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(54) **GRINDING METHOD AND GRINDING SYSTEM FOR BILLET**
VERFAHREN UND SYSTEM ZUM SCHLEIFEN VON BRAMMEN
PROCEDE ET SYSTEME DE RECTIFIAGE DE BILLETTES

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(56) References cited:

EP-A- 0 488 846	**BE-A- 895 665**
GB-A- 2 159 451	**JP-A- 61 159 373**
JP-A- 63 016 999	**JP-B- 56 034 431**
US-A- 4 872 293	**US-A- 5 117 366**

- **MANUFACTURING REVIEW, vol.2, no.2, June 1989 HASHISH**
- **PATENT ABSTRACTS OF JAPAN vol. 7, no. 221 (M-246) (1366) 30 September 1983 & JP-A-58 114 861 (HITACHI ZOSEN K.K.) 8 July 1983**

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Description

TECHNICAL FIELD

[0001] The present invention relates to material surface grinding and, in particular, to a grinding method and system for grinding defective surface portions of steel products such as slabs, blooms and billets in continuous casting lines or ingot casting lines or the like and after-processes following the same.

BACKGROUND ART

[0002] Steel products such as blooms, slabs and billets, formed by continuous casting or ingot casting processes, may develop various defects during their casting. Such defects will lead to a reduction in product yield and a deterioration in product quality in after-processes following the casting.

[0003] To cope with this problem, such defects are removed by reconditioning during or after the production of steel products such as slabs, blooms or billets, so that only steel products from which all defects have been removed are fed to the after-processes, thereby preventing a reduction in product yield and a deterioration in product quality.

[0004] Generally adopted means for reconditioning steel products are flame scarfing using a hot scarfer and grinding using a grinder. An example of the flame scarfing method is shown in Japanese Patent Laid-Open No. 52-5644, according to which a gantry frame is arranged to have two supporting beams, on which two movable nozzle operation units for side and upper surface are mounted, respectively. Another example of the flame scarfing method is shown in Japanese Patent Laid-Open No. 52-81048, according to which flame scarfing is performed by using a plurality of transversely arranged torches, making it possible to remove extensive defects without performing auxiliary flame scarfing in transverse direction at the beginning.

[0005] Regarding grinding using a grinder, an example thereof is shown in Japanese Patent Laid-Open No. 48-46993, according to which billets, etc. are ground by using an abrasive wheel whose grinding performance is improved by employing a hydraulic or pneumatic cylinder. Another example of the grinding method is shown in Japanese Patent Laid-Open No. 1-242729, according to which cast stainless steels or other stainless steel products are reconditioned to effectively remove any defective portions therefrom in a specific temperature range, thereby avoiding the problem of the self-hardening property of stainless steels.

[0006] Apart from the above-described methods of removing defects through reconditioning by flame scarfing or grinding, various other reconditioning methods have been proposed which are mainly directed to descaling during the production of steel products. For example, Japanese Patent Laid-Open No. 51-97894 discloses a method according to which a predetermined type of abrasive is sprayed through nozzles onto the surface of a stainless steel plate to effect wet grinding and descaling at the same time.

[0007] However, as will be discussed below, the above-described steel product reconditioning methods have various problems.

[0008] Both the flame scarfing method disclosed in Japanese Patent Laid-Open No. 52-5644, in which a gantry frame is arranged to have two supporting beams, on which two movable nozzle operation units for side and upper surface are mounted, respectively, and the method disclosed in Japanese Patent Laid-Open No. 52-81048, in which flame scarfing is performed by using a plurality of transversely arranged torches to make it possible to effect flame scarfing on extensive defects without performing auxiliary flame scarfing, have a problem in that the flame scarfing operation itself involves a high temperature and a large amount of dust, causing a deterioration in working conditions. Moreover, with these methods, it is difficult to discriminate any defects remaining on the surface of the steel products after flame scarfing.

[0009] Further, in flame scarfing, it is impossible to control the scarfing depth, creating an unevenness. Thus, some defects remain, but to prevent defects from remaining, the flame scarfing amount is increased, resulting in a reduction in yield.

[0010] Another problem with flame scarfing, compared with other types of methods, is that it reouires ecuipment on a larger scale for automatizing the process to achieve an improvement in working conditions and operational efficiency, resulting in high costs.

[0011] Regarding grinding methods using a grinder, e.g., the above-described method disclosed in Japanese Patent Laid-Open No. 48-46993, in which billets, etc. are ground by using an abrasive wheel whose grinding performance is improved by employing a hydraulic or a pneumatic cylinder, and the method disclosed in Japanese Patent Laid-Open No. 1-24729, in which steel reconditioning by a grinder is performed on cast stainless steels or other other stainless steels in a specific temperature range; these methods involve, like the above-described flame scarfing methods, an operation under unfavorable conditions of high temperature and a large amount of dust depending upon the steel type. Moreover, as in the above-described flame scarfing methods, it is difficult to discriminate any defects remaining on the steel surface after grinding, resulting in high defect-removal costs, etc.

[0012] Enlarging the grinder width results in a large amount of steel being unnecessarily ground and reouires a large driving power, which leads to an increase in running costs and a reduction in yield. On the other hand, reducing the grinder width results in a deterioration in efficiency because a large number of grinders are required, with the reconditioning time undesirably increased. The steel defect removal method such as disclosed in Japanese Patent Laid-Open No. 51-97894, in which wet blasting are performed by spraying an abrasive through nozzles onto the surface of a stainless steel plate, is, at the present level of technology, mainly directed to descaling and, technically, still not sufficiently developed to be adopted in removing defects from steel products. Thus, it cannot be adopted, practically speaking.

[0013] From BE-A-895 665 a technique of conditioning metal products including the steps of detecting defects existing on the surface of the metal product, of removing these defects by using a flame torch or mechanical cutting and of inspecting and cleaning the smoothed surface is known. The use of the mechanical grinding step or the flame scarfing step results in a low operation efficiency and reliability.

[0014] US-A-4 872 293 discloses an abrasion technique in which an abrasive water jet is used to smooth surfaces wherein the abrasive slurry is recycled after the grinding operation.

[0015] MANUFACTURING REVIEW, vol. 2, no. 2, June 1989, describes a grinding technique in which an abrasive water jet is used to process a metal product while the portion of the metal product to be processed is provided with a mask.

[0016] From Patent Abstract of Japan, vol. 7, no. 221 (M-246) (1366) a rust removing system is known which includes a detection system for detecting rusted parts on a surface, an abrasive device for ejecting grinding material onto the surface to remove the rusted parts, said abrasive device including a supply system for the grinding material and a recovery system for recovering used grinding material and recycling it to the supply system, and a grinding controller for receiving information from the detection system and controlling the operation of the abrasive device.

SUMMARY OF THE INVENTION

[0017] The present invention has been made with a view toward solving the problems in the above-described conventional steel reconditioning techniques. It is accordingly an object of the present invention to provide an excellent steel grinding method which makes it possible not only to easily discriminate any defects remaining on the surfaces of steel products after grinding, such discrimination being important when improving working conditions and automating the steel production process, but also to selectively remove defective portions in accordance with the defect. Thus, a reduction in product costs is achieved, an improvement in yield is attained and, further, the product quality can be positively guaranteed, thereby contributing much to those fields of the iron industry.

[0018] This object is met by the independent claims. Preferred embodiments are disclosed in the dependent claims.

[0019] The following technical means are adopted in the grinding method of the present invention: a predetermined abrasive in the form of fine particles, such as garnet sand, silica sand, alumina, iron sand, or cast-iron grit, is mixed with ultra-high-speed water jet to form an ultra-high-speed abrasive water jet which is continuously ejected through nozzle as jets having a fixed small diameter to impinge with impact upon the surface of steel products such as slabs, thereby automatically removing, without contact, any undesirable defects existing near the surface of such steel products. Further, automatic sensing is performed on the surface and near-surface portions of the steel products before and/or after the grinding so as to search for any defects and to detect the locations, etc. thereof, thereby making it possible to realize a completely automated, unmanned grinding line.

