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(54) **DEVICE FOR REMOVING FOREIGN MATTER FROM ROLL SURFACE, METHOD FOR REMOVING FOREIGN MATTER FROM ROLL SURFACE, AND METHOD FOR MANUFACTURING STEEL STRIP**

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(52) **U.S. Cl.**

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(57) **ABSTRACT**

A device for removing foreign matter from a roll surface. The device includes a blast processing unit and a press unit. The blast processing unit includes an ejection unit configured to eject a projectile material at a surface of a roll that conveys a steel strip inside a heating furnace, and a recovery unit configured to recover the projectile material. The press unit is configured to press the blast processing unit toward the surface of the roll.

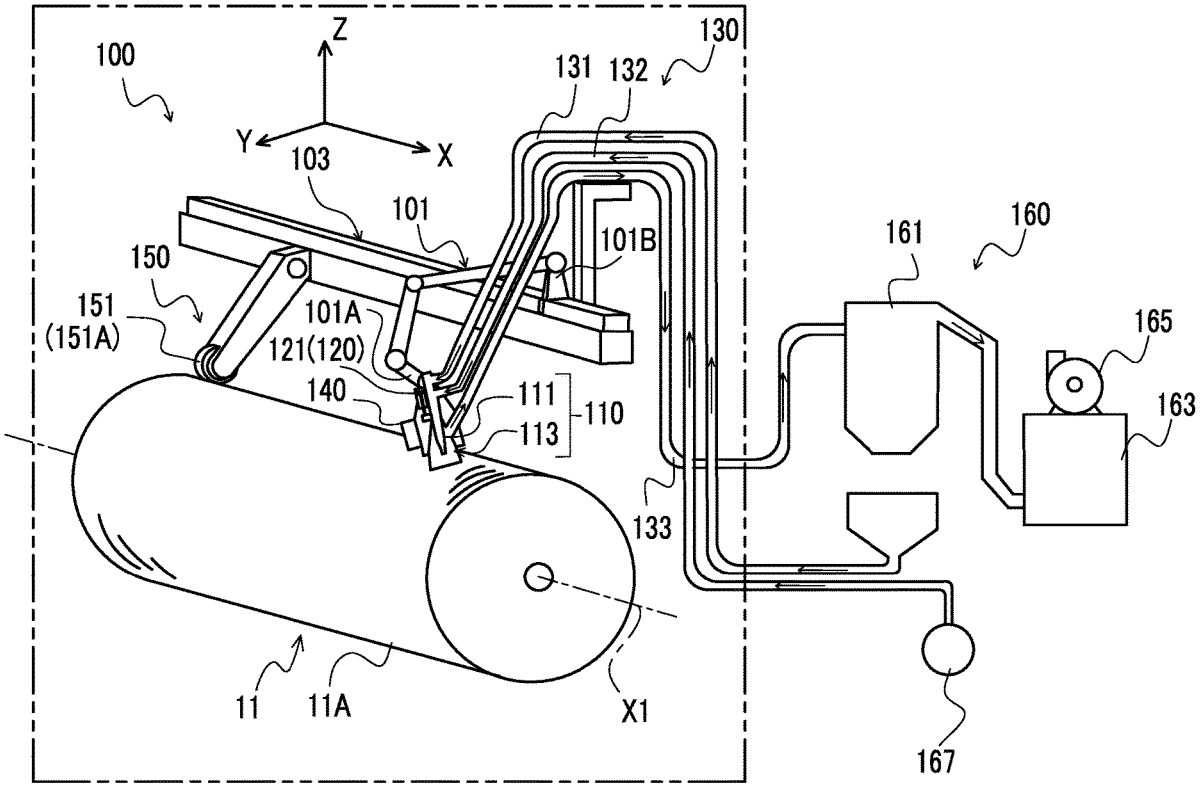


FIG.1

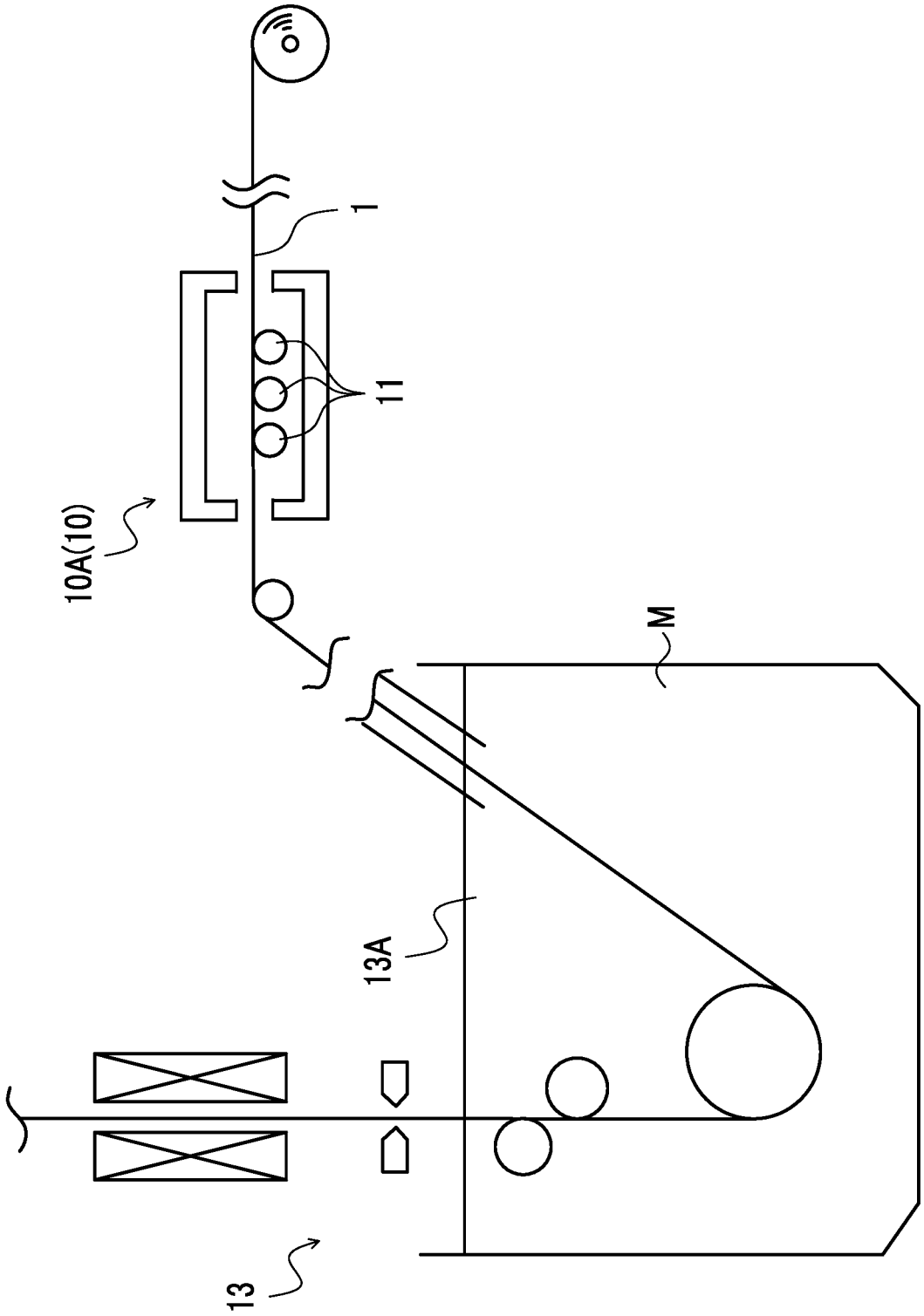


FIG.2

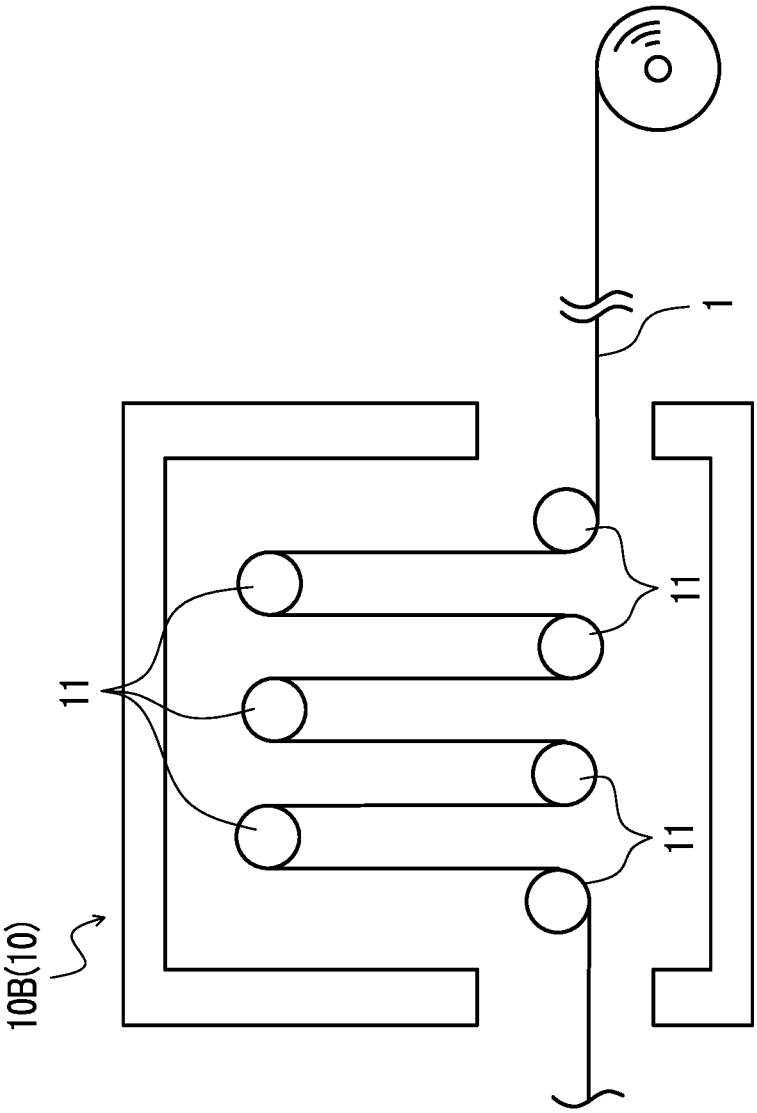


FIG.3

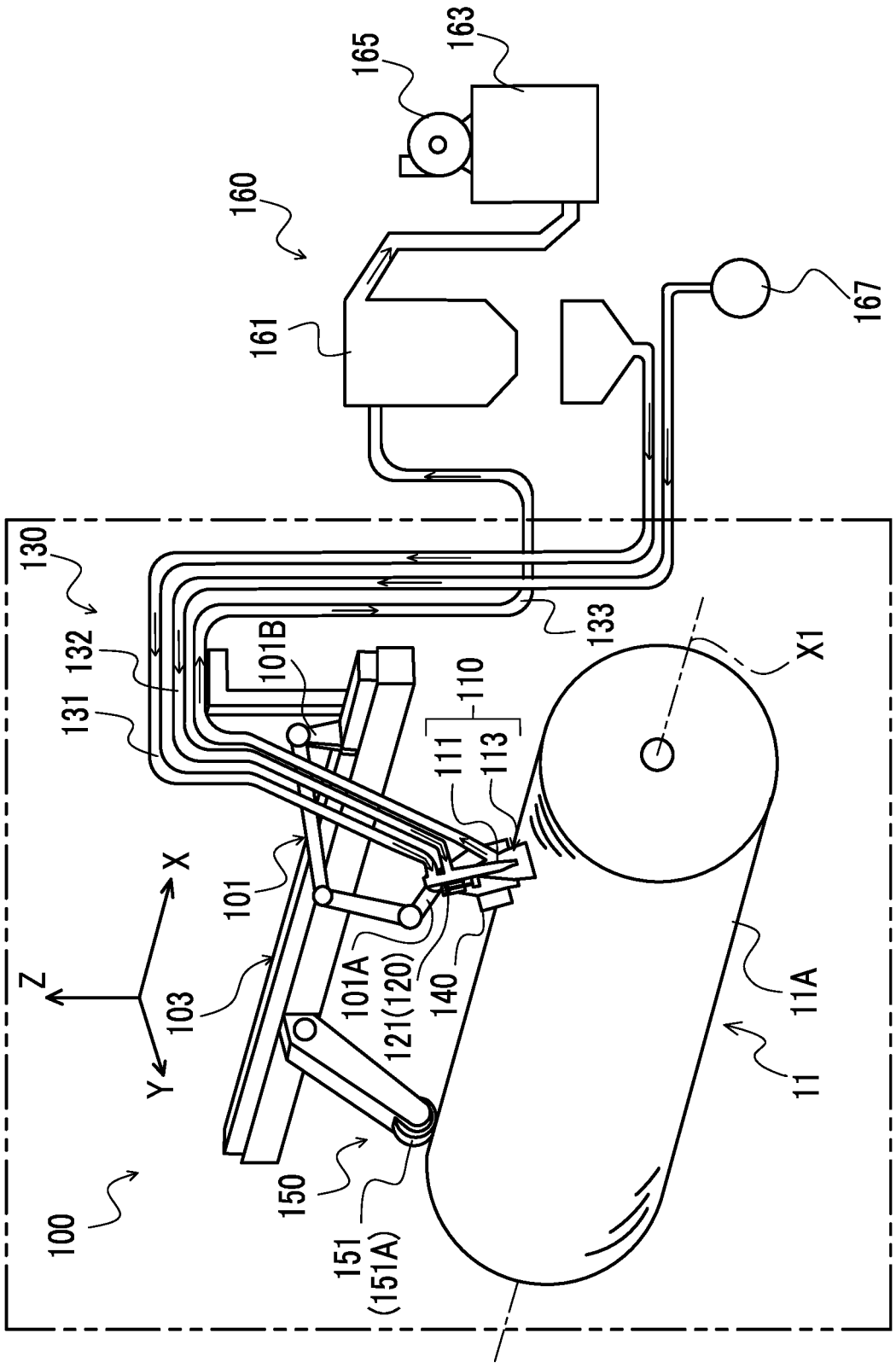

165
163
160
161
167
130
132
131
101B
133
X1
110
111
113
101
X
Z
Y
103
101A
121(120)
140
11A
11
100
150
151
(151A)

