuous length range of at least 2m within the rod.

Implementation Example 1

(Implementation Example 1)

[0026] An Fe-Co-based alloy steel ingot having the composition shown in Table 1 was bloomed, and then hot-rolling was performed to prepare a hot-rolled rod with a diameter of $\phi 11.8$ mm and a length of 2900 mm.

<Sample No. 1 to 3>

[0027] Without performing solution treatment on the aforementioned hot-rolled rod, a heating and straightening step was implemented by pulling the hot-rolled rod in its length direction under a condition of tensile load of 27 kN while heating the rod to a temperature of about 750°C , thereby producing Fe-Co-based alloy rods of Sample No. 1 to 3, which are examples of the present invention, with a length of 3050 mm.

<Sample No. 4 to 6>

[0028] After performing a solution treatment on the aforementioned hot-rolled rod by heating it to 850°C , holding for 30 minutes, and then rapidly cooling, a heating and straightening step was implemented to produce Fe-Co-based alloy rods of Sample No. 4 to 6, which are comparative examples, with a length of 3050 mm. The conditions for the heating and straightening step were set the same as those for Sample No. 1 to 3.

[Table 1]

(mass%)					
C	Si	Mn	Co	V	Residue
0.006	0.03	0.13	49.20	1.98	Fe and inevitable impurity

[0029] The area reduction ratio distribution was confirmed for the prepared samples of the examples of the present invention and comparative examples. The area reduction ratio was calculated by measuring the diameter before the heating and straightening step and after the heating and straightening step using a micrometer, and this diameter measurement was performed at 28 locations at equal intervals along the rod axial direction to obtain the distribution within a single rod. The distribution of the area reduction ratio within the rod is shown in FIG. 1 and FIG. 2. Moreover, in the heating and straightening step using electric heating, the chucking part is at an equal voltage and no current flows, so the temperature does not rise in the chucking part. In addition, because the chucking part is mechanically constrained, almost

no elongation occurs in the chucking part, which is a portion to be cut and removed in a later step. Therefore, the area reduction ratio in the range up to 250 mm from the rod end, where the influence of the chucking part in the heating and straightening step is significant, is not considered. The maximum value, minimum value, average value, and standard deviation of the area reduction ratio obtained from FIG. 1 and FIG. 2 are shown in Table 2. Here, the maximum value, minimum value, average value, and standard deviation of the area reduction ratio for examples of the present invention are derived from Sample No. 1 to 3, and the maximum value, minimum value, average value, and standard deviation of the area reduction ratio for the comparative examples are derived from Sample No. 4 to 6. From Table 2, it may be confirmed that although the average value of the area reduction ratio for examples of the present invention is almost the same as the average value of the comparative examples, the difference between the maximum value and the minimum value of the area reduction ratio for examples of the present invention is smaller, and the standard deviation is also smaller, indicating that the variation in the area reduction ratio is suppressed in examples of the present invention compared to the comparative examples.

[Table 2]

Sample	Area reduction ratio (%)			
	Maximum value	Minimum value	Average value	Standard deviation
Example of the present invention	7.3	2.2	4.5	1.1
Comparative example	10.1	1.3	4.3	2.0

[0030] Subsequently, the average grain size, GOS average value, and DC magnetic properties were confirmed for Sample No. 3 of example of the present invention and Sample No. 6 of the comparative example. The average grain size was determined using an optical microscope manufactured by Olympus, according to the comparison method of JIS G 0551. The GOS value measurement was performed using a field emission scanning electron microscope manufactured by ZEISS and the EBSD measurement and analysis system OIM (Orientation-Imaging-Micrograph) manufactured by TSL. The measurement field of view was $600\ \mu\text{m} \times 600\ \mu\text{m}$, the step distance between adjacent pixels was $1.5\ \mu\text{m}$, and the crystal grain diameter discrimination condition was observed with an orientation difference of 2° or more between adjacent pixels. The GOS average value was obtained from the resulting GOS value map. The average grain size and GOS average value were measured at the center axis position on the longitudinal cross-section (axial cross-section passing through the center axis). For the DC magnetic properties, after obtaining samples from the resulting rods, magnetic annealing was performed at 850°C for 3 hours, and the maximum permeability and coercivity were measured using a DC magnetization specific test device. These measurement results, along with the area reduction ratio at the sample collection positions, are shown in Table 3. The sample collection positions for example of the present invention and comparative example were 4 locations or 3 locations near the maximum value, the minimum value, and the center value of the area reduction ratio. From the results in Table 3, it may be confirmed that in example of the present invention, the average grain size number is larger than in the comparative example (crystal grain diameter is smaller than in the comparative example), and stable DC magnetic properties are obtained with respect to the fluctuation of the area reduction ratio and GOS average value (an indicator of strain), with suppressed variation.