[0020] Further, in accordance with the present invention, there is provided a grinding system for grinding the surface of materials such as steel slabs. In the grinding system, conventional wet blasting and liquid honing methods are further developed to realize a system for grinding the surface of materials such as steel slabs using an abrasive water jet with an increased pressure (normally 300 kgf/cm2 or more) and an improved energy density and machining efficiency. The system is formed by combining the following sub-systems as needed: a defect detection system for detecting defects on material surfaces; a grinding control system for transmitting signals regarding grinding conditions controlled on the basis of defect information detected by the defect detection system; an abrasive supply system for supplying abrasive in accordance with signals from the grinding control system; a grinding-nozzle-device system adapted to move relative to the material in accordance with signals from the grinding control system; and an abrasive recovery system for recovering the abrasive used for grinding, and restoring it to the abrasive supply system.

[0021] The defect detection system for detecting defects on material surfaces employs a defect detecting device, which may consist of an image processing apparatus based on magnetic particle inspection or ultrasonic flaw detection, or an apparatus using a telecamera.

[0022] Grinding using an abrasive water jet employs a non-heating-type method. Therefore, the method does not involve surface-defect obscuration caused by the influence of heat or the melting of material surface portions, so that the detection of defects after machining is easy to perform. Further, since the turning ON/OFF of the machining operation is easy, no ignition error as involved in flame scarfing occurs. In addition, due to the fact that the method adopts a non-contact-type machining means, the method is relatively free from service-life problems as compared with methods using grinding wheels, which makes it possible to easily construct an automated grinding system.

[0023] Moreover, when the sub-system for recovering the used abrasive is connected with the sub-system for supplying the abrasive to be mixed with a high-speed fluid jet, an abrasive circulation system is formed when the abrasive water jet is applied to the grinding of an extensive and continuous surface. A continuous operation is also possible when abrasive water jet nozzles, adapted to make a relative movement with respect to a plurality of steel products, are applied to the grinding of a wide material surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

Fig. 1 is a schematic diagram showing how cutting is performed by using an abrasive water jet;
Fig. 2 is a schematic diagram showing how partial cutting is performed by using the abrasive water jet;
Fig. 3 is a schematic diagram showing how surface grinding is performed by using the abrasive water jet;
Fig. 4 is a sectional view of an essential part of a grinding system according to the present invention, showing how surface grinding is performed on the surface of a slab by the system;
Fig. 5 is a partially sectional front view of the same;
Fig. 6 is a plan view showing defects on the surface of a slab and how a nozzle is moved over them;
Fig. 7 is a longitudinal sectional view of the same;
Fig. 8 is a block diagram showing a slab grinding system according to the present invention;
Fig. 9 is a plan view of a slab grinding system according to the present invention;
Fig. 10 is a front view of an essential part of the grinding system shown in Fig. 9;
Fig. 11 is a side view of an essential part of the grinding system shown in Fig. 9;
Fig. 12 is a block diagram showing another embodiment of the present invention;
Fig. 13 is a plan view of the embodiment shown in Fig. 12;
Fig. 14 is a side view of Fig. 13;
Fig. 15 is front view of an essential part of the embodiment shown in Fig. 13; and
Fig. 16 is a side view of an essential part of Fig. 15.

PREFERABLE EMBODIMENT OF THE INVENTION

[0025] Figs. 1 through 3 are schematic diagrams showing how a cast slab is ground by means of a high-pressure water jet mixed with abrasive (an abrasive water jet). Numeral 1 indicates a nozzle of a so-called abrasive water jet apparatus. High-pressure water jet at a fixed pressure is supplied to a mixing chamber (not shown) and mixed with an abrasive in the form of fine particles, such as garnet sand, silica sand, alumina, iron sand, or cast-iron grit to form a jet 2 having a fixed small diameter, which is expelled at ultra-high speed onto a steel slab 3 to be ground. Figs. 1 through 3 show how cutting (grinding) is performed when the relative traversing speed of the nozzle 1 with respect to the slab 3 (the nozzle feeding speed or the speed at which the slab 3 is fed) is varied.

[0026] Fig. 1 shows normal cutting, in which grinding is performed over the entire thickness t of the slab 3. In this case, the relative traversing speed of the nozzle is in a low-speed range which is low enough to enable the slab 3 to be cut in a satisfactory manner. Drag lines 4 are formed over the thickness t of the slab 3.

[0027] Fig. 2 shows a case in which the relative movement of the nozzle 1 and the slab 3 is made at a higher speed than in the case of Fig. 1. Here, the cutting is not effected over the entire thickness t of the slab 3, the cutting depth h1 showing a fluctuation by a difference $\Delta h1$ at the bottom portion formed by the cutting.

[0028] In the example of Fig. 3, the relative traversing speed between the nozzle 1 and the slab 3 is even higher than in the example of Fig. 2. The cutting depth h2 in this case is smaller than that in Fig. 2. At the same time, the fluctuation in depth $\Delta h2$ is also smaller than that in Fig. 2, with the result that the bottom surface formed by the cut grooves are practically smooth, thus making it possible to perform the so-called groove grinding.

[0029] In the present invention, the above grinding principle and grinding-speed ranges of the abrasive water jet are applied to the grinding of the surface of a steel slab 3.

[0030] Further, in the present invention, by adopting the above-described principle, the surface of the steel slab 3 is subjected, though microscopically, to a positive grinding action due to the the eroding effect of the abrasive grains in the ultra-high-speed water jet, thereby making it possible to remove defects under ideal conditions involving no generation of heat.

[0031] By the relative feeding of the nozzle 1 forming the above jet spout, it is possible to smooth the entire surface of the steel slab 3 by grinding it uniformly, or partially by selecting defective portions existing on or near the surface.

[0032] Further, due to the provision of the sub-system for detecting defects, etc. before and/or after the above-described grinding, it is possible to detect defects, etc. existing on or near the surface of the steel slab 3, and the positions and sizes of such defects. Information on these defects is input and fed back to be utilized in the grinding operation, whereby it is possible to stabilize the process for removing defects on the surface, etc. of steel products and to positively guarantee the quality thereof and, further, to realize a completely automated working process.

[0033] Further, since the steel surfaces after grinding are not covered with oxide scales or the like, defect detection after grinding is relatively easy to perform.

[0034] Next, an embodiment of the present invention will be described with reference to the drawings from

Fig. 4 onwards.

[0035] In the following description, the components which are the same as those of Figs. 1 through 3 will be referred to by the same reference numerals.

[0036] Figs. 4 and 5 show how the steel slab 3 is ground in accordance with an embodiment of the present invention, along with the construction of a nozzle head 4 of a side entrainment type. Abrasive 6 consisting of garnet sand or the like is supplied to a mixing chamber 10 by a negative pressure due to the venturi effect of an ultra-high-speed water jet 9 generated at a water nozzle 8 connected to a high-pressure water piping 7. The water jet 9 and the abrasive 6 are mixed with each other in the interior of the abrasive nozzle 1, which extends from the mixing chamber 10, accelerated and ejected from the abrasive nozzle 1 onto a predetermined portion of the slab 3 as a jet 2 having a predetermined small diameter to grind the surface of the slab 3 in relative movement, based on the grinding principle described above.

[0037] In the above process, the axis of the abrasive nozzle 1 is held at the proper angle with respect to the slab 3 in accordance with the kind of the slab and the type of defect, and the abrasive nozzle is caused to make a relative movement with respect to the slab 3 while swinging or rotating at an appropriate speed and pitch so as to sufficiently cover the defects, etc. on the surface, thereby effecting a desired grinding, etc.

[0038] In an experiment, the abrasive was supplied at a speed of 0.5 kg/min or more, and the high-pressure water was supplied at a pressure of 1000 kgf/cm^2 or more and a flow rate of 2 lit./min., the working distance between the nozzle and the steel being not more than 200 mm. In this case, the inpinging angle with respect to the slab 3 ranged, for example, from 10 to 170°, and the relative speed between the slab 3 and the abrasive nozzle 1 when the abrasive nozzle was swung or rotated was approximately 1 to 10 m/min. Under these conditions, very satisfactory results were obtained. Such conditions, however, somewhat differ depending upon the kind of slab, the type of defect and the kind of abrasive 6, etc.