FIG.4

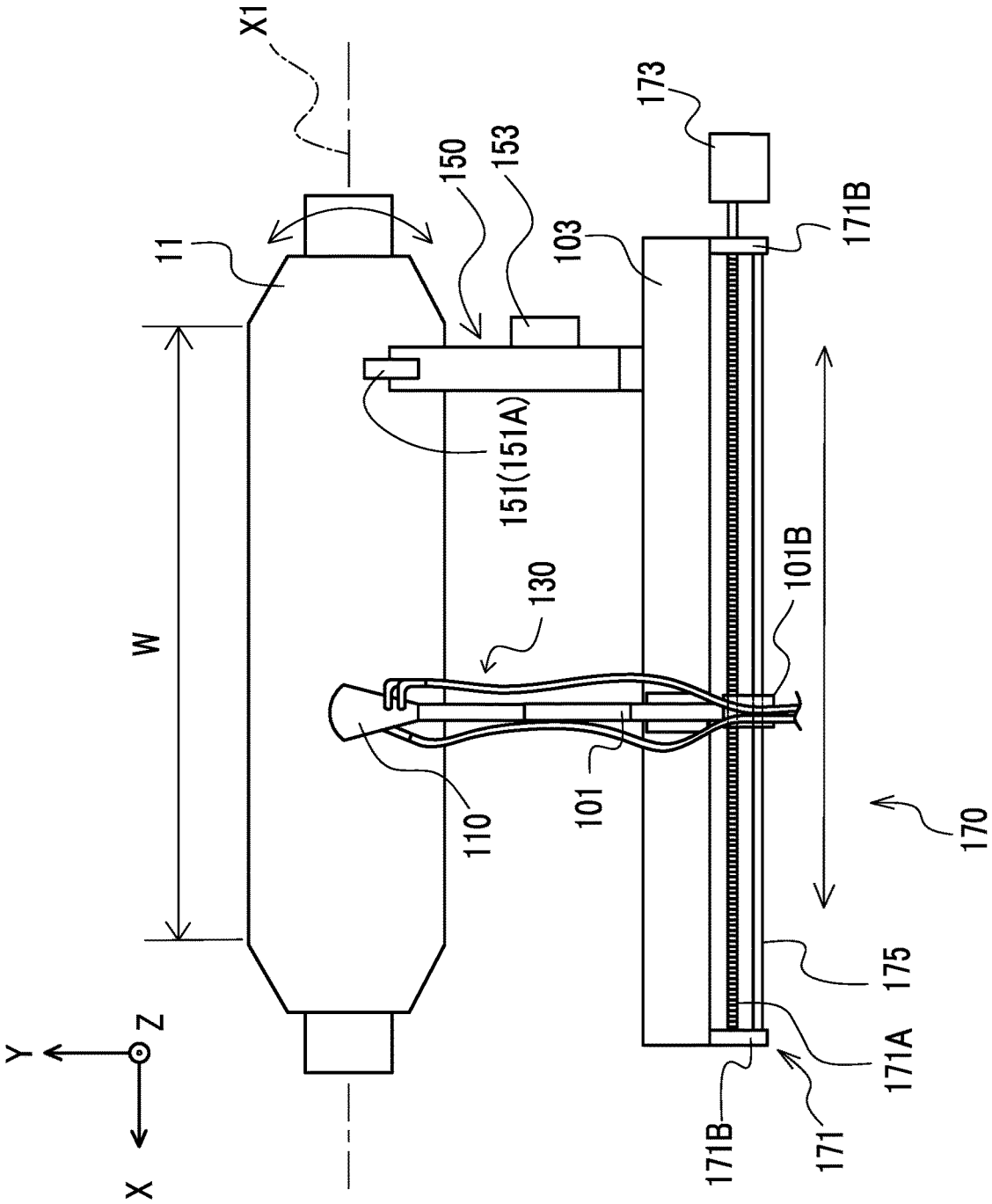

X1
150
153
173
11
103
171B
151(151A)
130
101B
W
110
101
170
175
171A
171B
171
Y
Z
X

FIG.5

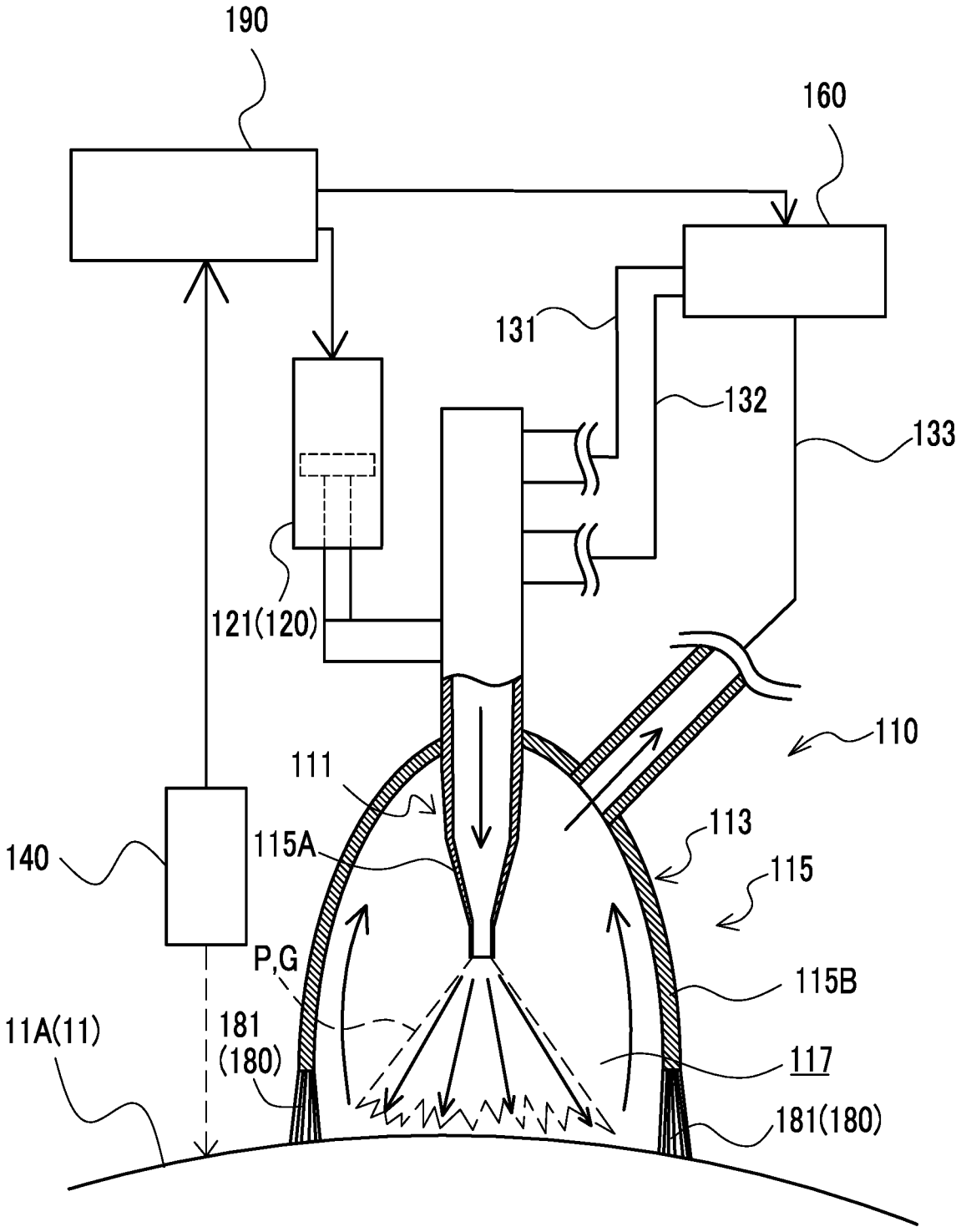

190
160
131
132
133
121(120)
110
111
113
115A
115
140
P,G
115B
11A(11)
181
(180)
117
181(180)

