Title: Method for descaling a metal strip

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Applicant(s): SMS Siemag Aktiengesellschaft

Inventor(s):
- Senokosov, Andrei Evgenievich
- Frommann, Klaus
- Kretschmer, Matthias
- Zerbe, Ruediger
- Senokosov, Evgeny Stepanovich
- Brisberger, Rolf
- Behrens, Holger

Agent / Attorney:
Griffith Hack, GPO Box 1285, Melbourne, VIC, 3001

Related Art:
- US 6099667
- JP 04-297561
The invention concerns a method for descaling a metal strip, especially a hot-rolled strip of normal steel, in which the metal strip is guided in a direction of conveyance through at least one plasma descaling unit, in which it is subjected to a plasma descaling, where the plasma descaling is followed directly or indirectly by an operation in which the metal strip is coated with a coating metal, especially by hot dip galvanizing of the metal strip, wherein the metal strip is coated with the coating metal by the vertical passage process, in which the coating metal is retained in the coating tank by an electromagnetic seal.
Applicant:  
SMS DEMAG AG

Invention Title:  
Method for descaling a metal strip

The following statement is a full description of this invention, including the best method for performing it known to us:
METHOD FOR DESCALING A METAL STRIP

The invention concerns a method for descaling a metal strip.

Steel strip must have a scale-free surface before it can be further processed, e.g., by cold rolling, by the application of a metallic coating, or by direct working into a finished product. Therefore, the scale that forms, for example, during hot rolling and the subsequent cooling phase must be completely removed. In previously known methods, this is accomplished by a pickling process, in which, depending on the grade of steel, the scale, which consists of various iron oxides (FeO, Fe$_3$O$_4$, Fe$_2$O$_3$) or, in the case of stainless steels, of chromium-rich iron oxides, is dissolved by means of various acids (e.g., hydrochloric acid, sulfuric acid, nitric acid, or mixed acid) at elevated temperatures by chemical reaction with the acid. Before the pickling operation, an additional mechanical treatment by stretcher-and-roller
leveling is necessary in the case of normal steel to break up the scale to allow faster penetration of the acid into the layer of scale. In the case of stainless, austenitic, and ferritic steels, which are much more difficult to pickle, an annealing operation and a preliminary mechanical scaling operation must be performed on the strip before the pickling process is carried out in order to produce a strip surface that can be pickled as well as possible. After the pickling operation, to prevent oxidation, the steel strip must be rinsed, dried, and, depending on requirements, oiled.

The pickling of steel strip is carried out in continuous lines, whose process section can be very long, depending on the strip speed. Therefore, installations of this type require very large investments. In addition, the pickling process uses a tremendous amount of power and entails great expense for the elimination of wastewater and the regeneration of the hydrochloric acid, which is the type of acid usually used for normal steel.

Due to these disadvantages, the prior art also includes various approaches for accomplishing the descaling of metal strands without the use of acids. Previous developments along these lines are generally based on mechanical removal of the scale (e.g., the
Ishiclean method, the APO method). However, with respect to their economy and the quality of the descaled surface, methods of these types are not suitable for the industrial descaling of wide steel strip. Therefore, acids continue to be used for descaling this type of strip.

Consequently, so far it has been necessary to accept the disadvantages with respect to economy and environmental pollution.

Recent approaches to the descaling of metal strands have been based on plasma technology. Methods and devices of the aforementioned type for descaling metal strands with different geometries, for example, metal strip or metal wire, are already well known in various forms in the prior art. Reference is made, for example, to WO 2004/044257 Al, WO 2000/056949 A1 and RU 2 145 912 C1. In the plasma descaling technology disclosed in the cited documents, the material to be descaled runs between special electrodes located in a vacuum chamber. The descaling is effected by the plasma produced between the steel strip and the electrodes, and the result is a bare metallic surface with no residue. Plasma technology thus represents an economical, qualitatively satisfactory and
environmentally friendly possibility for descaling and cleaning steel surfaces. It can be used for normal steel as well as for stainless, austenitic, and ferritic steels. No special pretreatment is necessary.

In plasma descaling, the strip thus runs through a vacuum chamber between electrodes arranged above and below the strip. The plasma is located between the electrodes and the surface of the strip on both sides of the strip. The action of the plasma on the scale results in the removal of the oxides on the surface of the strip, and this is associated with an increase in the temperature of the strip, which can be a serious disadvantage. The temperature increase can result in the formation of an oxide film on the surface of the strip when the descaled strip emerges from the vacuum and enters the air. An oxide film is unacceptable for further processing steps, such as cold rolling or the direct working of hot strip.