[0039] Figs. 6 and 7 show in more detail an example of the way the abrasive nozzle 1 is operated. As shown in the drawings, to cope with defects 12, 12', 12" and 12"', various kinds of swinging modes for the abrasive nozzle 1 can be combined in terms of grinding range, direction and pitch.

[0040] In the embodiment shown in Fig. 7, an appropriate rounding is effected in the boundaries between the surface portions 3' where grinding is performed on the defects 12, 12', 12" and 12"' and the surface portions and 3" where no grinding is performed, in order that extremely large differences in thickness may not be generated between these portions.

[0041] The abrasive nozzle 1 can also perform grinding as in the above case by a rotation within an appropriate radius, instead of swinging, and pitch feed.

[0042] Next, Fig. 8 is a block diagram showing the entire system including an inspection process. In the system shown, an articulated robot is used as a driving device 13 for the abrasive nozzle 1. Searching results obtained at an inspection stage 14 prior to grinding by a defect detecting mechanism 15 consisting of a CCD camera or the like are input to a defect detection system 16 as information on the defects 12, etc. on the slab 3 (in terms of location, size, depth, etc.), grinding being automatically performed in a grinding (scarfing) stage 17 in accordance with the information.

[0043] The entire surface of a continuous casting steel product is scanned with a telecamera by a camera driving device which operates in accordance with signals from a camera drive controller in a defect detection system, thereby obtaining defect information in terms of size, configuration, area, depth, etc. The image processing apparatus in defect detection system performs coordinate transformation on the location of any defect and, on the basis of the coordinates thereby obtained, the location is settled as an address on the steel surface. The information from the image processing apparatus in terms of configuration, depth, grinding range, procedures and location, is input to a collective-control computer in grinding controller. The input information is supplied to the grinding system to be used as driving instructions for controlling a nozzle drive controller, an abrasive supply system and high-pressure-water generator, etc. to cause the high-pressure fluid nozzle for abrasive water jetting to traverse the steel surface by means of a guide mechanism working on an address basis to perform grinding.

[0044] It is possible, as needed, to perform inspection by an optical inspection means during and after the grinding by using the defect detection mechanisms 15' and 15" and the defect detection system 16, utilizing the detection results for feedback during grinding or for re-grinding.

[0045] Further, this embodiment adopts a system in which the used abrasive 6 is recovered and supplied to an abrasive feeding device 19 for re-utilization, the fragmental abrasive being separated and removed by a recovery/re-feeding device 18.

[0046] Numeral 20 indicates a high-pressure water generator; numeral 7' indicates a high-pressure water piping; numeral 21 indicates a nozzle drive controller; numeral 22 indicates a grinding controller for overall grinding control; numeral 23 indicates waste abrasive; numeral 24 indicates new abrasive; and numeral 25 indicates an inspection stage. Figs. 9, 10 and 11 show external views of the entire system of the embodiment shown in Fig. 8, in which three articulated robots cooperate to continuously grind the surface of a steel slab 3 or the like in an average tact time of 7 minutes. The slab 3 is fed in the direction indicated by the arrows.

[0047] Next, another embodiment of the present invention will be described with reference to Figs. 12 through 16.

[0048] The system shown in the drawings comprises a defect detection system 101, an abrasive-water-jet-nozzle device 102, a supply system 103 for supplying high-pressure water and abrasive to the nozzles, and a recovery system 104 for recovering the used abrasive and re-feeding the same to the supply system 103.

[0049] Information from these systems are input to a grinding controller 105, and the input information is used for controlling the systems by a judgment function of the grinding controller 105.

[0050] The slab W to be ground is processed through three stages: inspection stage S1, grinding stage S2 and inspection stage S3. One of the inspection stages S1 and S3 may be omitted.

[0051] The defect detection system 101 comprises a defect detection system 111 for detecting defects on the slab surface prior to grinding, a defect detection system 112 for detecting surface defects during grinding, and a defect detection system 113 for detecting defects on the slab surface after grinding for the next process. The surface defect conditions in each of these stages are detected, and information thereon is input to the grinding controller 105, the abrasive nozzle device 102 and the supply system 103 being controlled in accordance with variations in the information.

[0052] The abrasive water jet nozzle device 102 comprises a nozzle drive controller 106 controlled by the grinding controller 105, and nozzles 108 driven by a nozzle driver 107.

[0053] Figs. 13 through 16 show a specific system arrangement for the system shown in Fig. 12.

[0054] The system shown comprises: a supply system 103 consisting of a high-pressure water generator 31 and an abrasive supply device 32 shown in Fig. 12; and front and rear nozzle devices 121 and 122 for respectively grinding the upper and lower surfaces of slabs, which are reversed by a reversing device 42. Each of the nozzle devices 121 and 122 has three nozzles 108 arranged along the longitudinal dimension of the slabs W produced by a continuous casting machine 41. Each nozzle 108 is attached to the tip of a 6-axis articulated robot 125 provided on a nozzle guide 124 arranged on a base 123 astride a slab moving bed 109. Each nozzle 108 is driven and controlled by the nozzle drive controller 106 and the nozzle driver 107 shown in Fig. 12.

[0055] A robot and an NC device can be used as the driving devices for the nozzles 108. One or a plurality of articulated robots may be installed on the floor, ceiling or walls, or in a combination of these installation locations. The driving devices may be stationary or, as in the example shown in the drawings, capable of travelling along one axis or more. The abrasive nozzle head may be of a direct injection type, in which the abrasive and water are mixed at high pressure beforehand and expelled at high pressure through the nozzle in a slurry-like state. Further, the nozzles may be operated so as to move in a variety of rotating and swinging movements.

[0056] As described above, in accordance with the present invention, a high-pressure water jet is mixed with abrasive and expelled against steel products, thereby making it possible to perform automatic grinding without contact. Thus, conventional defect removal means, such as flame scarfing and wheel grinding, which have been manually performed under severe working conditions involving noise and heat, can be dispensed with, thus leading to a marked improvement in working conditions (by realizing an unmanned working process, etc.) In addition, the method of the present invention provides the excellent effect of making it possible to positively remove any defects existing on or near the surface of a semi-processed steel product, the removal being effected in a stable manner and to a desired depth without involving any fusion or deterioration of the material caused by heat. Further, by utilizing the abrasive circulation system as needed, an excellent system can be provided in which it is possible to perform a continuous operation without deteriorating the function of the abrasive water jet itself, which leads to saving of resources and a reduction in cost.

[0057] Thus, the present invention provides an excellent machining means for the removal of steel surface defects from a semi-processed steel product, which removal has tended to become more and more necessary due to the recent increase in demand for higher quality materials.

Claims

1. A method for removing surface defects from a semi-processed steel product produced in a continuous casting stage or a stage subsequent to a continuous casting stage, comprising

    (a) detecting surface defects on said steel product;
    (b) ejecting at least one jet of fine abrasive particles mixed with high-pressure water onto said surface defects of said steel product in response to the detection result of step (a) to remove said surface defects; and
    (c) recovering and recirculating the fine abrasive particles for reuse in step (b).

2. The method according to claim 1, wherein said at least one jet is ejected through at least one nozzle (1; 108).

3. The method according to claim 2, wherein said at least one jet of said fine abrasive particles being fed at a rate of not lower than 0.5 kg/min, and said high-pressure water being supplied at a pressure of not lower than 1000 kgf/cm^2 and at a flow rate of not lower than 2 lit/min, said abrasive particles and high-pressure water being either mixed with each other beforehand in a high-pressure state or mixed within a head of said at least one nozzle (1; 108)

after ejection of the high-pressure water to obtain high-pressure water mixed with abrasive particles, said at least one jet being ejected onto the surface of the steel product at an impinging angle of 10 to 170°, and with a working distance between the nozzle and the steel surface of not more than 200 mm.

4. The method according to claim 2 or 3, wherein surface defects detected in step (a) are subjected to coordinate transformation by a defect detection system (16; 101) and said at least one high-pressure liquid ejecting nozzle (1; 108) is driven and moved in response to information obtained through the coordinate transformation by said defect detection system.

5. The method according to any of claims 1 to 4, further comprising a step of inspecting the surface of said steel product after step (b).