FIG.6

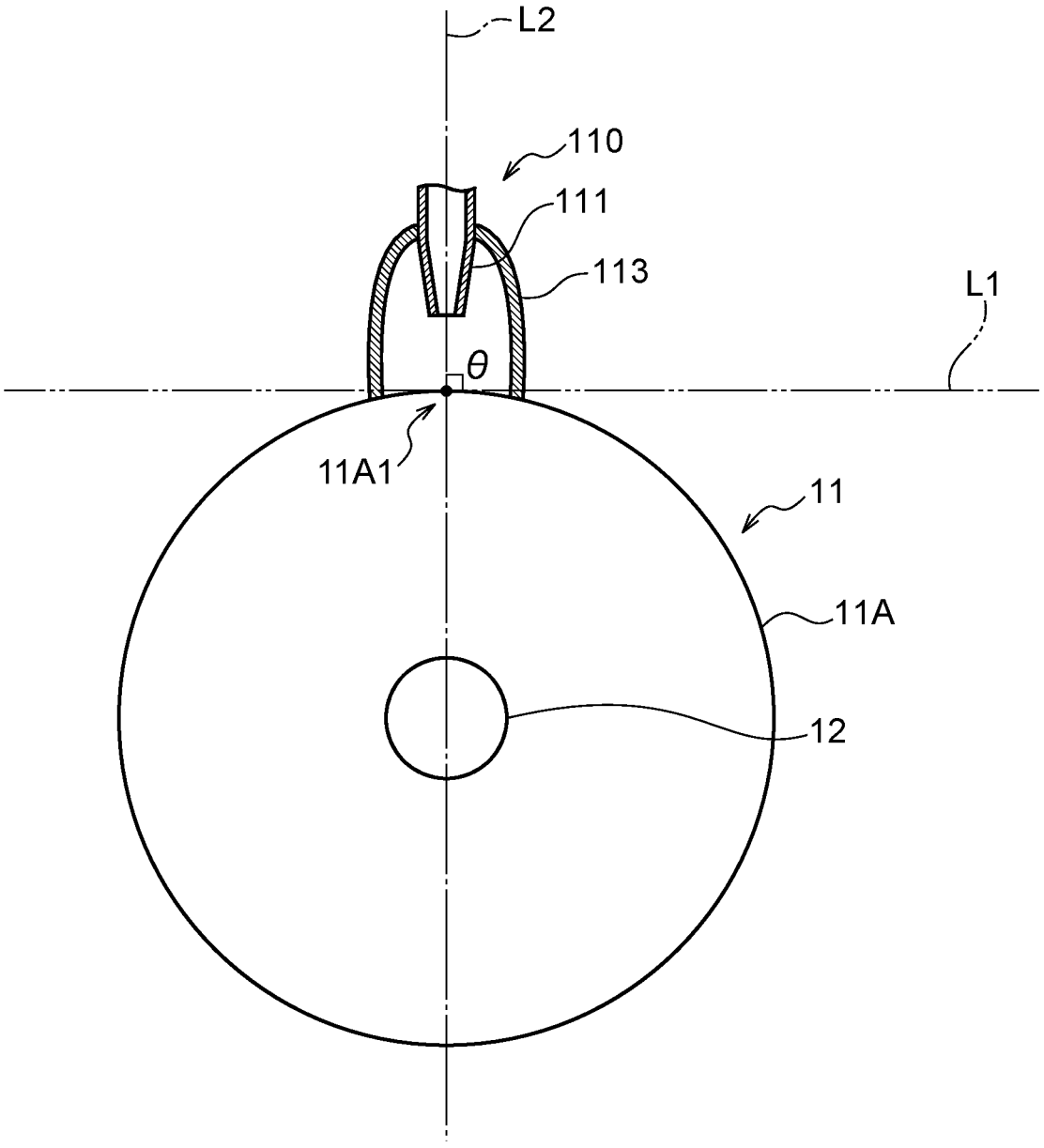


FIG.7A

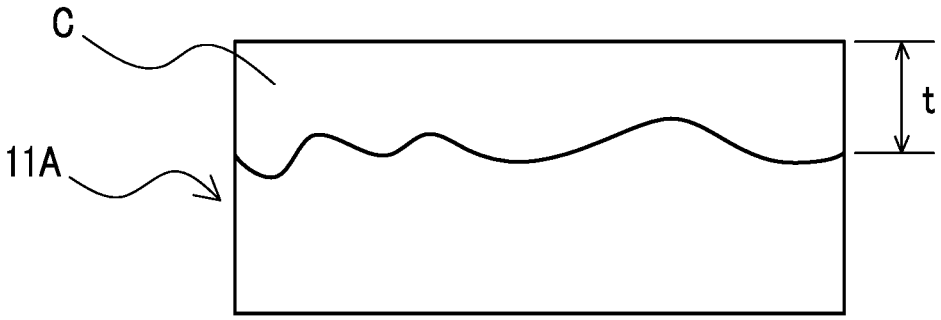


FIG.7B

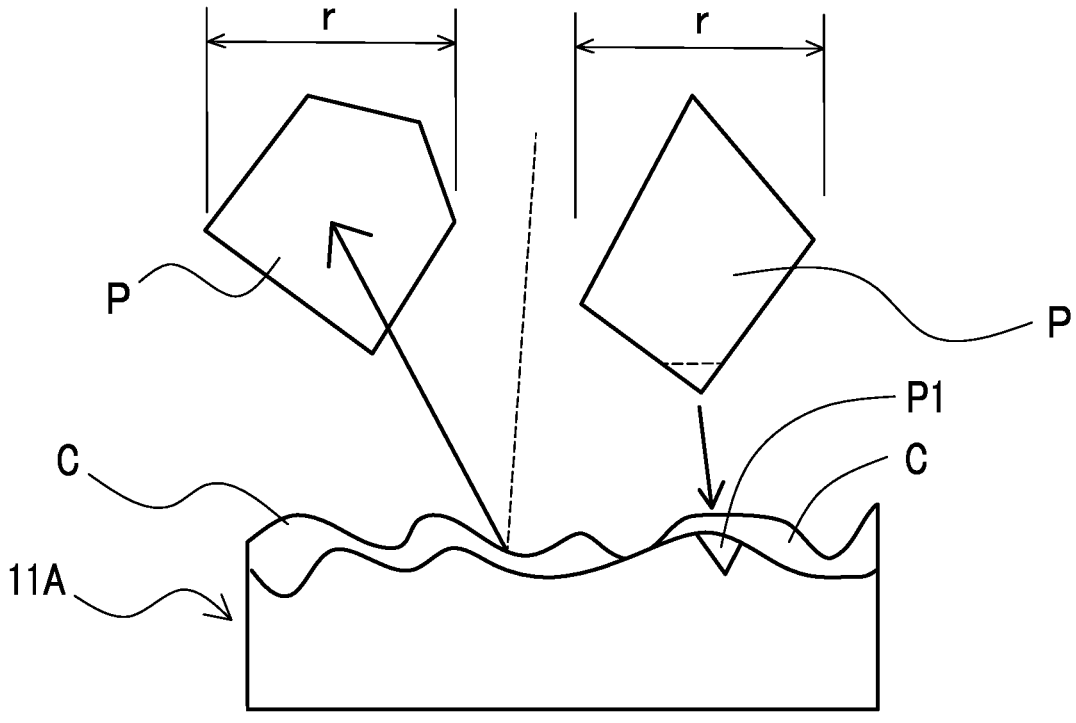


FIG.7C

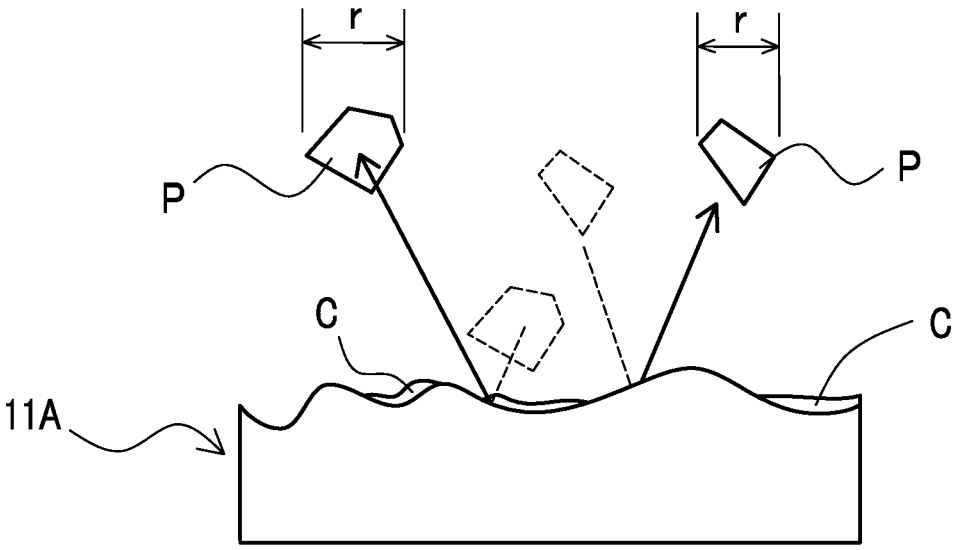


FIG.8

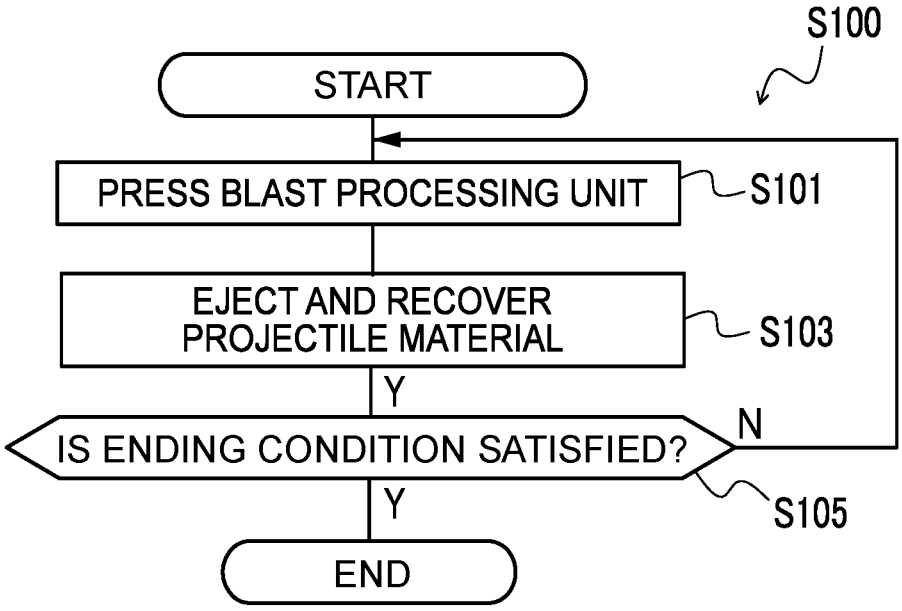

S100
START
PRESS BLAST PROCESSING UNIT
S101
EJECT AND RECOVER PROJECTILE MATERIAL
S103
Y
IS ENDING CONDITION SATISFIED?
N
S105
Y
END

FIG.9

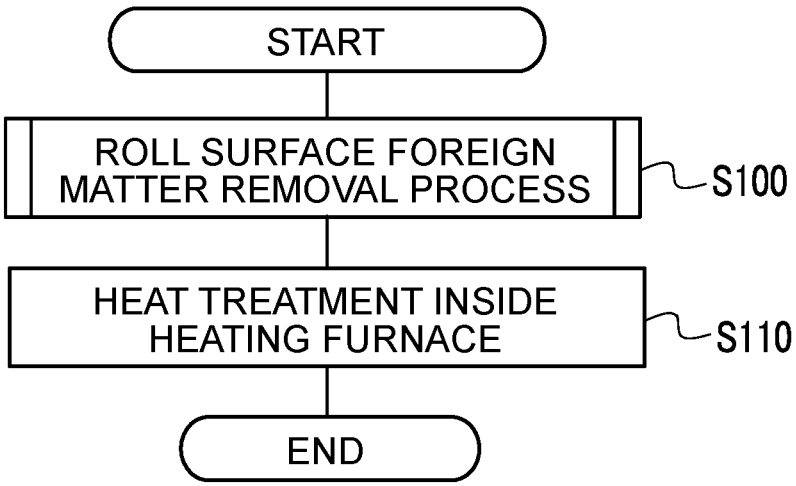
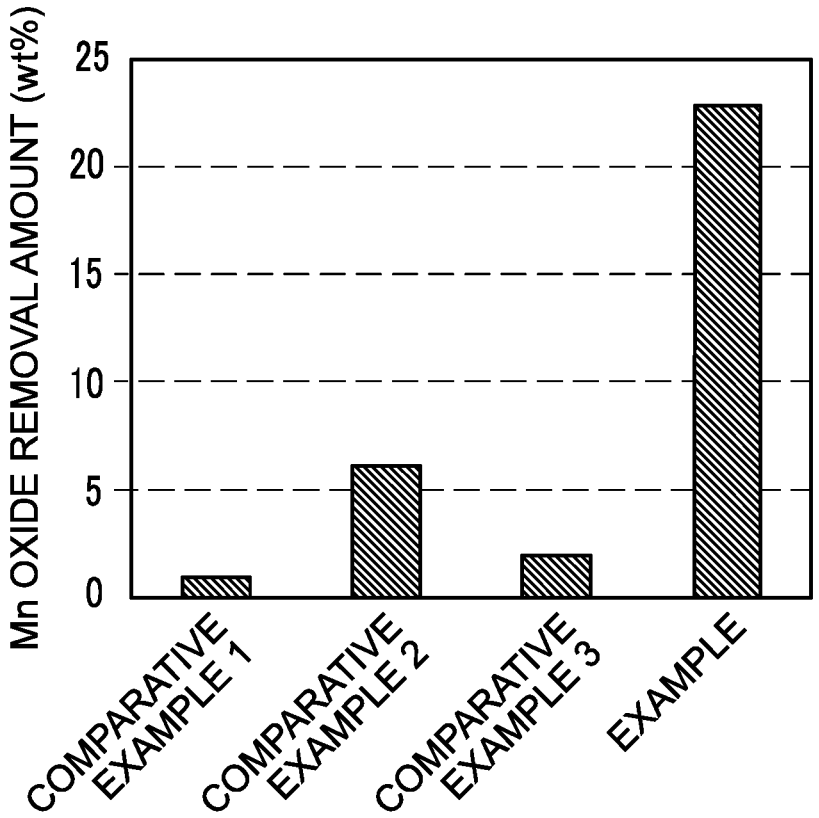

START
ROLL SURFACE FOREIGN MATTER REMOVAL PROCESS
S100
HEAT TREATMENT INSIDE HEATING FURNACE
S110
END

FIG.10


Mn OXIDE REMOVAL AMOUNT (wt%)
25
20
15
10
5
0
COMPARATIVE EXAMPLE 1
COMPARATIVE EXAMPLE 2
COMPARATIVE EXAMPLE 3
EXAMPLE

DEVICE FOR REMOVING FOREIGN MATTER FROM ROLL SURFACE, METHOD FOR REMOVING FOREIGN MATTER FROM ROLL SURFACE, AND METHOD FOR MANUFACTURING STEEL STRIP

TECHNICAL FIELD

[0001] The present disclosure relates to a device for removing foreign matter from a roll surface, a method for removing foreign matter from a roll surface, and a method for manufacturing a steel strip.

BACKGROUND ART

[0002] In processes to manufacture steel strips, there are rolls provided to convey the steel strips inside a heating furnace, such as a continuous annealing furnace or the like. There are demands to perform various treatments on surfaces of such rolls. For example, Japanese Patent Publication No. 3932947 describes technology in which roll surface maintenance is performed on conveyance rolls inside a heat treatment furnace to remove foreign matter adhered to rolls by using a foreign matter scraper means that places a portion of a thin member in surface contact with the roll.

[0003] Moreover, Japanese Patent Application Laid-Open (JP-A) No. 2002-120153 describes technology to plastically deform a surface layer by performing shot peening to a weld section on a shroud, which is a configuration member inside a nuclear reactor pressure vessel. Specifically, tensional residual stress remaining in the surface layer is converted into compressional residual stress by striking particles of steel spheres or the like against the surface layer of the weld section.

SUMMARY OF INVENTION

Technical Problem

[0004] Japanese Patent Publication No. 3932947 relates to a foreign matter scraper means in a roll surface maintenance device for rolls with prolonged exposure to a high temperature environment inside the heat treatment furnace, and foreign matter adhered to the rolls is removed by a foreign matter scraper means permanently attached to the inside of a heating furnace during operation. There is a problem with this in that due to foreign matter being removed while a sheet is passing, the foreign matter that has been removed adheres to the steel strip and results in defects.