Various proposals have been made to improve this situation by cooling the metal strip following the plasma descaling. Methods of this type are disclosed, for example, in JP 07132316 A, JP 06279842 A, JP 06248355 A, JP 03120346, JP 2001140051 A, and JP 05105941 A.
However, the concepts disclosed in this literature are aimed at cooling measures that are associated with considerable disadvantages in some cases or are relatively inefficient. For example, a cooling medium is sprayed, which makes it necessary to carry out a subsequent drying of the metal strip. If the metal strip is treated with a cooling gas, the cooling rate is very low, and, in addition, a solution of this type is not possible in a vacuum. The other proposed solutions offer almost no possibility of realizing a specific temperature program for the metal strip.

For most applications, controlled cooling of the metal strip during or after the descaling is necessary before the strip comes into contact with air. Systematic cooling of this type is not possible with the prior-art solutions.

In accordance with the invention, there is provided a method for descaling a metal strip, especially a hot-rolled strip of normal steel, in which the metal strip is guided in a direction of conveyance through at least one plasma descaling unit, in which it is subjected to a plasma descaling, where the plasma descaling is followed directly or indirectly by an operation in which the metal
strip is coated with a coating metal, especially by hot dip galvanizing of the metal strip, wherein the metal strip is coated with the coating metal by a continuous vertical galvanizing line process, in which the coating metal is retained in the coating tank by an electromagnetic seal, and in which the metal strip runs vertically through the coating tank without deflections.

In some embodiments the metal strip is a hot-rolled strip of normal steel or a hot-rolled or cold-rolled strip of austenitic or ferritic stainless steel, in which the metal strip is guided in a direction of conveyance through at least one plasma descaling unit, in which it is subjected to a plasma descaling.

Some embodiments of the invention provide a method for descaling a metal strip, with which it is possible to achieve increased quality during the production of the metal strip.

The metal strip is preferably plasma descaled and then coated, especially by hot dip galvanizing, in a coupled installation. The metal strip preheated by the plasma descaling is preferably guided, without exposure to air, from the plasma descaling into the protective gas
atmosphere of a continuous furnace necessary for the coating, in which the strip is further heated to the temperature required for the coating. In this regard, after the plasma scaling, the strip can be heated inductively by the "heat-to-coat" process. The strip, especially hot-rolled strip that is to be galvanized, can be heated very quickly under reduced atmosphere to 440°C to 520°C, especially about 460°C, before it enters the coating bath.

The coating operation downstream of the plasma scaling can be carried out by the conventional method
with a guide roller in the coating tank or by the vertical process (Continuous Vertical Galvanizing Line (CVGL) process), in which the coating metal is retained in the coating tank by an electromagnetic seal. The metal strip is immersed in the coating metal for only a very short time.

The plasma descaling installation can be coupled with a continuous furnace for the hot dip galvanizing of hot-rolled steel strip, such that a vacuum lock can be located on the exit side of the plasma descaling unit and a furnace lock of a standard design can be located on the entry side of the continuous furnace, which have a gastight connection with each other.

The latter coupling of the plasma descaling unit and the coating unit has special advantages, because hot-rolled steel strip must be completely free of oxides before the hot dip galvanizing in order for a strongly adherent zinc coating to be produced.

Furthermore, the strip must be heated to a temperature of about 460°C to 650°C, depending on the heating rate. In this regard, the heating of the strip caused by the plasma descaling can be utilized as
preheating of the strip before the strip enters the continuous furnace, which makes it possible to save energy and reduce the length of the furnace.

The drawings illustrate specific embodiments of the invention.

Figure 1 shows a schematic side view of a first embodiment of a device for descaling a metal strip.

Figure 2 shows a view similar to Figure 1 of a second embodiment of the device.

Figure 3 is a schematic drawing of three cooling rollers of a cooling unit at low cooling capacity.

Figure 4 is a drawing analogous to Figure 3 of the cooling unit at high cooling capacity.

Figure 5 shows a schematic side view of a device for descaling the metal strip and then hot dip galvanizing it.

Figure 1 shows a device for descaling a steel strip 1. This installation has a horizontal design. The steel strip 1 is unwound from a pay-off reel 19 and leveled in a stretcher-and-roller leveling machine 20 with the associated bridles 21 and 22, so that the metal strip 1 has the greatest possible flatness before the strip enters the process section of the plant under high
The strip 1 passes through several vacuum locks 23 and into a first plasma descaling unit 2, in which the vacuum necessary for the plasma descaling is produced and maintained by vacuum pumps of known design. Electrodes 24 are installed in the plasma descaling unit 2 on both sides of the strip 1 and produce the plasma necessary for the descaling.

The plasma causes the surface of the strip to be heated on both sides, which can lead to heating of the entire cross section of the strip to a temperature of a maximum of 200°C at the end of the plasma descaling unit 2. The degree of heating of the strip over its entire cross section depends, at constant energy of the plasma, mainly on the speed of conveyance \( v \) of the metal strip 1 and on the thickness of the strip, with strip heating decreasing with increasing strip speed \( v \) and strip thickness.