6. A system for removing surface defects from a semi-processed steel product, comprising a continuous casting stage or a stage subsequent to a continuous casting stage;

a defect detection system (16; 101) including a detector (15; 111) for detecting surface defects of the steel product;
an abrasive-water-jet-nozzle device (1, 13, 21; 102), being adapted to move relatively to the surface of the steel product for ejecting at least one jet of fine abrasive particles mixed with high-pressure water onto said surface defects to remove said surface defects;
a supply system (19, 20; 103) for supplying high-pressure water and fine abrasive particles to the abrasive-water-jet-nozzle device;
a recovery system (18, 104) for recovering used fine abrasive particles and recycling them to the supply system; and
a grinding controller (22, 105) for receiving information from the defect detection system and controlling operation of the abrasive-water-jet-nozzle device, the supply system and the recovery system.

7. The system according to claim 6, wherein said abrasive-water jet nozzle device (1, 13, 21; 201) is adapted to eject said at least one jet with said fine abrasive particles being fed at a rate of not lower than 0.5 kg/min, and said high-pressure water being supplied at a pressure of not lower than 1000 kgf/cm^2 and at a flow rate of not lower than 2 lit/min onto the surface of the steel product at an impinging angle of 10 to 170° with a working distance between the nozzle device and the steel surface of not more than 200 mm.

8. The system according to claim 6 or 7, wherein said abrasive-water-jet-nozzle device includes

at least one nozzle (1; 108);
at least one nozzle driver (13; 107) for driving said at least one nozzle; and
at least one nozzle driver controller (21; 106) for operating said at least one nozzle driver.

9. The system according to claim 8, wherein said at least one nozzle driver comprises at least one robot (13; 125).

10. The system according to claim 8, wherein said at least one nozzle driver is stationary.

11. The system according to claim 8, wherein said at least one nozzle driver is capable of driving along one or more axes.

12. The system according to any of claims 6 to 11, wherein said supply system comprises a high-pressure water generator (20; 31) and a fine abrasive particle supply device (19; 32).

13. The system according to any of claims 6 to 12, wherein said defect detection system includes an image processing apparatus based on ultrasonic flaw detection.

14. The system according to any of claims 6 to 13, wherein said defect detection uses a telecamera.

15. The system according to any of claims 6 to 14, wherein the defect detection system further includes at least a second detector (15; 112) for detecting defects on the surface during grinding or a third detector (15''; 113) for detecting defects on the surface after grinding.

Patentansprüche

1. Verfahren zum Entfernen von Oberflächendefekten von einem Stahl-Halbzeug, das in einer fortlaufenden Gießstufe oder einer Stufe, die auf eine fortlaufende Gießstufe folgt, hergestellt wird, mit

(a) Bestimmen von Oberflächendefekten auf dem Stahlerzeugnis;
(b) Bestrahlen der Oberflächendefekte des Stahlerzeugnisses in Reaktion auf das Ergebnis der Bestimmung in Schritt (a) mit wenigstens einem Strahl aus feinen Schleifteilchen, die mit Wasser unter hohem Druck gemischt sind, um die Oberflächendefekte zu entfernen; und
(c) Wiedergewinnen und Rückführen der feinen Schleifteilchen zur Wiederverwendung in

Schritt (b).

2. Verfahren gemäß Anspruch 1, wobei der wenigstens eine Strahl durch wenigstens eine Düse (1; 108) abgestrahlt wird.

3. Verfahren gemäß Anspruch 2, wobei der wenigstens eine Strahl von feinen Schleifteilchen mit einer Rate von nicht weniger als 0,5 kg/min zugeführt wird, das Wasser unter hohem Druck mit einem Druck von nicht weniger als 1000 kgf/cm^2 und einer Durchflußrate von nicht weniger als 2 lit/min zugeführt wird, wobei die Schleifteilchen und das Wasser unter hohem Druck entweder vor einem Hochdruckzustand miteinander gemischt werden oder im Kopf der wenigstens einen Düse (1; 108) nach dem Abstrahlen des Wasser mit hohem Druck gemischt werden, um Wasser mit hohem Druck, das mit Schleifteilchen gemischt ist, zu erhalten, wobei der wenigstens eine Strahl auf die Oberfläche des Stahlerzeugnisses unter einem Aufprallwinkel von 10 bis 170° auftrifft und die Arbeitsentfernung zwischen der Düse und dem Stahlerzeugnis nicht mehr als 200 mm beträgt.

4. Verfahren gemäß Anspruch 2 oder 3, wobei die im Schritt (a) bestimmten Oberflächendefekte Gegenstand einer Koordinatentransformation durch einen Defekt-Bestimmungssystem (16; 101) sind und die wenigstens eine Hochdruck-Flüssigkeit-Abstrahldüse (1; 108) in Reaktion auf Informationen, die durch die Koordinatentransformation des Defekt-Bestimmungssystem erhalten, angetrieben und bewegt wird.

5. Verfahren gemäß einem der Ansprüche 1 bis 4, wobei weiter die Oberfläche des Stahlerzeugnisses nach Schritt (b) untersucht wird.

6. System zum Entfernen von Oberflächendefekten von einem Stahl-Halbzeug mit

einer fortlaufenden Gießstufe oder einer Stufe, die auf eine fortlaufende Gießstufe folgt;
einem Defekt-Bestimmungssystem (16; 101) mit einem Detektor (15; 111) zum Bestimmen von Oberflächendefekten auf dem Stahlerzeugnis;
einem Schleifmittel-Wasser-Strahldüsenbauteil (1, 13, 21; 102), das geeignet ist, sich relativ zur Oberfläche des Stahlerzeugnisses zu bewegen, um die Oberflächendefekte mit wenigstens einem Strahl feiner Schleifteilchen, die mit Wasser unter hohem Druck gemischt sind, zu bestrahlen, um die Oberflächendefekte zu entfernen;
einem Versorgungssystem (19, 20; 103) zum Liefern von Wasser unter hohem Druck an das Schleifmittel-Wasser-Strahldüsenbauteil;
einem Wiedergewinnungssystem (18; 104) zum Wiedergewinnen der verwendeten feinen Schleifteilchen und zu ihrem Zurückführen in das Versorgungssystem; und
einer Abschleifsteuereinrichtung (22; 105) zum Empfangen von Informationen aus dem Defekt-Bestimmungssystem und zum Steuern des Schleifmittel-Wasser-Strahldüsenbauteils, des Versorgungssystems und des Wiedergewinnungssystems.

7. System gemäß Anspruch 6, wobei das Schleifmittel-Wasser-Strahldüsenbauteil (1, 13, 21; 201) geeignet ist zum Abstrahlen wenigstens eines Strahls mit feinen Schleifteilchen, die mit einer Rate von nicht weniger als 0,5 kg/min zugeführt werden, und mit Wasser unter hohem Druck, das mit einem Druck von nicht weniger als 1000 kgf/cm^2 und einer Durchflußrate von nicht weniger als 2 lit/min zugeführt wird, auf die Oberfläche des Stahlerzeugnisses, unter einem Aufprallwinkel von 10 bis 170°, wobei die Arbeitsentfernung zwischen dem Düsenbauteil und der Stahloberfläche nicht mehr als 200 mm ist.

8. System gemäß Anspruch 6 oder 7, wobei das Schleifmittel-Wasser-Strahldüsenbauteil

wenigstens eine Düse (1; 108);
wenigstens einen Düsenantrieb (13; 107) zum Antreiben der wenigstens einen Düse; und
wenigstens eine Düsensteuervorrichtung (21; 106) zum Betreiben des wenigstens einen Düsenantriebs aufweist.

9. System gemäß Anspruch 8, wobei der wenigstens eine Düsenantrieb wenigstens einen Roboter (13; 125) aufweist.

10. System gemäß Anspruch 8, wobei der wenigstens eine Düsenantrieb stationär ist.

11. System gemäß Anspruch 8, wobei der wenigstens eine Düsenantrieb zum Antreiben entlang einer oder mehrerer Achsen geeignet ist.

12. System gemäß einem der Ansprüche 6 bis 11, wobei das Versorgungssystem einen Erzeuger für Wasser unter hohem Druck (20; 31) und eine Versorgungseinrichtung für feine Schleifteilchen (19; 32) aufweist.

13. System gemäß einem der Ansprüche 6 bis 12, wobei das Defekt-Bestimmungssystem eine Bildverarbeitungsvorrichtung auf der Grundlage einer Ultraschall-Defektbestimmung aufweist.