[0005] Moreover, Japanese Patent Publication No. 3932947 does not consider processing related to periodic repairs and maintenance performed on conveyance rolls while the heating furnace is halted. For example, no consideration is given to foreign matter removal to restore surface roughness of the conveyance rolls. Moreover, even were the technology in Japanese Patent Publication No. 3932947 to be applied to periodic maintenance, then foreign matter adhered to the roll surface would be removed by the foreign matter scraper means, and the roll surface would actually be made smoother.

[0006] Moreover, were the technology in JP-A No. 2002-120153 to be applied to foreign matter removal from conveyance rolls, then surface profile would be deformed by the particles striking against the surface of the conveyance rolls, enabling compressional residual stress to be generated at the surface. However, the JP-A No. 2002-120153 does not consider the effective removal of foreign matter from the surface of conveyance rolls. Thus even were the technology of JP-A No. 2002-120153 to be employed, and particles to strike the surface of the conveyance roll, effective removal of foreign matter from the roll surface would still be difficult.

[0007] Moreover, in the case of JP-A No. 2002-120153, particles strike so as to promote deformation of the surface profile of the conveyance rolls, and so there is a high probability of large deformation to the profile of the struck roll surface to such an extent that the original profile prior to the foreign matter adhering is not restored. There are accordingly concerns regarding trouble occurring with the conveying of the steel strip due to the effect of large deformations to the conveyance rolls after being struck with the particles.

[0008] Thus in consideration of the above circumstances, an object of the present disclosure is to provide a novel and excellent device for removing foreign matter from a roll surface, the device enabling simple implementation of foreign matter removal from the surface of a conveyance roll provided inside a heating furnace, and to provide a method for removing foreign matter from a roll surface and a method for manufacturing a steel strip also enabling simple implementation thereof.

Solution to Problem

[0009] In order to solve the issues described above, an aspect of the present disclosure provides a device for removing foreign matter from a roll surface, the device including a blast processing unit and a processing unit. The blast processing unit includes an ejection unit configured to eject a projectile material at a surface of a roll that conveys a steel strip inside a heating furnace, and a recovery unit configured to recover the projectile material. The press unit is configured to press the blast processing unit toward the surface of the roll.

[0010] In order to solve the issues described above, another aspect of the present disclosure provides a method for removing foreign matter from a roll surface, the method including a process of pressing the blast processing unit of the roll surface foreign matter removal device described above against the surface of the roll, and a process of ejecting the projectile material from inside the blast processing unit and recovering the projectile material inside the blast processing unit.

[0011] In order to solve the issues described above, another aspect of the present disclosure provides a method for manufacturing a steel strip, the method including a process of removing foreign matter on a surface of a roll provided inside a heating furnace by using the roll surface foreign matter removal method described above, and a process of passing a steel strip through inside the heating furnace where the roll is provided and performing heat treatment.

Advantageous Effects

[0012] The present disclosure as explained above provides a device for removing foreign matter from a roll surface, the device enabling simple implementation of foreign matter removal from the surface of a conveyance roll provided inside a heating furnace, and provides a method for removing foreign matter from a roll surface and a method for manufacturing a steel strip also capable of enabling simple implementation thereof.

BRIEF DESCRIPTION OF DRAWINGS

[0013] FIG. **1** is a schematic diagram illustrating an example of a configuration of part of an operation line where a heating furnace according to an exemplary embodiment of the present disclosure is provided.

[0014] FIG. **2** is a schematic diagram illustrating an example of a configuration of part of an operation line where a heating furnace according to the present exemplary embodiment is provided.

[0015] FIG. **3** is a schematic diagram illustrating an example of a configuration of a device for removing foreign matter from a roll surface according to the present exemplary embodiment.

[0016] FIG. **4** is a plan view illustrating an example of a configuration of a device for removing foreign matter from a roll surface according to the present exemplary embodiment.

[0017] FIG. **5** is a schematic diagram to explain an example of a configuration of a blast processing unit according to the present exemplary embodiment.

[0018] FIG. **6** is a schematic diagram to explain a projection angle of projectile material when removing foreign matter using a blast processing unit according to the present exemplary embodiment.

[0019] FIG. **7**A is a schematic diagram of a roll surface to explain conditions of foreign matter removal using a blast processing unit according to the present exemplary embodiment.

[0020] FIG. **7**B is a schematic diagram of a roll surface to explain conditions of foreign matter removal using a blast processing unit according to the present exemplary embodiment.

[0021] FIG. **7**C is a schematic diagram of a roll surface to explain conditions of foreign matter removal using a blast processing unit according to the present exemplary embodiment.

[0022] FIG. **8** is a flowchart of a method for removing foreign matter from a roll surface according to the present exemplary embodiment.

[0023] FIG. **9** is a flowchart of a method for manufacturing a steel strip according to the present exemplary embodiment.

[0024] FIG. **10** is a graph illustrating manganese oxide removal amounts at a roll surface in an Example and Comparative Examples.

DESCRIPTION OF EMBODIMENTS

[0025] Detailed explanation follows regarding a preferable exemplary embodiment of the present disclosure, with reference to the appended drawings. Note that in the present specification and drawings the same reference numerals are appended to configuration elements having the substantially the same functional configuration, and duplicate explanation thereof will be omitted. Moreover, the same reference numerals or similar reference numerals are appended to the same portions or similar portions indicated in the following drawings. However, relationships between thickness and plan view dimensions in the drawings, as well as thickness proportions and the like in the various devices and various members in the drawings, may differ from those in reality. Accordingly, specific thicknesses and dimensions should be established with reference to the following explanation. Moreover, there are also portions having different dimensional relationships and proportions from each other included in the respective drawings.

1. Heating Furnace

[0026] First explanation follows regarding a heating furnace **10** according to an exemplary embodiment of the present disclosure, with reference to FIG. **1** and FIG. **2**. FIG. **1** is a schematic diagram illustrating an example of a configuration of part of an operation line where a heating furnace **10**A according to the present exemplary embodiment is provided. Moreover, FIG. **2** is a schematic diagram illustrating an example of a configuration of part of an operation line where a heating furnace **10**B according to the present exemplary embodiment is provided.

[0027] As illustrated in FIG. **1**, the heating furnace **10**A is, for example, a continuous annealing furnace provided to a continuous galvanizing line (CGL) in which a steel strip **1** is continually immersed in a plating bath **13**A and a plating process is performed to the surfaces of the steel strip. The heating furnace **10**A performs annealing of the steel strip **1** after cold rolling. The heating furnace **10**A is however not particularly limited, and for example may be a continuous heating furnace capable of performing continuous heat treatment on the steel strip **1**.

[0028] Moreover, as illustrated in FIG. **1**, a plating process apparatus **13** is provided downstream of the heating furnace **10**A in a conveyance direction, and performs galvannealing processing on the steel strip **1**. The conveyance direction is a direction of the steel strip **1**, from the right toward the left in FIG. **1**. The plating process apparatus **13** is an apparatus that immerses the steel strip **1** in the plating bath **13**A filled with a metal solution M, and that gives a specific coating weight of the metal solution M and forms a plating layer of alloy after the metal solution M has been continuously adhered to the surface of the steel strip **1**.

[0029] As illustrated in FIG. **1**, rolls **11** are provided inside the heating furnace **10**A to convey the steel strip **1**. The rolls **11**, called hearth rolls, are rotated by rotational force from a non-illustrated roll drive source, and convey the steel strip **1** inside the heating furnace **10**A.

[0030] Moreover, as illustrated in FIG. **2**, the heating furnace **10**B is a continuous annealing and processing line (CAPL) (note that C.A.P.L. is a registered trademark) provided as part of a rolling process. The heating furnace **10**B performs annealing to the steel strip **1** subsequently to cold rolling. The heating furnace **10**B is not particularly limited, and for example is a vertical heating furnace capable of performing continuous heat treatment such as overaging treatment to the steel strip **1**.

[0031] As illustrated in FIG. **2**, rolls **11** are provided inside the heating furnace **10**B for conveying the steel strip **1**. In addition, the rolls **11** in the heating furnace **10**B, which is a vertical heating furnace, convert the conveyance direction of the steel strip **1** to upward and downward directions. The rolls **11**, called hearth rolls, are rotated by rotational force from a non-illustrated roll drive source. Note that in the following explanation, sometimes the heating furnaces **10**A, **10**B are simply referred to as heating furnace **10**.

[0032] The rolls **11** employed in the heating furnace **10** as explained above have a specific roughness (namely, surface roughness) in order to convey the steel strip **1**. This secures frictional force between the rolls **11** and the steel strip **1**, and suppresses snaking of the steel strip **1** and the like when the steel strip **1** is passing. However, the roughness of the roll

surface is sometimes reduced below a specific value by wear from using the rolls **11** for a prolonged period of time, or by oxide formation and the like on the roll surface. As a result snaking of the steel strip **1** readily occurs when the steel strip **1** is passing, and sometimes this affects the operational stability.

[0033] In particular oxides caused by components in the steel are sometimes formed on the roll surface in cases in which the steel strip **1** is made from a high tensile steel. Specifically, manganese oxide caused by manganese (Mn), which is a component of steel, is formed as a coating layer on the roll surface. The roughness of the roll surface may accordingly be reduced to less than the specific value, resulting in snaking of the steel strip **1** or the like possibly occurring due to a reduction in the frictional force between the steel strip **1** and the rolls **11**. In particular, a phenomenon such as described above readily occurs in cases in which the steel strip **1** is high tensile steel having a tensile strength (TS) of 780 MPa or greater.

2. Device for Removing Foreign Matter from a Roll Surface

[0034] After diligent research by the authors of the present disclosure, the authors of the present disclosure have arrived at a way to perform foreign matter removal so as to restore roughness to the rolls **11** provided at the heating furnace **10**. The surface roughness of the rolls **11** is increased and the roughness restored by the processing for foreign matter removal. Explanation follows regarding a device **100** according to the present exemplary embodiment for removing foreign matter from a roll surface, with reference to FIG. **3** and FIG. **4**. FIG. **3** is a schematic diagram illustrating a configuration example of the roll surface foreign matter removal device **100** according to the present exemplary embodiment.

[0035] As illustrated in FIG. **3**, the roll surface foreign matter removal device **100** is a device that performs processing to restore roughness to a roll surface **11**A. Part of the configuration of the roll surface foreign matter removal device **100** (namely, the part contained in the region surrounded by double-dash broken lines in FIG. **3**) is provided inside the heating furnace **10** and performs foreign matter removal on the roll surface **11**A. For example, the roll surface foreign matter removal device **100** is installed in the heating furnace **10** when operation is halted for some reason such as for periodic maintenance or the like, and is removed from the heating furnace **10** during normal operation. In other words, the roll surface foreign matter removal device **100** is temporarily attached inside the heating furnace **10**, and is detachable after foreign matter removal work has been completed.

[0036] In cases in which there are plural of the rolls **11** provided inside the heating furnace **10**, the roll surface foreign matter removal device **100** performs foreign matter removal in sequence on each of the rolls **11**. Namely, after the roll surface foreign matter removal device **100** has performed foreign matter removal on one of the rolls **11** inside the heating furnace **10**, the roll surface foreign matter removal device **100** is temporarily detached, and then moved before being reattached at a location corresponding to another of the rolls **11**. The roll surface foreign matter removal device **100** then performs foreign matter removal on the other roll **11**. Note that plural of the roll surface foreign matter removal device **100** may be installed inside the heating furnace **10**.

Blast Processing Unit

[0037] Specifically, as illustrated in FIG. **3**, the roll surface foreign matter removal device **100** includes a blast processing unit **110** and a press unit **120**. The blast processing unit **110** performs blast processing on the roll surface **11**A, and roughens the roll surface **11**A by removing foreign matter on the roll surface **11**A. Specifically, the blast processing unit **110** is equipped with an ejection unit **111** to eject projectile material, corresponding to projectile material P in FIG. **5**, described later, against the roll surface **11**A, and with a recovery unit **113** to recover the projectile material. The ejection unit **111**, for example, ejects the projectile material together with a gas, corresponding to gas Gin FIG. **5**, described later. The projectile material is thereby impacted against the roll surface **11**A. In addition, the recovery unit **113**, for example, recovers the projectile material together with the gas by using suction.

[0038] An example of the projectile material is a polygonal shaped powder of a metal oxide, and in particular an example is a powder of aluminum oxide (namely, alumina particles). Aluminum oxide is chemically stable, and so any effect on operation of the heating furnace is suppressed even were some aluminum oxide to remain inside the heating furnace. Moreover, a general alumina powder is comparatively affordable as an abrasive, enabling a reduction in the cost of foreign matter removal operations.

[0039] Moreover, a zirconium oxide (namely, zirconia) powder is another example of the polygonal shaped metal oxide projectile material. Furthermore, a silicon carbide (SiC) powder is another example of the projectile material. The hardness of the projectile material is, for example, a Vickers hardness of from about 2000 to about 3000. In addition, the grit size of the projectile material is, for example, from 30 grit to 220 grit.