[Table 3]

Sample No.	Area reduction ratio (%)	Average Grain size Number	GOS Average value ($^\circ$)	Coercivity (A/m)	Maximum relative permeability	Remark
3	2.8	10.5	0.63	44	15000	Example of the present invention
	4.1	9.5	0.68	42	17000	
	5.1	10.0	0.79	41	18000	
	7.3	9.5	0.98	41	19000	
6	1.3	7.0	0.56	56	12000	Comparative example
	4.4	7.0	0.92	30	26000	
	10.1	6.5	1.76	37	23000	

[0031] Next, the coercivity distribution was measured for Sample No. 2 of the example of the present invention and Sample No. 5 of the comparative example. The coercivity was measured using a DC magnetization specific test device

after collecting a sample for magnetic properties from the rod and performing magnetic annealing at 850°C for 3 hours. The distribution of coercivity and the distribution of area reduction ratio are shown together in FIG. 3 and FIG. 4. However, in FIG. 3 and FIG. 4, the measurement positions in the ranges from 0 to 250 mm and from 2800 mm to 3050 mm (shaded part in FIG. 3 and FIG. 4) are not considered because of the significant influence of the chucking. It was confirmed that in the comparative example, the coercivity becomes extremely large (deteriorates) in the parts with small area reduction ratio, whereas in the example of the present invention, the deterioration of coercivity in the parts with small area reduction ratio is suppressed, and stable coercivity is obtained with suppressed variation.

[0032] Next, FIG. 5 shows the relationship between the area reduction ratio and coercivity derived from the results in Table 3, FIG. 3, and FIG. 4 for example of the present invention and the comparative example. In the range where the area reduction ratio is 2.5% or more, the comparative example exhibits excellent coercivity. Example of the present invention also shows excellent coercivity, although not as good as the comparative example. In the range where the area reduction ratio is 2.5% or less, the comparative example shows a rapid deterioration in coercivity and very unstable coercivity. In example of the present invention, it can be confirmed that stable coercivity is obtained and variation is suppressed even in the range where the area reduction ratio is 2.0 to 2.5%.

Claims

1. A method for producing Fe-Co-based alloy rod, comprising:

a hot-rolling step of performing hot-rolling on an Fe-Co-based alloy billet to obtain a hot-rolled rod with a length of 2m or more; and
a heating and straightening step of applying tensile stress while heating the hot-rolled rod to 500 to 900°C such that an area reduction ratio of the rod becomes 2.0 to 8.0%,
wherein no solution treatment is performed between the hot-rolling step and the heating and straightening step.

2. An Fe-Co-based alloy rod having an average GOS (Grain Orientation Spread) of 0.3° or more and 1.5° or less, an average grain size number measured on an axial cross-section of the rod of 8.0 or more and 12.0 or less, and a length of 2m or more.