14. System gemäß einem der Ansprüche 6 bis 13, wobei die Defektbestimmung eine Fernsehkamera verwendet.

15. System gemäß einem der Ansprüche 6 bis 14, wobei das Defekt-Bestimmungssystem weiter wenigstens einen zweiten Detektor (15'; 112) zum Bestimmen von Defekten auf der Oberfläche während des Abschleifens oder einen dritten Detektor (15"; 113) zum Aufnehmen von Defekten auf der Oberfläche nach dem Abschleifen aufweist.

Revendications

1. Procédé d'extraction de défauts de surface d'un produit d'acier semi-fini produit dans une étape de coulée continue ou une étape ultérieure à une étape de coulée continue, comprenant :

(a) la détection des défauts de surface du produit d'acier,
(b) la projection d'au moins un jet de fines particules abrasives mélangées à de l'eau à haute pression sur les défauts de surface du produit d'acier suivant le résultat de la détection de l'étape (a) afin que les défauts de surface soient enlevés, et
(c) la récupération et la recirculation des fines particules abrasives destinées à être réutilisées dans l'étape (b).

2. Procédé selon la revendication 1, dans lequel le jet au moins est projeté par une buse au moins (1 ; 108).

3. Procédé selon la revendication 2, dans lequel un jet au moins de fines particules abrasives transmises à raison de 0,5 kg/min au moins, et de l'eau à haute pression transmise à une pression qui n'est pas inférieure à 1000 bar (kgf/cm^2) et avec un débit qui n'est pas inférieur à 2 l/min sont soit mélangées mutuellement auparavant à l'état à haute pression, soit mélangées dans une tête de la buse au moins (1 ; 108) après éjection de l'eau à haute pression pour l'obtention d'eau à haute pression mélangée aux particules abrasives, le jet au moins étant projeté sur la surface du produit d'acier avec un angle d'incidence compris entre 10 et 170° et avec une distance d'usinage entre la buse et la surface d'acier qui ne dépasse pas 200 mm.

4. Procédé selon la revendication 2 ou 3, dans lequel les défauts de surface détectés dans l'étape (a) sont soumis à une transformation de coordonnées par un système (16 ; 101) de détection de défauts, et la buse (1 ; 108) de projection de liquide à haute pression au moins est entraînée et déplacée d'après les informations obtenues à l'aide de la transformation des coordonnées par le système de détection de défauts.

5. Procédé selon l'une quelconque des revendications 1 à 4, comprenant en outre une étape d'inspection de la surface du produit d'acier après l'étape (b).

6. Système d'enlèvement de défauts de surface d'un produit d'acier semi-fini, comprenant un étage de coulée continue ou un étage ultérieur à un étage de coulée continue,

un système (16 ; 101) de détection de défauts qui comprend un détecteur (15 ; 111) destiné à détecter les défauts de surface du produit d'acier,
un dispositif (1, 13, 21 ; 102) à buses de projection d'un jet d'eau abrasif, destiné à se déplacer par rapport à la surface du produit d'acier pour projeter au moins un jet de fines particules abrasives mélangées à de l'eau à haute pression sur les défauts de surface afin que ces défauts de surface soient supprimés,
un système (19, 20 ; 103) d'alimentation en eau à haute pression et en fines particules abrasives du dispositif à buses de projection d'un jet d'eau abrasif,
un système (18, 104) de récupération des fines particules abrasives utilisées et de recyclage vers le système d'alimentation, et
un organe (22, 105) de commande d'usinage par abrasion destiné à recevoir les informations du système de détection de défauts et à commander le fonctionnement du dispositif à buses de projection d'un jet d'eau abrasif, le système d'alimentation et le système de récupération.

7. Système selon la revendication 6, dans lequel le dispositif (1, 13, 21 ; 201) à buses de projection d'un jet d'eau abrasif est destiné à projeter le jet au moins ayant les fines particules abrasives avec un débit qui n'est pas inférieur à 0,5 kg/min, l'eau à haute pression étant transmise à une pression qui n'est pas inférieure à 1000 bar (kgf/cm^2) et avec un débit qui n'est pas inférieur à 2 l/min à la surface du produit d'acier avec un angle d'incidence compris entre 10 et 170°, à une distance de travail comprise entre le dispositif à buses et la surface d'acier qui ne dépasse pas 200 mm.

8. Système selon la revendication 6 ou 7, dans lequel le dispositif à buses de projection d'un jet d'eau abrasif comprend

au moins une buse (1 ; 108),
au moins un organe d'entraînement de buse (13 ; 107) destiné à entraîner la buse au moins, et

au moins un organe (21 ; 106) de commande d'organe d'entraînement de buses destiné à assurer le fonctionnement d'au moins un organe d'entraînement de buse.

9. Système selon la revendication 8, dans lequel l'organe d'entraînement de buse au moins comprend au moins un robot (13 ; 125).

10. Système selon la revendication 8, dans lequel l'organe d'entraînement de buse au moins est fixe.

11. Système selon la revendication 8, dans lequel l'organe d'entraînement de buse au moins peut être déplacé suivant un ou plusieurs axes.

12. Système selon l'une quelconque des revendications 6 à 11, dans lequel le système d'alimentation comprend un générateur (20 ; 31) d'eau à haute pression et un dispositif (19 ; 32) d'alimentation en fines particules abrasives.

13. Système selon l'une quelconque des revendications 6 à 12, dans lequel le système de détection de défauts comprend un appareil de traitement d'images mettant en oeuvre une détection ultrasonore de défauts.

14. Système selon l'une quelconque des revendications 6 à 13, dans lequel la détection de défauts met en oeuvre une caméra de télévision.

15. Système selon l'une quelconque des revendications 6 à 14, dans lequel le système de détection de défauts comprend au moins un second détecteur (15 ; 112) destiné à détecter les défauts à la surface pendant l'usinage par abrasion ou un troisième détecteur (15" ; 113) destiné à détecter des défauts à la surface après usinage par abrasion.