[0040] The gas ejected together with the projectile material is, for example, compressed air. The pressure of ejection is, for example, from about 0.2 MPa to about 0.7 MPa. Note that in the present exemplary embodiment the range of ejection pressure of the compressed air is preferably from 0.2 MPa to 0.5 MPa. Setting the range of ejection pressure as from 0.2 MPa to 0.5 MPa enables an oxide coating layer C of foreign matter to be removed efficiently.

[0041] In cases in which the ejection pressure is less than 0.2 MPa, this results in the ejected projectile material P not readily burrowing into the oxide coating layer C due to the low pressure, and so the oxide coating layer C is not able to be removed sufficiently. Moreover, in cases in which the ejection pressure exceeds 0.5 MPa, the ejected projectile material P burrows into the roll surface **11**A, and there is a concern that it might lodge in the roll surface **11**A. There is accordingly a concern that defects in the steel strip might be generated by the buried projectile material P. In the present exemplary embodiment in which the oxide coating layer C is manganese oxide, it has been found that sufficient manganese oxide can be removed even when the value of the ejection pressure is a comparatively low value in the range of from 0.2 MPa to 0.5 MPa.

[0042] The projectile material and gas ejected from the ejection unit **111** is supplied from outside the furnace through hoses **130** in FIG. **3**. Specifically, the projectile material is supplied from outside the furnace through a projectile material supply hose **131**. In addition, the gas is supplied from outside the furnace though a gas supply hose **132**. Although this will be described in more detail later,

ends on the furnace outside of the projectile material supply hose **131** and the gas supply hose **132** are connected to a projectile material supply source and to a gas supply source, respectively. Moreover, the projectile material and gas recovered by the recovery unit **113** is discharged to outside the furnace though a discharge hose **133**.

Press Unit

[0043] The press unit **120** presses the blast processing unit **110** toward the roll surface **11**A. Although this will be described in more detail later, a closed space is formed between an inner face of the blast processing unit **110** and the roll surface **11**A by the blast processing unit **110** being pressed toward the roll surface **11**A. The projectile material ejected from the ejection unit **111** is thereby prevented from flying around inside the furnace. An example of the press unit **120** is an air cylinder **121**.

[0044] The roll surface foreign matter removal device **100** may further include a link arm **101** to dispose the blast processing unit **110** and the press unit **120** at specific positions with respect to the roll surface **11**A. The link arm **101** is an arm shaped member coupled together through a single joint structure or plural joint structures. The link arm **101** enables the blast processing unit **110** and the press unit **120** to be disposed at specific positions with respect to the roll surface **11**A even in cases in which the diameters of the plural rolls **11** provided inside the heating furnace **10** differ from each other. The blast processing unit **110** and the press unit **120** are attached through a bracket to one end **101**A of the link arm **101**. Another end **101**B of the link arm **101** is attached to a main body **103** of the roll surface foreign matter removal device **100**, described later.

Detection Unit

[0045] The roll surface foreign matter removal device **100** further includes a detection unit **140** to detect a distance between the blast processing unit **110** and the roll surface **11**A. The detection unit **140** is disposed at a specific position with respect to the roll surface **11**A through a bracket attached to the one end **101**A of the link arm. The detection unit **140** measures the distance with respect to the roll surface **11**A. An example of the detection unit **140** is a laser sensor.

Roll Rotation Mechanism

[0046] The roll surface foreign matter removal device **100** may further include a roll rotation mechanism **150** to rotate the roll **11**. In particular the roll rotation mechanism **150** rotates the roll **11** in a state in which rotational force to convey the steel strip **1** is not being supplied to the rolls **11**. The roll rotation mechanism **150** rotates the roll **11** by, for example, rotating a rotation section **151** when an outer face **151**A thereof is in a state of contact with the roll surface **11**A.

[0047] As illustrated in FIG. **4**, the rotation section **151** is, for example, a small roller, and the rotation section **151** is driven by a drive source **153** such as a motor so as to rotate. Foreign matter removal from the surface of the roll **11** is readily performed by performing blast processing along a circumferential direction of the roll **11** while the roll **11** is being rotated. Moreover, for example, the roll **11** can still be rotated even in cases in which the roll drive source employed when conveying the steel strip **1** is unable to be used due to the power supply to the heating furnace **10** and peripheral equipment thereto being switched OFF during periodic maintenance of the heating furnace **10**. As a result surface foreign matter removal is implemented along the circumferential direction of the roll **11**, by independently using the roll surface foreign matter removal device **100** provided with the roll rotation mechanism **150**, and without needing power supply to the heating furnace **10** and the peripheral equipment thereto.

[0048] The roll rotation mechanism **150** rotates the roll **11** by rotating the rotation section **151** in a state in which the outer face **151**A is contacting the roll surface **11**A. Namely, the roll rotation mechanism **150** having a simple configuration suffices to rotate the roll **11**, enabling the roll surface foreign matter removal device **100** to be made more compact.

[0049] The roll surface foreign matter removal device **100** may also further include the main body **103**. Various configuration, such as the blast processing unit **110**, the press unit **120**, the roll rotation mechanism **150**, etc. as described above, is attached to the main body **103**. The roll surface foreign matter removal device **100** is installed inside the heating furnace **10** using the main body **103**. Operational efficiency is improved due to the main body **103** enabling the various configuration of the roll surface foreign matter removal device **100** to be attached and detached as a single body inside the heating furnace **10**.

[0050] For example, the main body **103** may be a structural body having a length direction running along an axial direction of the roll **11** parallel to the X direction in FIG. **3**. The structural body serving as the main body **103** is, for example, attached at two length direction ends to beam members provided along the direction of the steel strip **1** conveyance inside the heating furnace **10**. The beam members are omitted from illustration. For example, the main body **103** is attached through non-illustrated fixings to the beam members of the heating furnace **10**.

[0051] The roll surface foreign matter removal device **100** may include an air supply and exhaust system **160** outside the furnace to enable the projectile material recovered by the recovery unit **113** to be reused. Specifically, the roll surface foreign matter removal device **100** may include a recovery tank **161**, a dust collector **163**, and a blower **165**. A negative pressure relative to atmospheric pressure is induced inside the discharge hose **133**, the recovery tank **161**, and the dust collector **163** by exhausting air through the blower **165**. The projectile material recovered from the recovery unit **113** is thereby moved to the recovery tank **161** inside the discharge hose **133**.

[0052] The projectile material transported to the recovery tank **161** through the discharge hose **133** is sorted from matter other than projectile material, such as dust, by using centrifugal separation inside the recovery tank **161**. The sorted projectile material is re-supplied into the ejection unit **111** through the projectile material supply hose **131**. However, the dust and the like separated from the projectile material is collected by the dust collector **163**, and gas cleaned by the dust collection is discharged from the blower **165**.

[0053] The roll surface foreign matter removal device **100** includes a gas supply source **167** outside the furnace. Gas supplied at a specific pressure from the gas supply source **167** is supplied to the ejection unit **111** through the gas supply hose **132**. In the ejection unit **111** the projectile

material is ejected together with the gas supplied from the gas supply source **167**. An example of the gas supply source **167** is a factory air supply unit.

Movement Mechanism

[0054] FIG. **4** is a plan view illustrating a configuration example of the roll surface foreign matter removal device **100** according to the present exemplary embodiment. As illustrated in FIG. **4**, the roll surface foreign matter removal device **100** may include a movement mechanism **170** to move the blast processing unit **110** along an axial direction of the roll **11** parallel to the X direction in FIG. **4**. The movement mechanism **170** is able to move the blast processing unit **110** at least in a region of the axial direction of the roll **11** excluding beveled portions at the axial direction ends thereof (namely a region W in FIG. **4**). Foreign matter is able to be removed from the roll surface **11**A over a wider range by moving the blast processing unit **110** along the axial direction of the roll **11**. Moreover, a more compact roll surface foreign matter removal device **100** is realized due to not needing to provide multiple blast processing units **110** to widen the projection range.

[0055] An example of the movement mechanism **170** is a screw feed mechanism as illustrated in FIG. **4**. Specifically, the movement mechanism **170** includes a screw feed mechanism **171**, a drive source **173**, and a guide shaft **175**.

[0056] The screw feed mechanism **171** includes a screw shaft **171**A provided with an axial direction along a direction of rotation axis X**1** of the roll **11**, and support sections **171**B supporting both ends of the screw shaft **171**A so as to enable rotation. In the following the direction of rotation axis X**1** will simply be referred to as the "roll axis direction". Note that rotation axis X**1** matches the axial direction of the roll **11**.

[0057] The screw shaft **171**A is a rod shaped member having an outer peripheral face provided with a screw thread of a specific pitch. As illustrated in FIG. **4**, the screw shaft **171**A is inserted into the other end **101**B of the link arm **101** while being threaded together therewith. The drive source **173** is coupled to an end of the screw shaft **171**A, in a configuration such that the screw shaft **171**A is rotated by the drive source **173**. The blast processing unit **110** is accordingly screw-fed and moved along the axial direction of the roll **11** by rotation of the screw shaft **171**A.

[0058] The guide shaft **175** is a rod shaped member provided along the axial direction of the roll **11** and parallel to the screw shaft **171**A. Each of the two ends of the guide shaft **175** are supported by the support sections **171**B of the screw shaft **171**A.

[0059] Note that although the movement mechanism **170** described above is an example in which the blast processing unit **110** is moved linearly along the axial direction of the roll **11**, the present disclosure is not limited to this example. The movement mechanism **170** may move the blast processing unit **110** in any manner such that the movement direction of the blast processing unit **110** includes a component along the axial direction of the roll **11**, and the movement mechanism **170** may, for example, be configured so as to move the blast processing unit **110** in a meandering or sloping pattern.

[0060] Detailed explanation now follows regarding a configuration of the blast processing unit **110**, with reference to FIG. **5**. FIG. **5** is a schematic diagram to explain an example of a configuration of the blast processing unit **110**. As illustrated in FIG. **5**, the blast processing unit **110** performs blast processing on the roll surface **11**A in a state pressed by the air cylinder **121** serving as the press unit **120**. In the blast processing unit **110**, the ejection unit **111** is provided at the center of the blast processing unit **110**, and the recovery unit **113** is provided at the periphery of the ejection unit **111**. Namely, after the projectile material P ejected from the ejection unit **111** has impacted the roll surface **11**A, the projectile material P is recovered from the recovery unit **113** provided at the periphery of the ejection unit **111**.

[0061] Specifically, as illustrated in FIG. **5**, the blast processing unit **110** includes a double-walled tubular shaped body **115**. Namely, the blast processing unit **110** includes the double-walled tubular shaped body **115** configured from an inner tube **115**A and an outer tube **115**B surrounding the inner tube **115**A. As illustrated in FIG. **5**, in the blast processing unit **110**, the inner tube **115**A forms at least part of the ejection unit **111**, and the outer tube **115**B forms at least part of the recovery unit **113**. When viewed in horizontal cross-section of the blast processing unit **110**, the double-walled tubular shaped body **115** has a double-walled ring shaped structure configured by the inner tube **115**A and the outer tube **115**B, however this indicates being at least partially formed by such a structure.

[0062] More specifically, the inner tube **115**A is a so-called blast gun for ejecting the projectile material P, and the outer tube **115**B is a hollow half-spindle shaped hood provided surrounding the blast gun. The projectile material P ejected together with the gas G from the blast gun attached to the center of hood serving as the outer tube **115**B impacts the roll surface **11**A and rebounds therefrom. The rebounding projectile material P travels along the inner peripheral face of the hood and is recovered from the recovery unit **113**. Namely, as indicated by the arrows in FIG. **5**, the projectile material P is suctioned from the recovery unit **113** by the flow of the gas G inside the hood of the blast gun. The projectile material P is accordingly prevented from flying around after impacting the roll surface **11**A.

[0063] Namely, the blast processing unit **110** is pressed by the press unit **120**, and the projectile material P is ejected by the ejection unit **111** in a state in which a closed space **117** is formed between the blast processing unit **110** and the roll surface **11**A. The projectile material P is thereby suppressed from flying around inside the heating furnace **10**. Moreover, recovery is performed by the recovery unit **113** in the closed space **117** between the blast processing unit **110** and the roll surface **11**A. The proportion of the projectile material P recovered is raised by better suppressing the projectile material P from flying around inside the heating furnace **10** in this manner. Reference here to the closed space does not indicate a space that is completely closed with respect to outside, and may be a space closed off from the outside to an extent capable of suppressing the projectile material P from flying around.

[0064] Furthermore, a flexible member **180** may be provided to an end portion on the roll surface **11**A side of the outer tube **115**B. In cases in which the blast processing unit **110** pressed by the press unit **120** makes direct contact with the roll surface **11**A, there is a load accompanying pressing acting on the roll surface **11**A. Providing the flexible member **180** at the end portion of the outer tube **115**B distributes the load applied to the roll surface **11**A when the blast processing unit **110** is being pressed toward the roll surface **11**A by the press unit **120**. As a result defects are suppressed

from being generated on the roll surface **11**A. Furthermore, the projectile material P is also better suppressed from flying around inside the heating furnace **10** due to any gap between the outer tube **115**B of the blast processing unit **110** and the roll surface **11**A being filled by the flexible member **180**.

