EUROPEAN PATENT SPECIFICATION

Heat treating furnace for a continuously supplied metal strip
Ofen zum Durchlaufglühen von Metallband
Four pour le traitement thermique de bandes métalliques en marche continue

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Description

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] The present invention relates to a continuous heat treating furnace for a metal strip such as a continuous annealing furnace for annealing a continuously supplied steel strip or the like, and especially to a continuous heat treating furnace for a metal strip. The furnace is provided with a preheating section for preheating the metal strip to some temperature on an incoming side, and a heating section for treating the metal strip at a higher temperature.

[0002] In the annealing furnace exchanger for use in the invention, which anneals the metal strip, the temperature of the circulating gas to be blown over the surface of the metal strip in the preheating section is efficiently raised by re-circulating the heated exhaust gas from the preheating section.

2. Description of Related Art

[0003] A conventional continuous annealing furnace for continuously annealing a strip or a metal-strip continuous heat treating furnace is known wherein the furnace structure has a heating section for heating a metal strip to its transformation temperature $A_2$ or higher. This heating device, constituted of multiple radiant tubes, is disposed around the continuously supplied strip. As the metal strip is supplied, if the necessary heat treating process is the annealing transformation temperature $A_2$ or higher. This heating device, constituted of multiple radiant tubes, is disposed around the continuously supplied strip. As the metal strip is supplied, if the necessary heat treating process is the annealing...

[0004] To solve this problem, a high-temperature combustion exhaust gas or accordingly heated gas is supplied from the burner to the radiant tubes. Then, the strips can be heated with the radiant heat from outer walls of the radiant tubes. Consequently, by maintaining the in-furnace atmosphere as the non-oxidizing atmosphere or the reduction atmosphere, oxidation of the strip can be avoided as well as efficient heating of the supplied strip.

[0005] In a conventional continuous annealing furnace for annealing a metal strip or the like, by passing the heating-section exhaust gas or another combustion exhaust gas through the heat exchanger, heat is applied to the circulated gas. By blowing the gas over the metal strip passing through the preheating section, the temperature of the metal strip is raised.

[0006] Additional information pertaining to convective heat exchangers for recovering heat via tubes and regenerative burners is disclosed in Japanese published patent application 4-80969. A regenerative radiant tube burner is disclosed in Japanese laid open patent applications 6-257738 and 6-257724.

[0007] The foregoing related arts have problems. In an actual continuous annealing operation, to improve the production efficiency, the strip supply speed (plate passing speed) has a lower limitation. To improve equipment efficiency, the size of the heating section through which the strip passes should be as short as possible. To satisfy such a requirement, the in-furnace or radiant-tube temperature has to be set relatively higher than the desired ultimate strip temperature. Specifically, by raising the radiant-tube temperature, thereby increasing the difference between the in-furnace temperature and the strip temperature, the strip can be quickly heated to a predetermined higher temperature. However, by raising the radiant-tube temperature above the desired strip temperature, the radiant-tubes are subjected to additional thermal load and subsequent breakdown.

[0008] Specifically, thermal stress and high-temperature creep cause the radiant tubes to break. Their high-temperature life is deteriorated, and when the temperature of the radiant tubes is raised, the fuel consumption rate is increased, thereby disadvantageously increasing cost as well.

[0009] In the above first example, the high-temperature life of the radiant-tubes is shortened by several years. In the latter, the fuel consumption rate is directly reflected in increased cost. Therefore, economic constraints have focused improvements on decreasing the fuel consumption rate.

[0010] In an attempt to solve this problem, the combustion efficiency of the burner for heating the radiant tubes is raised. A sensible heat of combustion exhaust gas resulting from heating of the radiant tubes is recovered by a convective heat exchanger to a sensible heat of combustion air. Specifically, by increasing the temperature of the combustion air supplied to the burner, the combustion efficiency in the burner is enhanced.

[0011] Realizing the above solution, the operation line is provided with a preheating section for preheating the strip. In the preheating section, the sensible heat of the combustion exhaust gas from the burner is recovered as the sensible heat of a predetermined gas by a convective heat exchanger in the same manner as aforementioned. By blowing the heated gas directly onto the strip in the preheating section, the temperature of the strip can be directly increased.
SUMMARY OF THE INVENTION

[0017] It is an object of the present invention to provide a continuous heat treating furnace for a metal strip and a metal strip annealing heat exchanger which is able to recover the sensible heat of combustion exhaust gas from a burner in the heating section with a high degree of efficiency. This object is achieved according to the invention by the subject matter of claim 1 and independent claim 13. Embodiments of the invention are indicated in the subclaims. An advantage of the invention consists in that the recovered sensible heat is returned to the predetermined gas and the preheating section blows the gas steadily over the metal strip to increase the temperature of the metal strip supplied to the heating section. As a result, the temperature increase in the heating section is not as great, so the temperature requirement in the furnace can be lowered. Hence, the radiant tubes are kept at a lower temperature, thereby reducing fuel consumption while extending the high-temperature life of the radiant tubes. Further, the blowing of the gas over the metal strip in the preheating section is stabilized, while at the same time the combustion exhaust gas and the blowing gas can be efficiently used.