FIG. 1

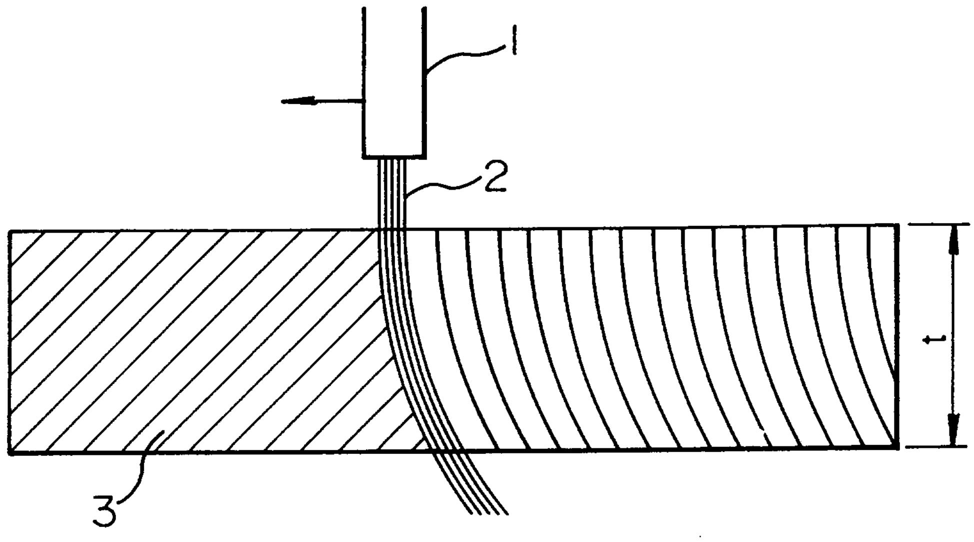

FIG. 2

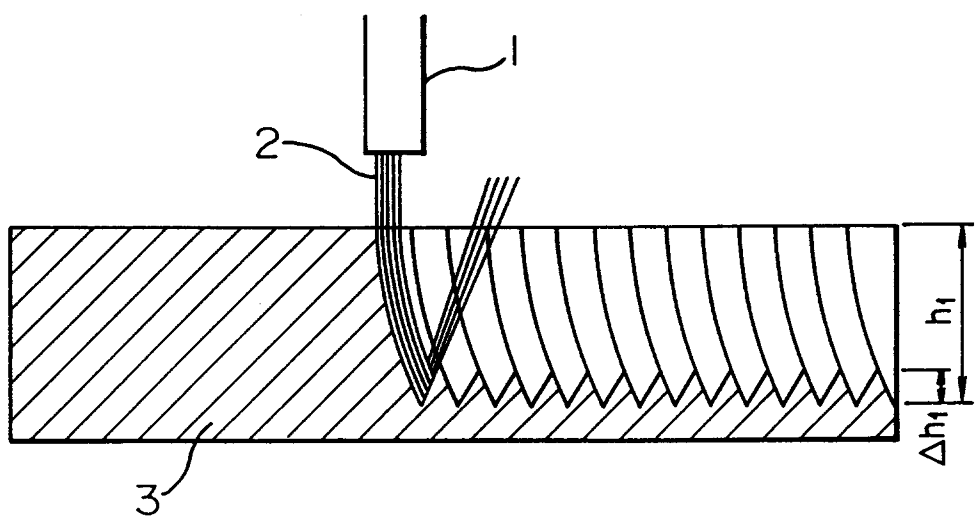

FIG. 3

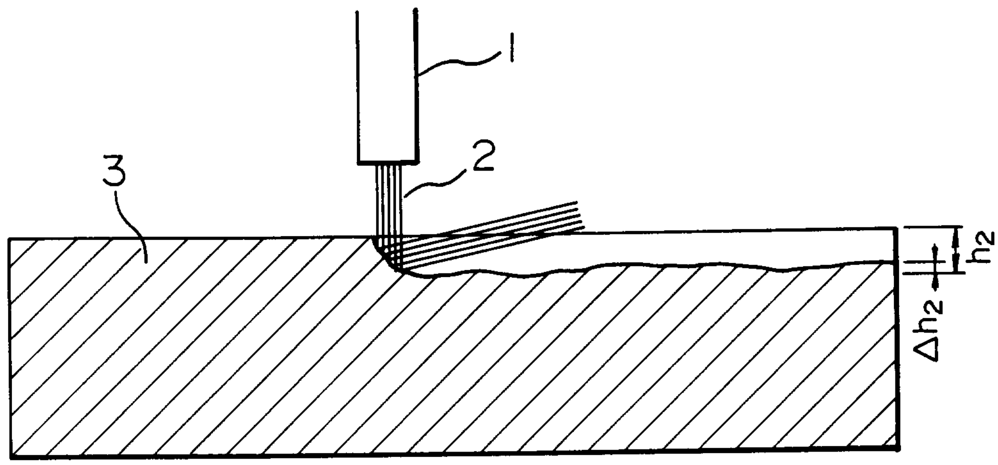

FIG. 4

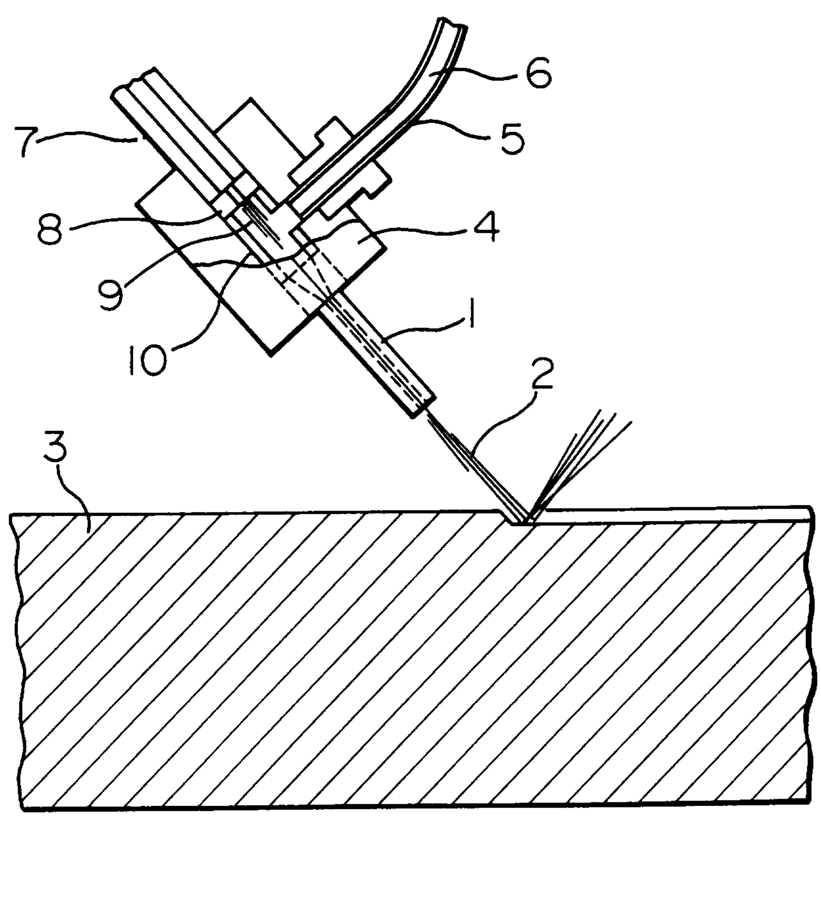

FIG. 5

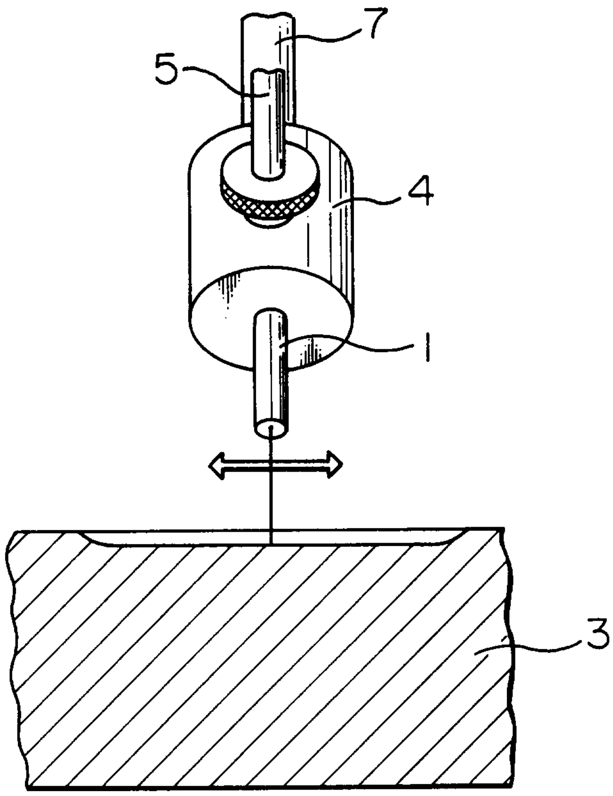

FIG. 6

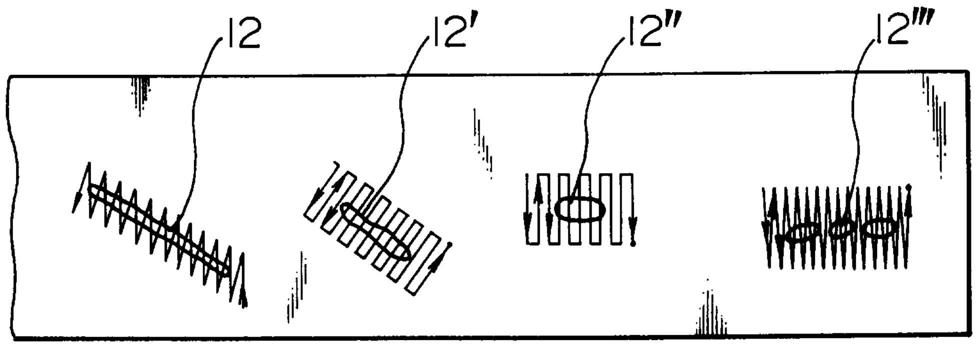