[0065] An example of the flexible member **180** is, as illustrated in FIG. **5**, a brush shaped member **181** attached to the end portion of the outer tube **115**B. The brush shaped member **181** has one end fixed to the outer tube **115**B side, and the other end thereof includes plural bristles extending toward the roll surface **11**A. When the blast processing unit **110** is pressed by the press unit **120**, the plural bristles of the brush shaped member **181** in this example deform so as to tilt toward the outer periphery, enabling any gap between the outer tube **115**B and the roll surface **11**A to be filled.

[0066] Note that the flexible member **180** may have flexibility of any amount enabling gaps between the outer tube **115**B and the roll surface **11**A to be filled and enabling a response to load applied by the press unit **120**, and the shape, configuration, and material of the flexible member **180** is not particularly limited. An example of the flexible member **180** is a rubber sheet, and this may be stuck to the surface of the end portion of the outer tube **115**B opposing the roll surface **11**A. The flexible member **180** may also be a sponge form member attached to the end portion of the outer tube **115**B.

[0067] Explanation follows regarding an example of operation of the roll surface foreign matter removal device **100**. Namely, the blast processing unit **110** is pressed against the roll surface **11**A by the air cylinder **121** serving as the press unit **120**. Moreover, the projectile material P is projected from the ejection unit **111** of the blast processing unit **110** and foreign matter removal is performed on the roll surface **11**A. Moreover, the projectile material P hitting and bouncing off the roll surface **11**A is recovered by the recovery unit **113**.

[0068] As illustrated in FIG. **6**, a projection angle θ of the projectile material P with respect to the roll surface **11**A is defined as an angle, as viewed along the axial direction of the roll **11**, on the acute angle side from out of angles formed between a tangent L**1** to the roll surface **11**A at a projection target position **11**A**1** and a center axis L**2** of the inner tube that is the ejection unit **111** of the blast processing unit **110**. In the present exemplary embodiment the projection angle θ is 90 degrees. Note that an intersection point in FIG. **6** between the left-right direction extension of the double-dash broken line of tangent L**1** and the center axis L**2** of the single-dash broken line extending in the up-down direction is the projection target position **11**A**1** of the projectile material P.

[0069] In the present disclosure the projection angle θ is preferably in a range of from 80 degrees to 90 degrees. Setting the range of the projection angle θ to from 80 degrees to 90 degrees enables efficient removal of the oxide coating layer C adhered to the roll surface **11**A. The ejected projectile material P does not readily burrow into the oxide coating layer C in cases in which the projection angle θ is less than 80 degrees, and the oxide coating layer C is not able to be sufficiently cut away.

[0070] Moreover, the distance between the blast processing unit **110** and the roll surface **11**A is detected by the detection unit **140** while the foreign matter removal is being performed by the blast processing unit **110**. The ejection of the projectile material P is halted in cases in which the blast processing unit **110** and the roll surface **11**A have become separated by a specific distance or greater. An example of the specific distance at which ejection of the projectile material P is halted is about several mm to several tens of mm. The projectile material P is thereby suppressed from flying around inside the heating furnace **10**. Note that in the present exemplary embodiment in which compressed air is ejected at a range of pressure from 0.2 MPa to 0.5 MPa, the separation distance between the blast processing unit **110** and the roll surface **11**A is preferably not more than 5 mm from the perspectives of both efficiently removing the oxide coating layer C and reducing loss of compressed air.

[0071] The operational example such as described above is, for example, controlled by a controller **190** in FIG. **5**. Specifically, as illustrated in FIG. **5**, the controller **190** controls the air supply and exhaust system **160** so as to supply the projectile material P and gas G into the blast processing unit **110** as well as to recover the projectile material P. The controller **190** controls operation of the air cylinder **121** so as to press the blast processing unit **110**.

[0072] Furthermore, the controller **190** derives the distance between the blast processing unit **110** and the roll surface **11**A based on the detection result of the distance to the roll surface **11**A as detected by a laser sensor serving as the detection unit **140**. Furthermore, the controller **190** controls the air cylinder **121** or the air supply and exhaust system **160** based on the derived result. The functionality of the controller **190** is, for example, realized by cooperation between a central processing unit (CPU), random access memory (RAM), read only memory (ROM), and the like.

[0073] The controller **190** may also control the roll rotation mechanism **150** and the movement mechanism **170**. Namely, the controller **190** may perform foreign matter removal on the roll surface **11**A using the blast processing unit **110** while the roll rotation mechanism **150** is operated and the roll **11** is rotated. Moreover, the controller **190** may operate the movement mechanism **170** and move the blast processing unit **110** from one position to another position along the axial direction of the roll **11**. This concludes explanation regarding a schematic configuration of the roll surface foreign matter removal device **100** according to the present exemplary embodiment.

3. Roll Surface Foreign Matter Removal Conditions

[0074] Next explanation follows regarding conditions of foreign matter removal on the roll surface **11**A according to the present exemplary embodiment, with reference to FIG. **7**A to FIG. **7**C. FIG. **7**A to FIG. **7**C are schematic diagrams of the roll surface **11**A to explain conditions of foreign matter removal by using the blast processing unit **110**. As illustrated in FIG. **7**A, sometimes there is an oxide coating layer C formed on the roll surface **11**A in an initial state prior to foreign matter removal.

[0075] For example, manganese oxide caused by a manganese component in the steel strip **1** may be formed as a coating layer on the roll surface **11**A with an average thickness t of about 100 for example as illustrated in FIG. **7**A. There is a reduction in the roughness of the roll surface **11**A due to an oxide coating layer C being formed in this manner, and sometimes snaking of the steel strip **1** occurs. To address this issue, foreign matter removal is performed so as to restore the surface roughness of the roll **11** while operation of the heating furnace **10** has been halted, during periodic maintenance or the like of the heating furnace **10**.

[0076] In the foreign matter removal by the roll surface foreign matter removal device **100** according to the present exemplary embodiment, the roughness of the roll surface **11**A is restored by ejecting the projectile material P at the roll surface **11**A. Specifically, as illustrated in FIG. **7**B, polygonal shaped alumina particles having an average particle size r of from about 300 μm to about 425 μm (namely alumina particles having a grit size of from about 30 grit to about 60 grit) are ejected together with compressed air at a pressure of about 0.5 MPa at the roll surface **11**A. The roll surface **11**A is roughened while thereby removing the oxide coating layer C that decreased the roughness.

[0077] Roughening processing of the roll surface **11**A by foreign matter removal indicates processing preformed to achieve a surface roughness Ra on the roll surface **11**A of a specific value or greater. A guide example of such roughening processing is achieving a Ra of 3 μm or greater, and in particular an Ra of 6 μm or greater.

[0078] As illustrated in FIG. **7**B, a fragment P**1** of the projectile material P has fractured when the projectile material P impacted the roll surface **11**A, and has lodged in the roll surface **11**A. To address this, as illustrated in FIG. **7**C, a projectile material P having a smaller particle size may be projected to remove the fragment P**1** of the projectile material P that had lodged in the roll surface **11**A. Specifically, polygonal shaped alumina particles having an average particle size r of from about 90 μm to 125 mm (namely, alumina particles of grit size from about 80 grit to 250 grit) are ejected together with compressed air at the roll surface **11**A. The roughness of the roll surface **11**A is thereby adjusted while the fragment P**1** of the projectile material P that lodged in the roll surface **11**A is also removed.

[0079] In other words, after a first blast processing is performed by ejecting as a first projectile material a projectile material P having a first average particle size, a second blast processing is performed by ejecting as a second projectile material a projectile material P having a second average particle size smaller than the first average particle size. This enables the surface roughness of the roll surface **11**A to be adjusted while being able to efficiently remove the oxide coating layer C on the roll surface **11**A. Furthermore, fragment P**1** of the projectile material P is suppressed from lodging in the roll surface **11**A, enabling fragments P**1** of the projectile material P to be prevented from acting as growth nuclei for a new oxide coating layer C. Moreover, the second blast processing may be performed by ejection of the projectile material P having the second average particle size plural times, such as from about 3 to 5 times. Moreover, the first blast processing may also be performed plural times.

[0080] Moreover, a third blast processing may also be performed by ejecting, as a third projectile material, projectile material P having a third average particle size even smaller than the second average particle size. Namely, in the present disclosure, a subsequent blast processing using a projectile material having an average particle size even smaller than the average particle size of the immediately previous blast processing may be performed plural times. This concludes explanation of conditions for roughening processing on the roll surface **11**A according to the present exemplary embodiment.

4. Method for Removing Foreign Matter from a Roll Surface

[0081] Next explanation follows regarding a method for removing foreign matter from a roll surface according to the present exemplary embodiment, with reference to FIG. **8**. FIG. **8** is a flowchart of a method for removing foreign matter from a roll surface according to the present exemplary embodiment. As illustrated in FIG. **8**, at step S**101** in a roll surface foreign matter removal process S**100**, the blast processing unit **110** of the roll surface foreign matter removal device **100** installed inside the heating furnace **10** is first pressed against the roll surface **11**A.

[0082] Then at step S**103**, the projectile material P is ejected from inside the blast processing unit **110**, and the projectile material P inside the blast processing unit **110** is recovered. Specifically, the projectile material P from the ejection unit **111** of the blast processing unit **110** is ejected together with the gas G. Furthermore, the projectile material P is suctioned up together with the gas G by the recovery unit **113** of the blast processing unit **110**.

[0083] Then at step S**105**, determination is made as to whether or not an ending condition to end the roll surface foreign matter removal process S**100** is satisfied. A specific example of the ending condition is that the foreign matter removal has been performed on the roll surface **11**A for a specific period of time, or that an input to end the foreign matter removal work has been input by an operator. The roll surface foreign matter removal process S**100** is ended in cases in which determination is made that the ending condition has been satisfied. However, the roll surface foreign matter removal process S**100** returns to step S**101** in cases in which determination is made that the ending condition to end the roll surface foreign matter removal process S**100** has not been satisfied. The foreign matter removal work may be performed on another roll **11** after operation on one of the rolls **11** has been completed.

[0084] Note that some processes may be added to, or modified in, the roll surface foreign matter removal process S**100** according to the present exemplary embodiment. For example, a process to move the blast processing unit **110** along the roll axial direction using the movement mechanism **170** may be included, and a process to rotate the roll **11** using the roll rotation mechanism **150** may be included. Furthermore, in the ejection of the projectile material P at step S**103**, a configuration may be adopted in which, after performing the ejection and recovery of projectile material P having the first average particle size as a process of the first blast processing, a process of the second blast processing is performed to eject and recover projectile material P having a second average particle size smaller than the first particle size. This completes explanation regarding the roll surface foreign matter removal method according to the present exemplary embodiment.

Method for Manufacturing a Steel Strip

[0085] Next, description follows regarding a method of manufacturing the steel strip **1**, with reference to FIG. **9**. FIG. **9** is a flowchart of a method for manufacturing the steel strip **1** according to the present exemplary embodiment. As illustrated in FIG. **9**, first the roll surface foreign matter removal process S**100** is performed as described above. Specifically, the foreign matter removal is performed on the roll surface **11**A for a roll **11** in the heating furnace **10** when operation has been halted to perform periodic maintenance or the like in the heating furnace **10**. Then at step S**110** in FIG. **9**, the steel strip **1** is passed through inside the heating furnace **10** where the roll **11** is provided and heat treatment is performed. Specifically, operation of the heating furnace **10** is started, and the steel strip **1** is passed through inside the

heating furnace **10** while being supported by the rolls **11**, and various processing is performed on the steel strip **1** including overaging processing, or heat treatment called annealing. Thus roughening of the roll surface **11**A is implemented by removing the foreign matter formed on the surface of the rolls **11** employed for steel strip conveyance in this manner, enabling snaking of the steel strip **1** inside the heating furnace **10** to be suppressed.

[0086] In particular, the steel strip **1** may be a high tensile steel. In high tensile steel cases, formation of an oxide coating layer C on the roll surface **11**A is caused by components in the steel, thereby decreasing the roughness of the roll surface **11**A. As a result snaking of the steel strip **1** is liable to occur. By conveying the steel strip **1** with the rolls **11** inside the heating furnace **10** that have been subjected to the roll surface foreign matter removal process S**100**, snaking of the steel strip **1** is suppressed from occurring. This accordingly enables removal by blast processing even in cases in which the oxide coating layer C forms on the roll surface **11**A readily due to the components contained in the steel strip **1**. As a result snaking of the steel strip **1** can be suppressed from occurring.

[0087] Note that in the method for manufacturing the steel strip **1** according to the present exemplary embodiment there are some processes that may be added to or modified. For example, the steel strip **1** may be immersed continuously in the plating bath **13**A, and then a plating processing process may be performed after a heat treatment process at step S**110**. Furthermore, various processing, control, or detection processes for manufacturing the steel strip **1** may be added to the method for manufacturing the steel strip **1**. This completes explanation regarding the method for manufacturing the steel strip **1** according to the exemplary embodiment of the present invention.