The not yet completely descaled strip 1 runs from the plasma descaling unit 2 into a cooling unit 4, which is equipped with cooling rollers 6, 7, 8. The cooling unit 4 has a gastight connection with the plasma
The strip 1 passes around the cooling rollers 6, 7, 8, whose peripheral regions are cooled from the inside with water, which removes the heat via a coolant circulation. The high strip tension causes the strip 1 to make good contact with the cooling rollers 6, 7, 8 as it wraps around them in order to ensure the greatest possible heat transfer.

The metal strip 1 alternately wraps around the cooling rollers 6, 7, 8 from above and below. There are preferably three to seven cooling rollers. The cooling water for cooling the cooling rollers is continuously supplied and removed through rotary feed-throughs.

In the system illustrated in Figure 1, the cooling unit 4 has three cooling rollers 6, 7, 8, which are separately driven. Depending on the cooling capacity and the maximum strip speed "v" of the installation, more cooling rollers would be possible and useful. Temperature sensors 12 for continuous measurement of the temperature of the metal strip 1 are located on the entry side and the exit side of the cooling unit 4. The angle
of wrap $\alpha$ (see Figures 3 and 4) and thus the intensity of cooling of the metal strip 1 by the cooling unit 4 can be controlled by adjusting one (or more) of the cooling rollers 6, 7, 8 (see Figures 3 and 4), for example in the vertical direction. At the end of the cooling unit 4, the maximum strip temperature should be about 100°C.

The cooled strip 1 runs from the cooling unit 4 into a second plasma descaling unit 3, which has a gastight connection with the cooling unit 4 and in which vacuum pumps produce the same vacuum as in the first plasma descaling unit 2. The descaling of the strip 1, which was still incomplete after the first descaling unit 2, is completed in the second plasma descaling unit 3, which is constructed similarly to the first. As in the case of the first plasma descaling unit 2, during its passage through the second plasma descaling unit 3, the strip 1 is heated to an end temperature that is about 100°C to 200°C above the temperature at which it enters the second plasma descaling unit 3, depending on the strip speed $v$ and on the cross-sectional area of the strip. When it leaves the plasma descaling unit 3, the strip 1 passes through a gastight lock 25 and into a second cooling unit 5, which is filled with a protective gas (e.g., nitrogen) and, like the first cooling unit 4, is equipped with
cooling rollers 9, 10, 11.

The individual plasma descaling units 2 and 3 and any additional units of this type are preferably all of the same length.

The number of cooling rollers 6, 7, 8, 9, 10, 11 depends on the capacity of the installation. In cooling unit 5, the cooling rollers 9, 10, 11 cool the strip 1 to a final temperature that does not exceed 100°C. As in the case of the first cooling unit 4, temperature sensors 13 for measuring the strip temperature are located on the entry side and the exit side of the cooling unit 5. At the end of the cooling unit 5, there is another gastight lock 26 that prevents air from entering the cooling unit 5. This measure ensures that the strip 1 leaves the process section of the line at a maximum temperature of 100°C and that the bare surface of the strip cannot be oxidized by atmospheric oxygen.

The process section of the installation is followed by a tension bridle 18 that consists of two or three rolls and applies the necessary strip tension or, together with the bridle 22, maintains the necessary strip tension. The elements labeled 17 and 18 thus
constitute means for producing a tensile force in the strip 1. The tensile force produced in the strip 1 serves to ensure good contact between the strip 1 and the cooling rollers 6, 7, 8, 9, 10, 11. The strip 1 then runs through additional necessary units, such as a strip accumulator and trimming shear, to the coiler 27 (as shown) or to other coupled units, e.g., to a tandem mill.

Depending on the calculated required cooling capacity, the proposed plasma descaling installation can have one or more plasma descaling units 2, 3 followed by cooling units 4, 5. The specific embodiment according to Figure 1 has two of these units. If only one cooling unit 4 is used, then it is designed similarly to the second cooling unit 5 described here with the locks 25 and 26 associated with the second cooling unit 5.

Figure 2 shows an alternative embodiment of the installation for descaling steel strip 1, in which the plasma descaling units 2 and 3 are arranged vertically. All of the operations in this installation are identical with those of the installation explained in connection with Figure 1. A vertical arrangement can be more advantageous under certain conditions than a horizontal arrangement due to its shorter overall length.
Figures 3 and 4 show that the angle of wrap $\alpha$ of the strip 1 around the rollers 6, 7, 8 (recorded here for the angle of wrap around the roller 7) can be varied by vertical displacement of the cooling roller 7 (see double arrow), which is positioned between the two cooling rollers 6 and 7, so that the heat flow from the metal strip 1 to the cooling rollers 6, 7, 8 also varies. The middle cooling roller 7 is vertically displaced by moving means 16, which are shown schematically and in the present case are designed as a hydraulic piston-cylinder system.