FIG. 7

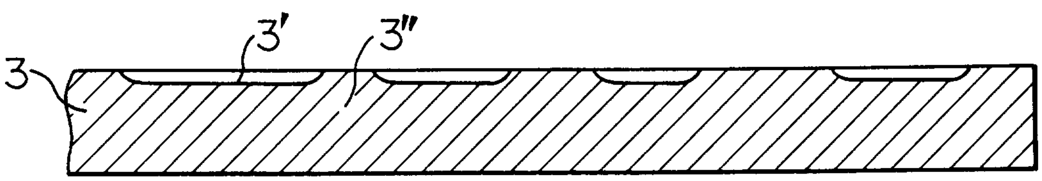

FIG. 8

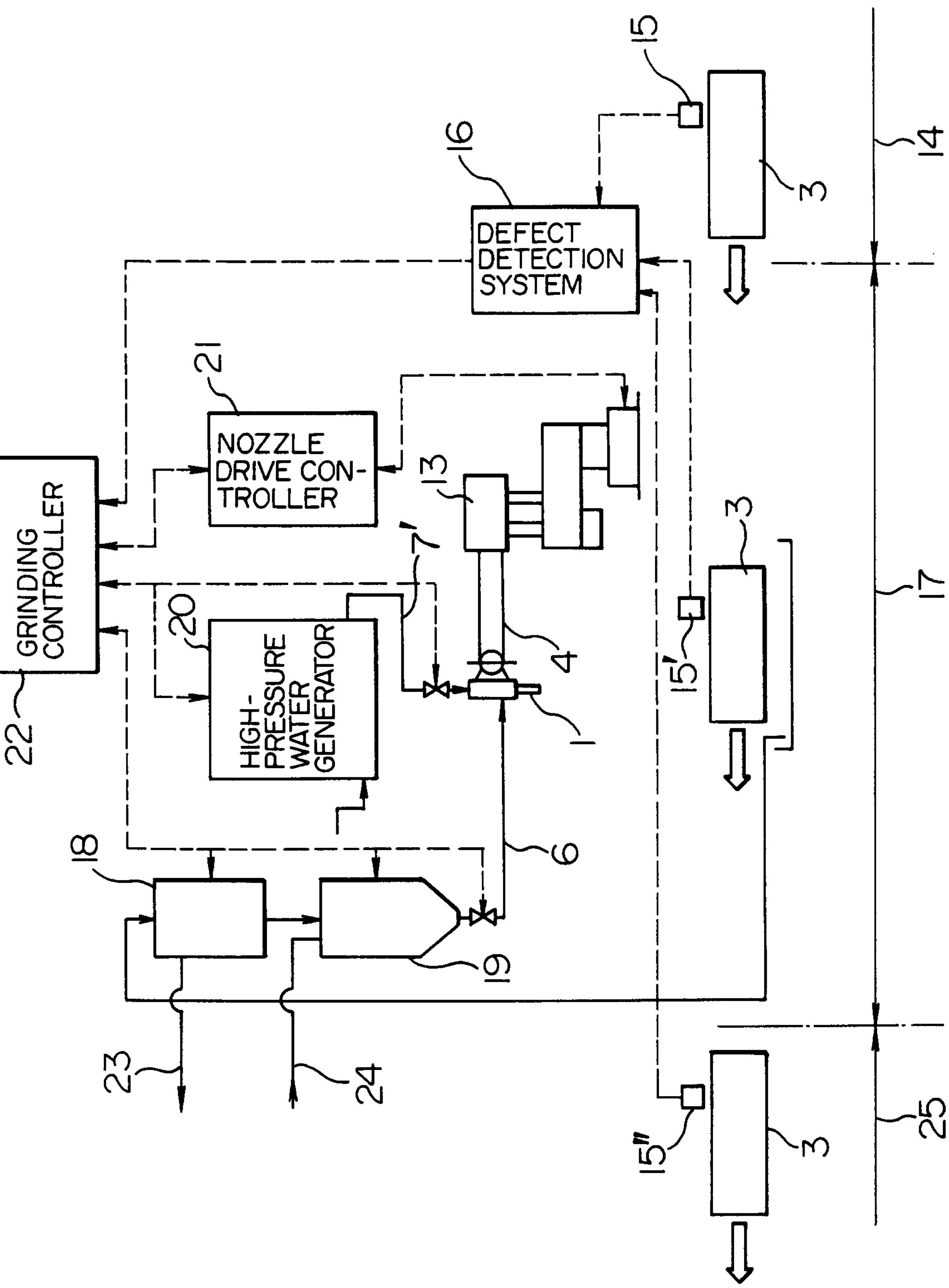
DEFECT DETECTION SYSTEM
NOZZLE DRIVE CON-TROLLER
GRINDING CONTROLLER
HIGH-PRESSURE WATER GENERATOR
1
3
4
6
7
7'
13
14
15
15'
15"
16
17
18
19
20
21
22
23
24
25