[0018] To attain this effect with the greatest efficiency, this invention provides an inventive heat exchanger which efficiently recovers the sensible heat of combustion exhaust gas from the heating section of a metal-strip annealing furnace which uses multiple burners (including a direct heating furnace or the like) and which can apply the recovered heat to the metal strip as it passes the preheating section of the annealing furnace.

[0019] According to an embodiment of the invention, when the relationship between a sectional area of the purging gas passing section and a sectional area of the circulating gas passing section, satisfies following condition, the effects of the invention can be efficiently attained:
wherein:

\[ \frac{S_1}{S_2} \geq \frac{1}{[Q_a/V_1]-1} \]  

To prevent the circulating gas from being contaminated, static pressure of the purging gas can be set higher than the static pressure of the exhaust gas. To effect this, the purging gas supply path may be branched from the circulating gas supply path or connected to an incoming path of the purging gas passing section and to an outgoing path of the circulating gas passing section.

The material of the regenerator is preferably Al₂O₃, SUS310 or SUS316 according to Japanese Industrial Standards, or another material superior in heat and corrosion resistance.

**BRIEF DESCRIPTION OF THE DRAWINGS**

- Fig. 1 is a schematic representation of a continuous metal-strip heat treating furnace;
- Fig. 2 is a perspective, schematic representation of the preheating section in the continuous annealing furnace shown in Fig. 1;
- Fig. 3 is a diagram of the valve system of the preheating section shown in Fig. 2;
- Fig. 4 is a timing diagram of the valve system shown in Fig. 3;
- Fig. 5 shows the flow of heat in the continuous annealing furnace shown in Fig. 1;
- Fig. 6 is a plot of the life evaluation characteristic of the radiant tube;
- Fig. 7 is a plot of the estimated life of the radiant tube as a function of furnace temperature;
- Fig. 8 is a schematic representation of a preheating section in a prior art continuous annealing furnace;
- Fig. 9 shows the flow of heat in the prior art continuous annealing furnace shown in Fig. 8;
- Fig. 10 shows a first embodiment of a regenerative heat exchanger according to the invention;
- Fig. 11 shows a second embodiment of the regenerative heat exchanger according to the invention;
- Fig. 12 is a first sectional view of the regenerative heat exchange shown in Fig. 11;
- Fig. 13 is a second sectional view of the regenerative heat exchange shown in Fig. 11;
- Fig. 14 is a third sectional view of the regenerative heat exchange shown in Fig. 11;
- Fig. 15 shows the fifth embodiment of the regenerative heat exchange installed in a prior art convective heat exchanger;
- Fig. 16 shows a third embodiment of the regenerative heat exchanger according to the invention;
- Fig. 17 shows a fourth embodiment of the regenerative heat exchanger according to the fifth embodiment of the invention;
- Fig. 18 is a schematic representation of Fig. 17 including the preheating section;
- Fig. 19 is a plan view of the heat exchanger according to an embodiment of the invention; and
- Fig. 20 is a schematic representation showing the size of the heat exchanger.

**DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS**

**[0022]** Fig. 1 shows an embodiment of a continuous annealing furnace for a strip (cold rolled steel plate) in which a continuous metal-strip heat treating furnace according to the invention is operated.

**[0023]** Fig. 1 shows the construction of a vertical continuous annealing furnace which continuously anneals a strip 50. The continuous annealing furnace in Fig. 1 is formed by an incoming-side device (not shown) which has a coil rewinder, a welding machine, a washing machine and the like, a preheating section 100, a heating section 200, a soaking section 300 and an outgoing-side device (not shown) which has a plate temperature adjusting section, for adjusting a plate temperature as required, a heat treating section, a shearing machine, a winder and the like. These devices are all constructed in a tower-like vertical configuration due to size restrictions in the installation area.

**[0024]** After welding different sections of the material together to form a continuous strip, the strip is sequentially passed through the preheating section 100, the heating section 200 and the soaking section 300. It is thereafter passed through the plate temperature adjusting section and the thermal treating section if necessary. Finally, the strip is cooled
to a normal temperature.

The heating section 200 and the soaking section 300 are similar or the same in structure as conventional heating and soaking sections. In the heating section 200, the strip material, which has been continuously supplied from the incoming-side device and preheated, is heated for example to a recrystallization temperature or higher. Specifically, when the strip material is cold rolled steel plate formed at an in-furnace temperature of 900 to 950°C, the steel plate is heated to a strip temperature of 700 to 800°C. The heated cold rolled steel plate is held for a required period of time in the soaking section 300, then reaches the plate temperature adjusting section. Therefore, multiple radiant tubes are disposed in the same manner as the related prior art in the vicinity of the strip 50 where it passes through the heating section 200. Combustion exhaust gases having passed the radiant tubes are supplied to the regenerative heat exchanger described later.