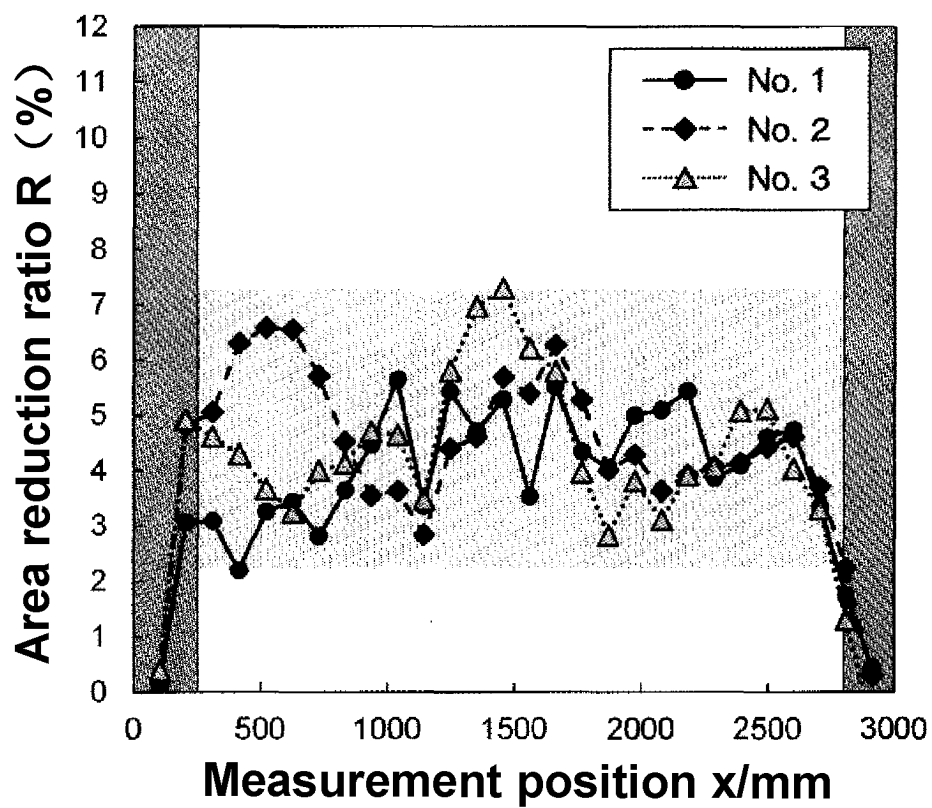


FIG. 1

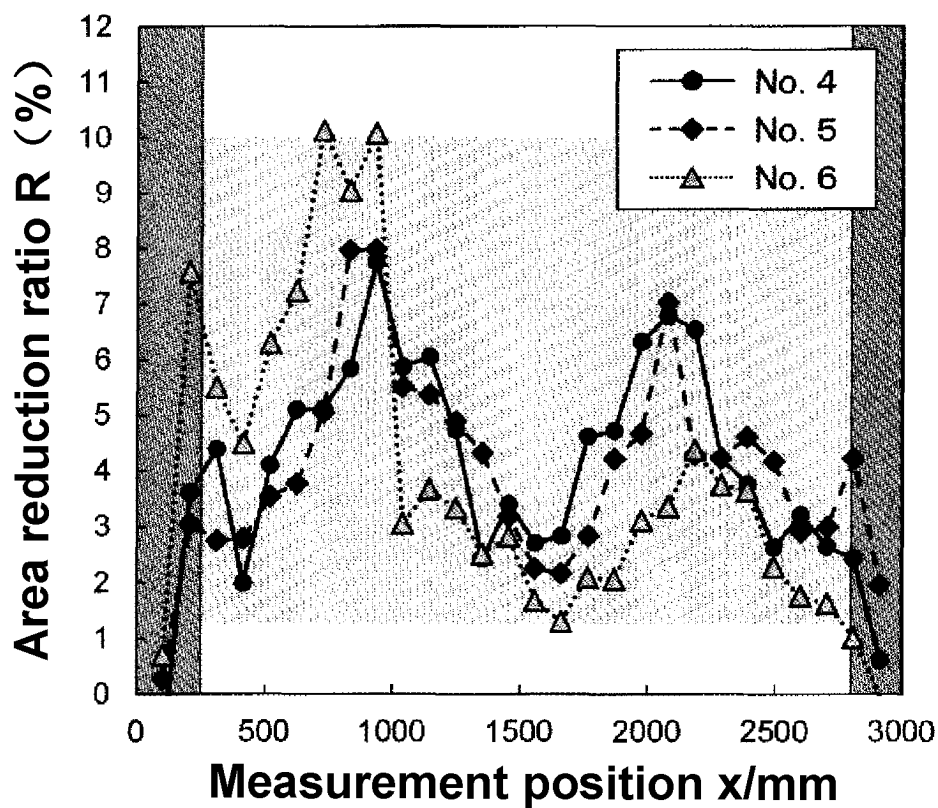


FIG. 2

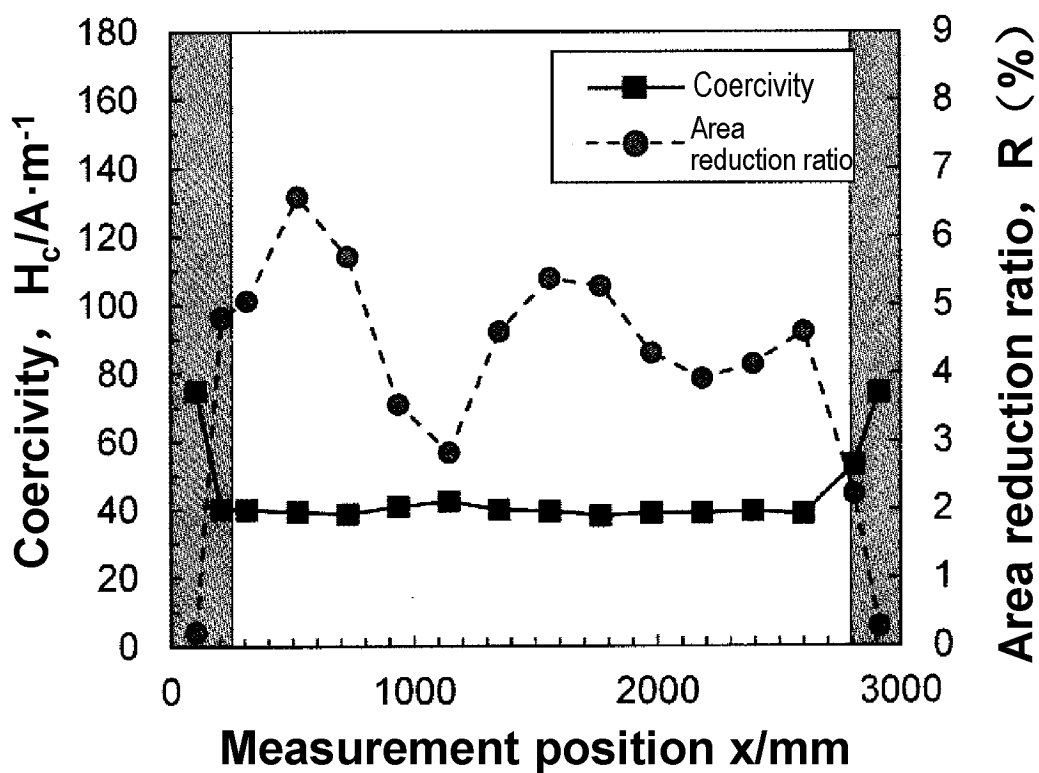


FIG. 3

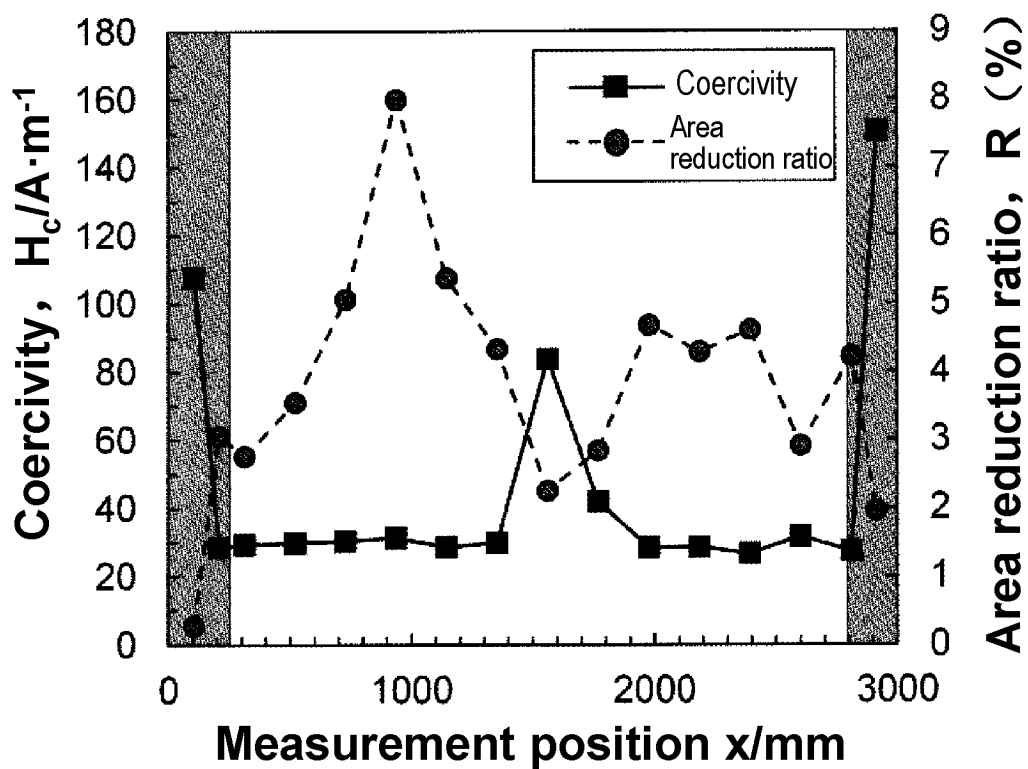


FIG. 4

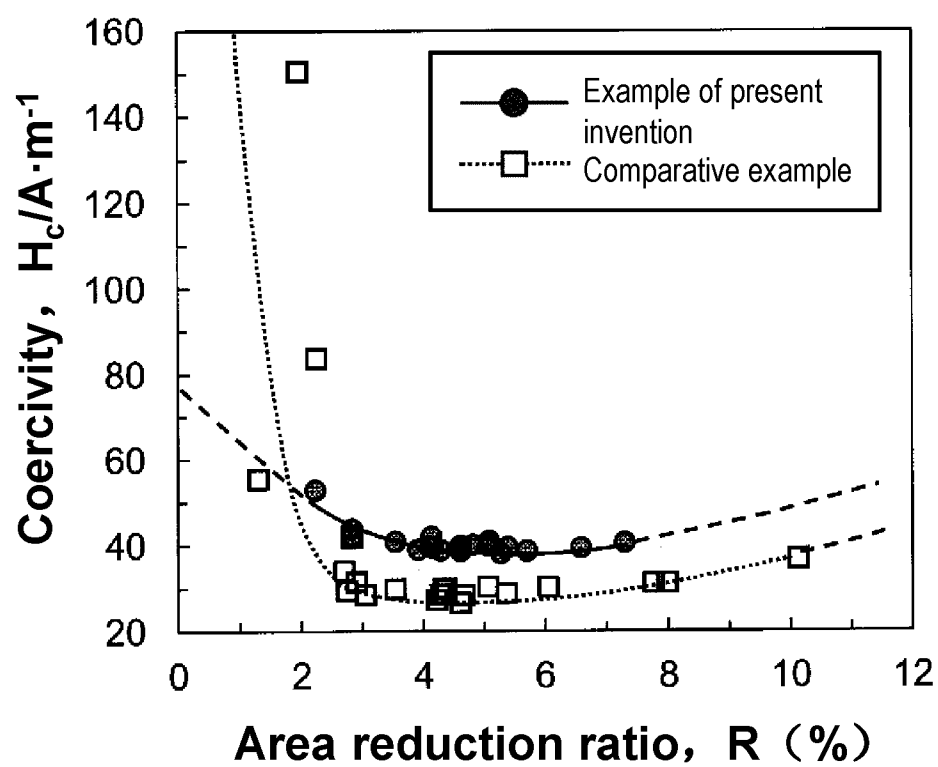


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/027225

A. CLASSIFICATION OF SUBJECT MATTER

C21D 8/12(2006.01)i; **C22C 30/00**(2006.01)i; **C22C 19/07**(2006.01)i; **C22C 38/00**(2006.01)i; **C22F 1/00**(2006.01)n;
C22F 1/10(2006.01)i

FI: C22F1/10 J; C21D8/12 F; C22C38/00 303S; C22C19/07 C; C22C30/00; C22F1/00 694B; C22F1/00 691B; C22F1/00 691Z; C22F1/00 694Z; C22F1/00 683; C22F1/00 694A; C22F1/00 624; C22F1/00 660C; C22F1/00 661Z