Measurement of the strip temperature in or at the end of the cooling units 4, 5 by the temperature sensors 12, 13 makes it possible to control the cooling capacity in the cooling units 4, 5 via automatic control units 14 and 15, which are shown only in a highly schematic way in Figure 1, so that a desired exit temperature of the strip 1 can be realized. If the measured temperature is too high, a higher angle of wrap $\alpha$ can be adjusted by driving the moving means 16, so that the strip 1 is more intensely cooled. In principle, it is also possible to increase or decrease the speed of conveyance "$v"$ of the strip 1 through the installation in order to decrease or
increase the cooling effect. Of course, this then requires coordination between the two automatic control units 14 and 15.

Figure 5 shows a drawing of a solution in which the heat introduced into the metal strip by the plasma descaling is used to apply a coating metal to the strip immediately following the descaling. Figure 5 shows the process section comprising a coupled plasma descaling and hot dip galvanizing line for hot-rolled steel strip. After the stretcher leveling in the stretcher-and-roller leveling machine 20 (stretcher leveling unit), the strip passes through a vacuum lock 23 and into the plasma descaling unit 2, where it is descaled and in the process is heated to about 200°C to 300°C, depending on the strip speed and the strip thickness.

The strip 1 then passes through a vacuum exit lock 25, through the furnace entry lock 29 connected with it, and into a continuous furnace 28. On the entry side of the furnace 28, there is a pair of tension rolls 30 (hot bridle), which produces the high strip tension that is needed in the plasma descaling unit 2. Downstream of the pair of tension rolls 30, the strip temperature is measured with a temperature sensor 12, by which the
amount of additional strip heating necessary in the continuous furnace 28 is automatically controlled. From the position of the sensor 12, the strip 1 passes through the inductively heated continuous furnace 28, in which it is very quickly heated to about 460°C by the heat-to-coat process. The strip then passes through a snout 31 into the coating tank 32, in which it is hot dip galvanized. The coating thickness is controlled by stripping jets 34. The metal strip 1 is cooled in the air cooling line 35 which follows. It is then sent through additional necessary processing steps, for example, temper rolling, stretcher leveling, and chromating.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated
features but not to preclude the presence or addition of further features in various embodiments of the invention.
List of Reference Symbols

1 metal strip
5 2 plasma descaling unit
3 plasma descaling unit
4 cooling unit
5 cooling unit
6 cooling roller
10 7 cooling roller
8 cooling roller
9 cooling roller
10 cooling roller
11 cooling roller
15 12 temperature sensor
13 temperature sensor
14 automatic control unit
15 automatic control unit
16 moving means
20 17 means for producing a tensile force
18 means for producing a tensile force
19 pay-off reel
20 stretcher-and-roller leveling machine
21 bridle
25 22 bridle
23 vacuum lock
24 electrodes
25 lock
26 lock
5 27 coiler
28 continuous furnace
29 furnace entry lock
30 pair of tension rolls
31 snout
10 32 coating tank
33 guide roller
34 stripping jets
35 air cooling line

15 R direction of conveyance
α angle of wrap
v conveyance speed
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method for descaling a metal strip, especially a hot-rolled strip of normal steel, in which the metal strip is guided in a direction of conveyance through at least one plasma descaling unit, in which it is subjected to a plasma descaling, where the plasma descaling is followed directly or indirectly by an operation in which the metal strip is coated with a coating metal, especially by hot dip galvanizing of the metal strip, wherein the metal strip is coated with the coating metal by a continuous vertical galvanizing line process, in which the coating metal is retained in the coating tank by an electromagnetic seal, and in which the metal strip runs vertically through the coating tank without deflections.

2. A method in accordance with Claim 1, wherein the metal strip is first plasma descaled and then coated, especially by hot dip galvanizing, in a coupled installation.

3. A method in accordance with Claim 1 or 2, wherein the metal strip preheated by the plasma descaling is guided, without exposure to air, from the plasma descaling into the protective gas atmosphere of a
continuous furnace necessary for the coating.

4. A method in accordance with Claim 3, wherein the metal strip is further heated in the continuous furnace to the temperature required for the coating.

5. A method in accordance with Claim 3 or 4, wherein the metal strip is inductively heated in the continuous furnace.

6. A method in accordance with any of Claims 3 to 5, wherein the metal strip is heated in the continuous furnace to 440°C to 520°C, especially about 460°C, before it enters the coating bath.

7. A method substantially as herein described with reference to the accompanying drawings.