FIG. 9

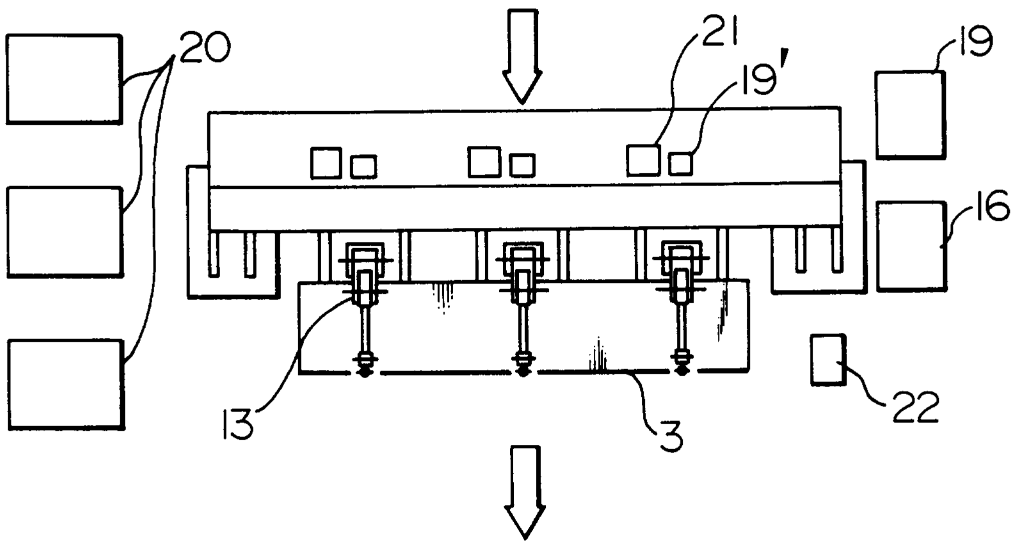

FIG. 10

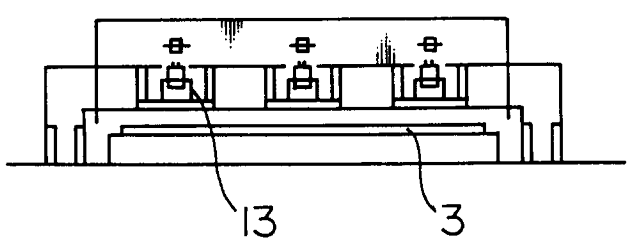

FIG. 11

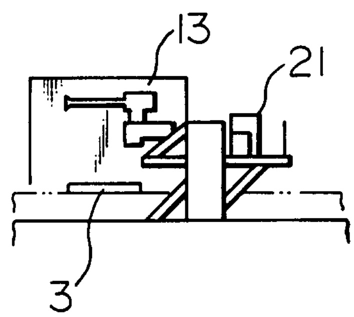

FIG. 12

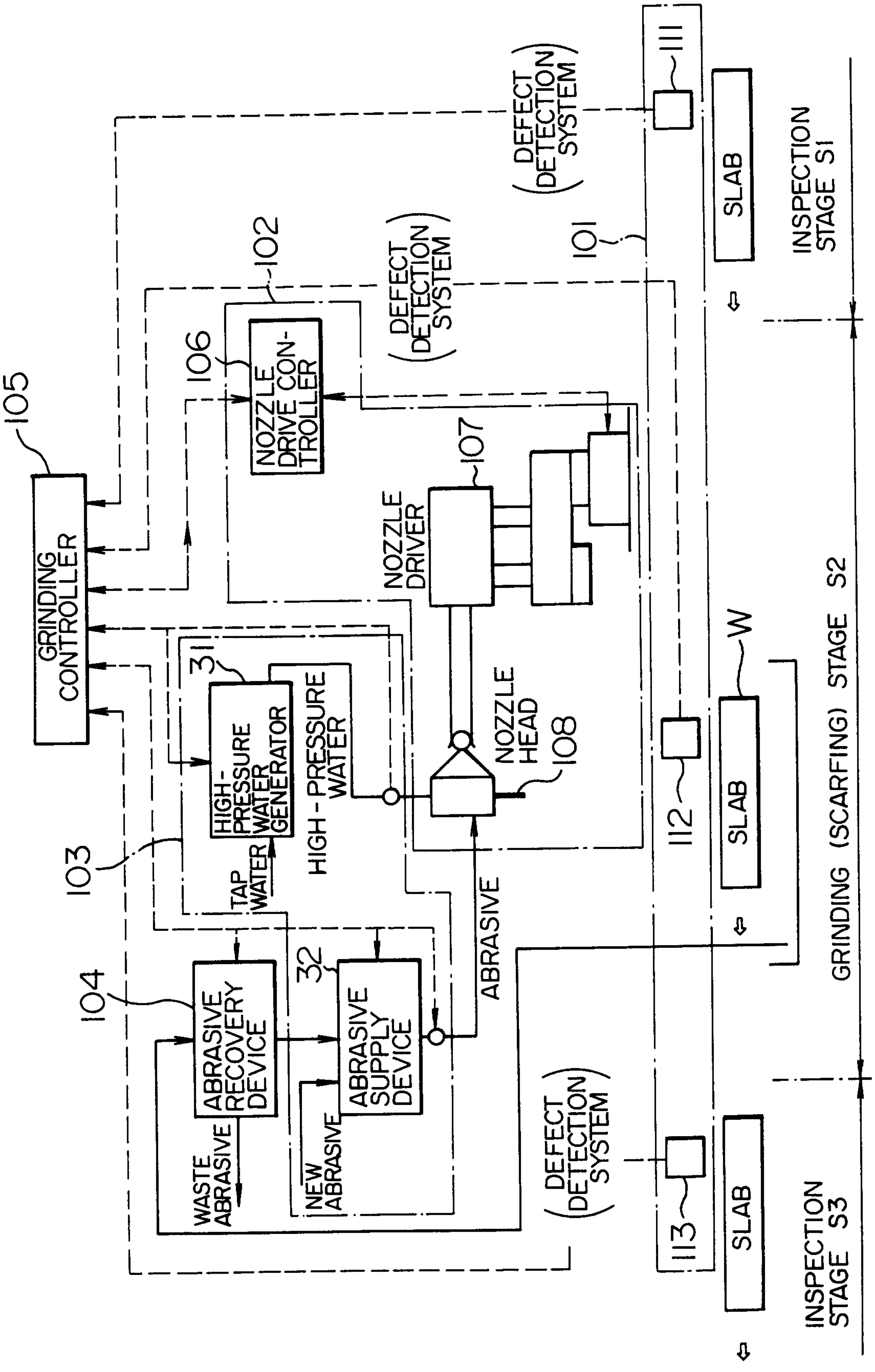
105
GRINDING CONTROLLER
106
NOZZLE DRIVE CON-TROLLER
102
DEFECT DETECTION SYSTEM
DEFECT DETECTION SYSTEM
111
101
SLAB
INSPECTION STAGE S1
107
NOZZLE DRIVER
31
HIGH-PRESSURE WATER GENERATOR
HIGH-PRESSURE WATER
NOZZLE HEAD
108
TAP WATER
103
104
ABRASIVE RECOVERY DEVICE
32
ABRASIVE SUPPLY DEVICE
ABRASIVE
WASTE ABRASIVE
NEW ABRASIVE
112
W
SLAB
GRINDING (SCARFING) STAGE S2
DEFECT DETECTION SYSTEM
113
SLAB
INSPECTION STAGE S3

FIG. 13

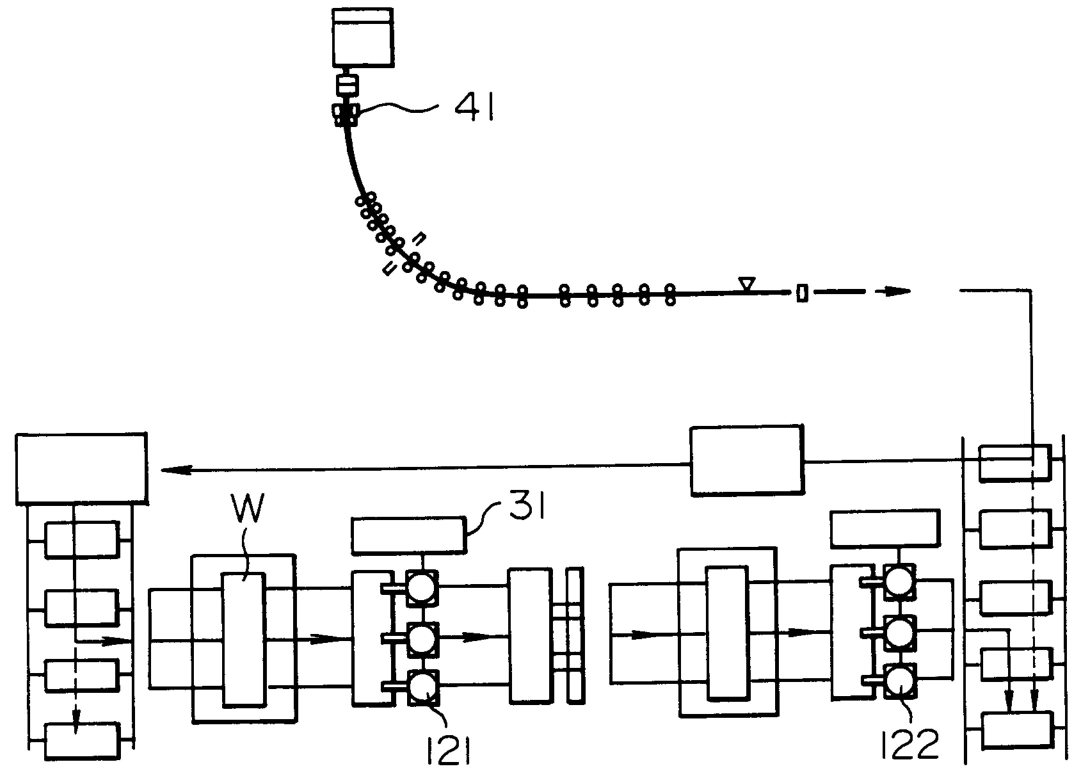

FIG. 14

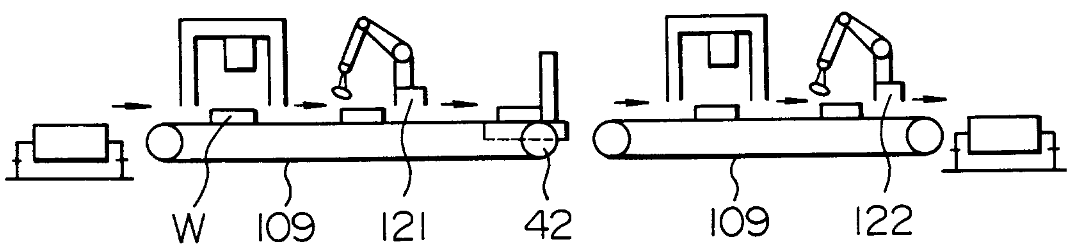

FIG. 15

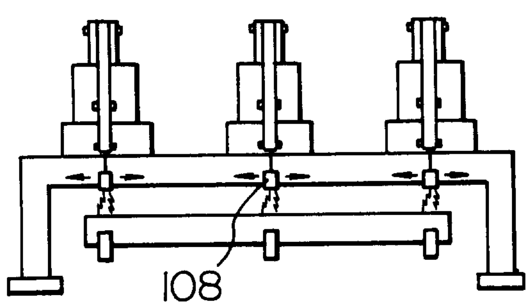

FIG. 16