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)

C21D8/12; C22C30/00; C22C19/07; C22C38/00; C22F1/00; C22F1/10

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	WO 2021/182518 A1 (HITACHI METALS LTD) 16 September 2021 (2021-09-16) claims, paragraphs [0008]-[0020], table 1-2	1-2
A	JP 2004-515644 A (IMPHY UGINE PRECISION) 27 May 2004 (2004-05-27) entire text	1-2
A	US 2009/0184790 A1 (VACUUMSCHMELZE GMBH & CO. KG) 23 July 2009 (2009-07-23) entire text, all drawings	1-2

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

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search

04 October 2023

Date of mailing of the international search report

17 October 2023

Name and mailing address of the ISA/JP

**Japan Patent Office (ISA/JP)
 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
 Japan**

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2023/027225

5

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2021/182518 A1	16 September 2021	CN 115279926 A claims, paragraphs [0019]- [0048], tables 1-2	
JP 2004-515644 A	27 May 2004	US 2004/0099347 A1 entire text WO 2001/086665 A1 EP 1281182 A1 FR 2808806 A1 AU 6041201 A KR 10-0711188 B1 AT 465500 T ES 2342766 T3	
US 2009/0184790 A1	23 July 2009	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP H07166239 A [0004]
- WO 2021182518 A [0004]