Operation and Advantageous Effects

[0088] In the present exemplary embodiment foreign matter removal is performed by the blast processing unit **110** equipped with the ejection unit **111** ejecting the projectile material P against the roll surface **11**A of the roll **11** that conveys a steel strip inside the heating furnace **10** and the recovery unit **113** for recovering the projectile material P. The blast processing unit **110** is pressed toward the roll surface **11**A by the press unit **120**. Thus foreign matter removal is simply implemented on a roll surface **11**A disposed on an operation line by performing the foreign matter removal using blast processing on the roll **11** inside the heating furnace **10**. Moreover, the blast processing unit **110** ejects the projectile material P while being pressed, and the projectile material P is also recovered by the recovery unit **113**, thereby suppressing projectile material P from remaining inside the heating furnace **10**.

[0089] Namely, for example, in cases in which foreign matter removal is not performed and a roll **11** having reduced roughness is replaced by another roll **11**, there is a need for man hours to be spent on the detachment and attachment operations themselves, and also a need for man hours to be spent on auxiliary operations such as centering and the like when performing attachment. The present exemplary embodiment enables foreign matter removal to be performed in a state in which the roll **11** is attached to the heating furnace **10**, namely while on an operation line, and the foreign matter removal work is implemented simply. Furthermore, compared to roll replacement, the present exemplary embodiment reduces the costs for the operations needed for such an approach, such as preparing and storing the replacement rolls **11**.

[0090] Moreover, for example, sometimes unevenness occurs in the removal of the oxide coating layer C in cases in which a chemical treatment such as acid pickling is performed to restore the roughness of the roll **11**. There is also a concern with acid pickling regarding the deterioration of equipment due to acid splashing out into the heating furnace **10**, and furthermore many man hours are expected to be needed for the handling of acid solution, such as in the preparation and disposal processing thereof. However, the present exemplary embodiment realizes more uniform restoration of roughness by physically removing the oxide coating layer C using the blast processing unit **110** to perform roughness restoration on the roll surface **11**A, than with chemical processing using acid pickling or the like.

[0091] In the present exemplary embodiment the ejection unit **111** is provided at the center of the blast processing unit **110**, and the recovery unit **113** is provided at the periphery of the ejection unit **111**. Providing the recovery unit **113** at the periphery of the ejection unit **111** enables the projectile material P ejected from the ejection unit **111** to be efficiently recovered and also enables the blast processing unit **110** to be made more compact.

[0092] In the present exemplary embodiment the blast processing unit **110** includes the double-walled tubular shaped body **115** configured by the inner tube **115**A and the outer tube **115**B surrounding the inner tube **115**A. The inner tube **115**A forms the ejection unit **111**, and the outer tube **115**B forms the recovery unit **113**. Thus not only does this enable efficient recovery of the projectile material P ejected from the ejection unit **111**, but also enables the blast processing unit **110** to be made more compact.

[0093] In the present exemplary embodiment the flexible member **180** is provided at an end portion of the outer tube **115**B, enabling leakage of the projectile material P from the blast processing unit **110** to be suppressed by the flexible member **180** contacting the roll surface **11**A. Providing the flexible member **180** also enables load to be distributed over the roll surface **11**A when pressed.

[0094] The present exemplary embodiment detects the distance between the blast processing unit **110** and the roll surface **11**A using the detection unit **140** for detecting the distance between the blast processing unit **110** and the roll surface **11**A, thereby enabling separation of the blast processing unit **110** from the roll surface **11**A to be detected, and enabling leakage of the projectile material P to be prevented.

[0095] In the present exemplary embodiment the blast processing unit **110** is moved in the roll axial direction by the movement mechanism **170** moving the blast processing unit **110** along the axial direction of the roll **11**, enabling removal of foreign matter and uniform roughening on the roll surface **11**A to be performed uniformly along the axial direction. Moreover, due to not needing to provide plural blast processing units **110** or widen the projection range, the roll surface foreign matter removal device **100** including the blast processing unit **110** may be made more compact.

[0096] In the present exemplary embodiment blasting is performed while the roll **11** is being rotated using the roll rotation mechanism **150** for rotating the roll **11**, and this enables removal of foreign matter and roughening on the roll surface **11**A to be performed uniformly along the circumferential direction. Moreover, including the roll rotation

mechanism **150** for rotating the roll **11**, for cases of a state in which rotational force is not being supplied to the rolls **11** for conveying the steel strip **1**, enables the roll **11** to be rotated without using the roll drive source employed when conveying the steel strip **1**. Namely, the roll **11** is rotated by imparting external rotational force through the rotation section **151** abutting the roll surface **11**A. This facilitates control of the roll rotation speed to match the blast processing.

[0097] In the present exemplary embodiment the ejection unit **111** ejects the projectile material P together with the gas G, and the recovery unit **113** recovers the projectile material P together with the gas G by suction. This facilitates recovery of the projectile material P by the projectile material P being ejected with the gas G and also being suctioned with the gas G. Ejecting the gas G also enables impurities to be suppressed from remaining on the roll surface **11**A more that in cases in which wet blasting is performed.

[0098] In the present exemplary embodiment the projectile material P is polygonal shaped alumina particles having sufficient hardness, enabling foreign matter to be efficiently removed from the roll surface **11**A. The polygonal shaped alumina particles are also chemically stable, making them unlikely to act as growth nuclei for the oxide coating layer C even were they to remain on the roll surface **11**A. This concludes explanation of the roll surface foreign matter removal device **100** and the roll surface foreign matter removal method according to an exemplary embodiment of the present invention.

EXAMPLES

[0099] In order to evaluate the performance of the roll surface foreign matter removal device **100** and the roll surface foreign matter removal method according to the present disclosure, the roll surface foreign matter removal device **100** for the roll surface **11**A was applied to foreign matter removal performed on the roll **11** inside the heating furnace **10**, and the removal amount of oxide coating layer C from the roll surface **11**A was investigated.

[0100] Specifically, a removal amount of manganese oxide coating layer from the roll surface **11**A was investigated for each of a case in which dry ice was employed as the projectile material P for Comparative Example 1, a case in which spherical grains of grit size **40** were employed as the projectile material P for Comparative Example 2, and a case in which spherical grains of grit size **120** were employed as the projectile material P for Comparative Example 3. The manganese oxide coating layer removal amount was also investigated for polygonal shaped alumina particles of grit size **46** as the projectile material P for Example. The manganese oxide removal amounts refer here to a reduction in the composition of manganese components in the vicinity of the roll surface between before and after foreign matter removal.

[0101] Specifically, the projectile material P was projected together with compressed air at a pressure of 0.3 MPa and at a projection angle of 90 degrees at the roll surface **11**A. Note that projection conditions, such as the pressure of gas etc., were all the same except for the projectile materials P. Moreover, the amount of manganese was measured prior to foreign matter removal using a portable X-ray fluorescence instrument. The amount of manganese was also measured after foreign matter removal using the portable X-ray fluorescence instrument. The amount of reduction in the composition of manganese components was then computed by subtracting the amount of manganese as measured after foreign matter removal from the amount of manganese as measured before foreign matter removal.

[0102] Note that 10 particles of the projectile material P were selected at random to determine the shape of the projectile material P in the present exemplary embodiment. The cross-section profile of the selected projectile material P was then observed using an SEM. Note that another inspection instrument other than an SEM may be employed as long as the cross-section profile can be confirmed. Next the angle of locations of angular shape (namely corner portions, hereafter referred to as "corners") was measured in the cross-section profile outline of each of the selected particles of projectile material P. Corners for which the angle of the internal angle at the corner is an angle within a preset range, namely satisfies a condition of being from 60 degrees to 170 degrees, are corners deemed to satisfying the criterion of the present exemplary embodiment. The individual particles were taken one-by-one to measure the number of corners satisfying the criterion. For the group of particles measured, an average value was then computed as expressed by the number corners included per single particle that are individual corners satisfy the criterion. The shape of the projectile material P is determined to be "polygonal shaped" in cases satisfying a condition of the result of this computation being an average of two or more corners. Moreover, the shape of the projectile material P is determined to be "spherical" in cases in which this condition is not satisfied. The projectile material P satisfying the above condition is employed in the Example.

[0103] FIG. **10** is a graph illustrating examples of manganese oxide removal amounts from the roll surface **11**A. As illustrated in FIG. **10**, the manganese oxide removal amount was about 1% by weight for Comparative Example 1 with dry ice as the projectile material P. For Comparative Example 2 and Comparative Example 3 with spherical grains as the projectile material P, the manganese oxide removal amount was about 6% by weight for Comparative Example 2 having a comparatively large particle size, and was about 2% by weight for Comparative Example 3 having a comparatively small particle size.

[0104] However, the manganese oxide removal amount was 23% by weight for the Example with the polygonal shaped alumina particles as the projectile material P. Thus it is clear that according to the Example employing the polygonal shaped alumina particles as the projectile material P, the manganese oxide removal amount exceeded 20% by weight as a rough indication of oxide removal amount.

[0105] The present Example thereby demonstrates that removal of the oxide coating layer C of the roll surface **11**A and restoration of the roughness of the roll surface **11**A is enabled by application of the roll surface foreign matter removal device **100** and the roll surface foreign matter removal method according to the present disclosure. Furthermore, removal of the oxide coating layer C is demonstrated as achievable more effectively by employing the polygonal shaped alumina particles as the projectile material P in comparison to the other projectile materials of the Comparative Examples.

[0106] Specifically, differences in the respective effects of Comparative Examples 1 to 3 and the Example arise for the following reasons. The projectile material P is polygonal shaped in the Example, and so there are pointed portions,

including the apexes of the polygonal shape of the projectile material P and the regions in the vicinity of the apexes. A large force is accordingly imparted to the oxide coating layer C at the impact positions of the pointed portions of the projectile material P when the projectile material P impacts the oxide coating layer C on the roll surface **11**A. As a result there is a large degree of breakdown of oxide coating layer C by the impact from the projectile material P, enabling the manganese oxide removal amount to be increased.

[0107] However, in Comparative Example 1 there is an extremely small mass of matter impacting due to the projectile material P being dry ice, and so the force imparted to the oxide coating layer C is also extremely small. This results in a comparatively small degree of breakdown of the oxide coating layer C being generated by the impact of the projectile material P, resulting in a small manganese oxide removal amount.

[0108] Moreover, in Comparative Example 2 the grit size of the particles of the projectile material P is 40 grit, which is comparatively close to the grit size of the particles of the projectile material P in the Example of 46 grit. However, the shape of the particles of the projectile material P in Comparative Example 2 is spherical instead of polygonal shaped as in the Example. This means that compared to cases in which the ejected particles have a polygonal shape as in the Example, even in cases in which the particles have the same maximum length for example, in Comparative Example 2 the contact surface area of the ejected projectile material P spherical particles with the oxide coating layer C is larger than in the Example. As a result the pressure imparted by the particles of the ejected projectile material P to the oxide coating layer C per unit contact surface area is smaller than in cases in which the ejected particles have a polygonal shape. There is accordingly insufficient breakdown of the oxide coating layer C in Comparative Example 2.

[0109] Moreover, similarly to in Comparative Example 2, the shape of the projectile material P in Comparative Example 3 is also spherical. The force imparted by the ejected particles to the oxide coating layer C per unit contact surface area is accordingly smaller than in cases in which the ejected particles have a polygonal shape. Moreover, the grit size of the particles of the projectile material P in Comparative Example 3 is 120 grit, this being larger than the projectile material P in Comparative Example 2, which is 40 grit. Thus in Comparative Example 3 the contact surface area between the ejected particles of projectile material P and the oxide coating layer C is even larger than in Comparative Example 2. As a result the amount of the oxide coating layer C that is broken down in Comparative Example 3 is further decreased from in Comparative Example 2.

[0110] Although details have been described regarding a preferably exemplary embodiment of the present disclosure with reference to the appended drawings, the present disclosure is not limited thereto. It will be obvious to any person of ordinary skill in the art of the present disclosure that various modifications and applications are conceivable that fall within a range of the technical idea as recited in the scope of the patent claims, and such modifications and applications should also be considered as falling within the technical scope of the present disclosure.

[0111] For example, although in the exemplary embodiment described above the blast processing unit **110** is illustrated by an example provided at an upper face side of the roll **11**, the present disclosure is not limited to such an example. For example, the blast processing unit **110** may be provided at a lower face side of the roll **11**, such that the projectile material P is ejected from below.

[0112] Moreover, although the exemplary embodiment described above illustrates an example in which there is a single blast processing unit **110**, there may be plural, such as two, of the blast processing units **110**. In such cases a configuration may be adopted in which different types of the projectile material P are ejected from each of the blast processing units **110**. For example, projectile material P having a first particle size may be ejected from the ejection unit **111** of one of the blast processing units **110**, and projectile material P having a second particle size smaller than the first particle size may be ejected from the ejection unit **111** of another of the blast processing units **110**.

[0113] Moreover, although the exemplary embodiment described above illustrates an example in which the ejection unit **111** and the recovery unit **113** are an integrated body in the blast processing units **110**, the present disclosure is not limited to such an example. For example, the ejection unit **111** and the recovery unit **113** may be separate bodies in the blast processing units **110**.

[0114] Moreover, although the exemplary embodiment described above illustrates an example of the roll rotation mechanism **150** in which the rotation section **151** is abutted against the roll **11** and rotates the roll **11**, the present disclosure is not limited to such an example. For example, a belt for transmitting rotational force from a drive source may be attached to the roll **11** so as to serve as a rotation mechanism of the present disclosure, such that the roll **11** is rotated by using such a belt.

[0115] Furthermore, a configuration may be adopted that is not provided with the roll rotation mechanism **150** of the exemplary embodiment described above, such that the roll **11** is rotated by a roll drive source that rotates the roll **11** when conveying the steel strip **1**.

[0116] **1** steel strip

[0117] **10**, **10**A, **10**B heating furnace

[0118] **11** roll

[0119] **11**A roll surface

[0120] **11A1** projection target position

[0121] **12** roll shaft

[0122] L**1** tangent

[0123] L**2** center axis

[0124] θ projection angle

[0125] **13** plating process apparatus

[0126] **13**A plating bath

[0127] **100** roll surface foreign matter removal device

[0128] **101** link arm

[0129] **101**A one end

[0130] **101**B other end

[0131] **103** main body

[0132] **110** blast processing unit

[0133] **111** ejection unit

[0134] **113** recovery unit

[0135] **115** double-walled tubular shaped body

[0136] **115**A inner tube

[0137] **115**B outer tube

[0138] **117** closed space

[0139] **120** press unit

[0140] **121** air cylinder

[0141] **130** hose

[0142] **131** projectile material supply hose

[0143] **132** gas supply hose
[0144] **133** discharge hose
[0145] **140** detection unit
[0146] **150** roll rotation mechanism
[0147] **151** rotation section
[0148] **151**A outer face
[0149] **153** drive source
[0150] **160** air supply and exhaust system
[0151] **161** recovery tank
[0152] **163** dust collector
[0153] **165** blower
[0154] **167** gas supply source
[0155] **170** movement mechanism
[0156] **171** screw feed mechanism
[0157] **171**A screw shaft
[0158] **171**B support sections
[0159] **173** drive source
[0160] **175** guide shaft
[0161] **180** flexible member
[0162] **181** brush shaped member
[0163] **190** controller
[0164] C oxide coating layer
[0165] M metal solution
[0166] P projectile material
[0167] G gas
[0168] X**1** rotation axis

Supplement

[0169] The following aspects are conceptualized from the present specification.
[0170] Namely, Aspect 1 is a device for removing foreign matter from a roll surface, the device including:
[0171] a blast processing unit including an ejection unit configured to eject a projectile material at a surface of a roll that conveys a steel strip inside a heating furnace, and a recovery unit configured to recover the projectile material; and a press unit configured to press the blast processing unit toward the surface of the roll.
[0172] Aspect 2 is the roll surface foreign matter removal device according to Aspect 1, wherein:
[0173] the ejection unit is provided at a center of the blast processing unit; and
[0174] the recovery unit is provided at a periphery of the ejection unit.
[0175] Aspect 3 is the roll surface foreign matter removal device according to Aspect 1 or Aspect 2, wherein:
[0176] the blast processing unit includes a double-walled tubular shaped body configured from an inner tube and an outer tube surrounding the inner tube; and
[0177] the inner tube is the ejection unit and the outer tube is the recovery unit.
[0178] Aspect 4 is the roll surface foreign matter removal device according to Aspect 3, wherein a flexible member is provided at an end portion of the outer tube.
[0179] Aspect 5 is the roll surface foreign matter removal device according to any one of Aspects 1 to 4, further including a detection unit configured to detect a distance between the blast processing unit and the surface of the roll.
[0180] Aspect 6 is the roll surface foreign matter removal device according to Aspect 5, wherein ejection of the projectile material by the ejection unit is halted, in a case in which the distance between the surface of the roll and the blast processing unit is detected by the detection unit to be a specific value or greater.
[0181] Aspect 7 is the roll surface foreign matter removal device according to any one of Aspects 1 to 6, further including a movement mechanism configured to move the blast processing unit along an axial direction of the roll.
[0182] Aspect 8 is the roll surface foreign matter removal device according to any one of Aspects 1 to 7, further including a roll rotation mechanism configured to rotate the roll.
[0183] Aspect 9 is the roll surface foreign matter removal device according to any one of Aspects 1 to 8, wherein:
[0184] the ejection unit is configured to eject the projectile material together with a gas; and
[0185] the recovery unit is configured to recover the projectile material together with the gas by using suction.
[0186] Aspect 10 is the roll surface foreign matter removal device according to Aspect 9, wherein the ejection unit is configured to eject the gas in a pressure range of from 0.2 MPa to 0.5 MPa.
[0187] Aspect 11 is the roll surface foreign matter removal device according to any one of Aspects 1 to 10, wherein the ejection unit is configured to project the projectile material against the surface of the roll at a projection angle of from 80 degrees to 90 degrees, as viewed along an axial direction of the roll.
[0188] Aspect 12 is the roll surface foreign matter removal device according to any one of Aspects 1 to 11, wherein the projectile material is alumina particles.
[0189] Aspect 13 is a method for removing foreign matter from a roll surface, the method including:
[0190] a process of pressing the blast processing unit of the roll surface foreign matter removal device according to any one of Aspects 1 to 12 against the surface of the roll; and
[0191] a process of ejecting the projectile material from inside the blast processing unit and recovering the projectile material inside the blast processing unit.
[0192] Aspect 14 is the roll surface foreign matter removal method according to Aspect 13, wherein in processing of ejecting the projectile material, after a first projectile material having a first average particle size has been ejected, a second projectile material having a second average particle size smaller than the first average particle size is ejected.
[0193] Aspect 15 is a method for manufacturing a steel strip, the method including:
[0194] a process of removing foreign matter on a surface of a roll provided inside a heating furnace by using the roll surface foreign matter removal method according to Aspect 13; and
[0195] a process of passing a steel strip through inside the heating furnace where the roll is provided and performing heat treatment.
[0196] Aspect 16 is the steel strip manufacturing method according to Aspect 15, wherein: the process of removing is performed while rotating the roll by imparting rotational force using a rotation mechanism abutted against the surface of the roll.
[0197] Aspect 17 is the steel strip manufacturing method according to Aspect 15 or Aspect 16, wherein the steel strip is a high tensile steel.
[0198] Other Aspects
[0199] The following Other Aspects can be conceptualized from the present specification.
[0200] Namely, Other Aspect 1 is a device for performing roughening processing of a roll surface, the device including:

[0201] a blast processing unit including an ejection unit configured to eject a projectile material at a surface of a roll that conveys a steel strip inside a heating furnace, and a recovery unit configured to recover the projectile material; and

[0202] a press unit configured to press the blast processing unit toward the surface of the roll.

[0203] Other Aspect 2 is the roll surface roughening processing device according to Other Aspect 1, wherein:

[0204] the ejection unit is provided at a center of the blast processing unit; and

[0205] the recovery unit is provided at a periphery of the ejection unit.

[0206] Other Aspect 3 is the roll surface roughening processing device according to Other Aspect 1 or Other Aspect 2, wherein:

[0207] the blast processing unit includes a double-walled tubular shaped body configured from an inner tube and an outer tube surrounding the inner tube; and

[0208] the inner tube is the ejection unit and the outer tube is the recovery unit.

[0209] Other Aspect 4 is the roll surface roughening processing device according to Other Aspect 3, wherein a flexible member is provided at an end portion of the outer tube.

[0210] Other Aspect 5 is the roll surface roughening processing device according to any one of Other Aspects 1 to 4, further including a detection unit configured to detect a distance between the blast processing unit and the surface of the roll.

[0211] Other Aspect 6 is the roll surface roughening processing device according to Other Aspect 5, wherein ejection of the projectile material by the ejection unit is halted, in a case in which the distance between the surface of the roll and the blast processing unit is detected by the detection unit to be a specific value or greater.

[0212] Other Aspect 7 is the roll surface roughening processing device according to any one of Other Aspects 16, further including a movement mechanism configured to move the blast processing unit along an axial direction of the roll.

[0213] Other Aspect 8 is the roll surface roughening processing device according to any one of Other Aspects 1 to 7, further including a roll rotation mechanism configured to rotate the roll.

[0214] Other Aspect 9 is the roll surface roughening processing device according to any one of Other Aspects 18, wherein:

[0215] the ejection unit is configured to eject the projectile material together with a gas; and

[0216] the recovery unit is configured to recover the projectile material together with the gas by using suction.

[0217] Other Aspect 10 is the roll surface roughening processing device according to any one of Other Aspects 1 to 9, wherein the projectile material is alumina particles.

[0218] Other Aspect 11 is a method for performing roughening processing of a roll surface, the method including:

[0219] a process of pressing the blast processing unit of any one of Other Aspects 1 10 against the surface of the roll; and

[0220] a process of ejecting the projectile material from inside the blast processing unit and recovering the projectile material inside the blast processing unit.

[0221] Other Aspect 12 is a method for manufacturing a steel strip, the method including: a process of roughening a surface of a roll provided inside a heating furnace by using the roll surface roughening processing method according to Other Aspect 11; and a process of passing a steel strip through inside the heating furnace where the roll is provided and performing heat treatment.

[0222] Other Aspect 13 is the steel strip manufacturing method according to Other Aspect 12, wherein the steel strip is a high tensile steel.

[0223] The Other Aspects described above exhibit the following advantageous effect.

[0224] The roll surface roughening processing device, the roll surface roughening processing method, and the steel strip manufacturing method according to the Other Aspects enable roughening of a surface of a conveyance roll provided inside a heating furnace to be simply implemented.

[0225] The entire content of the disclosure of Japanese Patent Application No. 2019-224801 filed on Dec. 12, 2019 is incorporated by reference in the present specification.

[0226] All publications, patent applications and technical standards mentioned in the present specification are incorporated by reference in the present specification to the same extent as if each individual publication, patent application, or technical standard was specifically and individually indicated to be incorporated by reference.

1. A device for removing foreign matter from a roll surface, the device comprising:

a blast processing unit including an ejection unit configured to eject a projectile material at a surface of a roll that conveys a steel strip inside a heating furnace, and a recovery unit configured to recover the projectile material; and

a press unit configured to press the blast processing unit toward the surface of the roll.

2. The roll surface foreign matter removal device according to claim **1**, wherein:

the ejection unit is provided at a center of the blast processing unit; and

the recovery unit is provided at a periphery of the ejection unit.

3. The roll surface foreign matter removal device according to claim **1**, wherein:

the blast processing unit has a double-walled tubular shaped body configured from an inner tube and an outer tube surrounding the inner tube; and

the inner tube is the ejection unit and the outer tube is the recovery unit.

4. The roll surface foreign matter removal device according to claim **3**, wherein a flexible member is provided at an end of the outer tube.

5. The roll surface foreign matter removal device according to claim **1**, further comprising a detection unit configured to detect a distance between the blast processing unit and the surface of the roll.

6. The roll surface foreign matter removal device according to claim **5**, wherein ejection of the projectile material by the ejection unit is halted, in a case in which the distance between the surface of the roll and the blast processing unit is detected by the detection unit to be a specific value or greater.

7. The roll surface foreign matter removal device according to claim 1, further comprising a movement mechanism configured to move the blast processing unit along an axial direction of the roll.

8. The roll surface foreign matter removal device according to claim 1, further comprising a roll rotation mechanism configured to rotate the roll.

9. The roll surface foreign matter removal device according to claim 1, wherein:

the ejection unit is configured to eject the projectile material together with a gas; and

the recovery unit is configured to recover the projectile material together with the gas by using suction.

10. The roll surface foreign matter removal device according to claim 9, wherein the ejection unit is configured to eject the gas in a pressure range of from 0.2 MPa to 0.5 MPa.

11. The roll surface foreign matter removal device according to claim 1, wherein the ejection unit is configured to project the projectile material against the surface of the roll at a projection angle of from 80 degrees to 90 degrees, as viewed along an axial direction of the roll.

12. The roll surface foreign matter removal device according to claim 1, wherein the projectile material is alumina particles.

13. A method for removing foreign matter from a roll surface, the method comprising:

a process of pressing the blast processing unit of the roll surface foreign matter removal device according to claim 1 against the surface of the roll; and

a process of ejecting the projectile material from inside the blast processing unit and recovering the projectile material inside the blast processing unit.

14. The roll surface foreign matter removal method according to claim 13, wherein, in processing of ejecting the projectile material, after a first projectile material having a first average particle size has been ejected, a second projectile material having a second average particle size smaller than the first average particle size is ejected.

15. A method for manufacturing a steel strip, the method comprising:

a process of removing foreign matter on a surface of a roll provided inside a heating furnace by using the roll surface foreign matter removal method according to claim 13; and

a process of passing a steel strip through inside the heating furnace where the roll is provided, and performing heat treatment.

16. The steel strip manufacturing method according to claim 15, wherein:

the process of removing is performed while rotating the roll by imparting rotational force using a rotation mechanism abutted against the surface of the roll.

17. The steel strip manufacturing method according to claim 15, wherein the steel strip is a high tensile steel.

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