The preheating section is shown in Fig. 2 for giving background information to the invention. As shown in Fig. 2, the combustion exhaust gas exhausted from the radiant tubes of the heating section is supplied through existing exhaust gas incoming piping 10i to existing convective heat exchanger 11. The convective heat exchanger 11 is disposed on one side of the preheating section, and is exhausted through the existing exhaust gas outgoing piping 10o to an exhaust fan (not shown). Atmospheric gas (air) is supplied to the convective heat exchanger 11 from a suction fan 12 for taking in the atmospheric gas (i.e. air) from the preheating section via the existing air incoming piping 13i. Subsequently, the air heated by the convective heat exchanger 11 is passed through the existing air outgoing piping 13o to a plenum chamber or another diffusion blower (not shown), which blows the air to the strip 50 as it is passes through the preheating section. Specifically, the multiple tubes (not shown) are arranged, in the convective heat exchanger 11. The air supplied to the tubes is heated by the convective heat transmitted from the high-temperature combustion exhaust gas which flows around the tubes. The heated air is then blown from the plenum chamber to the strip 50 to heat the strip 50.

As shown in Fig. 2 for background information, on a face of the preheating section, three regenerative heat exchangers 1A, 1B and 1C are provided. Each of the regenerative heat exchangers 1A, 1B and 1C has a regenerating chamber with a spherical or short tubular regenerator contained therein and two connection chambers which are interconnected in such a manner so that they can be ventilated. From the existing incoming exhaust gas piping 10i, an incoming exhaust gas pipe 14 is additionally branched into three portions which are connected via incoming exhaust gas valves 2A, 2B and 2C to the connection chambers of the regenerative heat exchangers 1A, 1B and 1C, respectively. The existing incoming air piping 15 is additionally branched and connected to incoming air piping 16 which has an air supply fan 7 interposed halfway between the incoming air valves and the convective heat exchanger 11 and the section fan 12. The incoming air piping 15 is branched into three portions which are connected via incoming air valves 3A, 3B and 3C to the connection chamber of the regenerative heat exchangers 1A, 1B and 1C, respectively. The existing outgoing exhaust gas piping 10o is additionally branched and connected to exhaust gas outgoing piping 16 whose tip is branched into three portions which are connected via outgoing exhaust gas valves 4A, 4B and 4C to the connection chambers of the regenerative heat exchangers 1A, 1B and 1C, respectively. The existing outgoing air piping 13o is additionally branched and connected to the outgoing air piping 17 whose end is branched into three portions which are connected via the outgoing air valves 5A, 5B and 5C to the connection chambers of the regenerative heat exchangers 1A, 1B and 1C, respectively. Each of the three end portions of the outgoing air piping 17 is further branched into two portions. The further branched portions are connected via purging valves 6A, 6B and 6C to the connection chambers of the regenerative heat exchangers 1A, 1B and 1C, respectively. Except for the purging valves 6A, 6B and 6C, and the associated pipes, flow rates of the valves 2A, 2B and 2C and the associated pipes are equal or substantially equal to one another. Furthermore, the flow rates of the purging valves 6A, 6B and 6C, and the associated pipes, are set less than the flow rates of the other valves and pipes. Further, the piping and valve system connected to the regenerative heat exchanger 1A is denoted as System A, a piping and valve system connected to the regenerative heat exchanger 1B as System B, and a piping and valve constitution connected to the regenerative heat exchanger 1C is denoted as System C.

The valve system is shown in Fig. 3. The opening and closing of the valves is controlled by a processing computer (not shown). The control is shown in the timing diagram of Fig. 4.

As shown in the timing diagram of Fig. 4, for example, the exhaust gas incoming valves 2A and 2B and the outgoing exhaust gas valves 4A and 4B of the Systems A and B are opened, while the incoming air valve 3C and the outgoing air valve 5C of the System C are opened. All other valves are closed. Specifically, in the regenerative heat exchangers 1A and 1B of the Systems A and B, the sensible heat of the combustion exhaust gas is stored in the regenerators, while the air sensible heat is raised from the regenerator of the System C regenerative heat exchanger 1C which has reserved the heat. The high-temperature air is then blown from the plenum chamber to the strip 50. For example, if the temperature of the regenerator of the System A regenerative heat exchanger 1A, which has stored heat, reaches the vicinity of its upper limit and no more heat continues to be stored, then the System A incoming exhaust gas valve 2A is closed so that no combustion exhaust gas can be supplied to the regenerator of the System A regenerative heat exchanger 1A. Even in this condition, the System C regenerative heat exchanger 1C can blow the
Subsequently, when the System A incoming exhaust gas valve 2A is completely closed, the System A purging valve 6A is opened. At this time, the System A regenerative heat exchanger 1A is still filled with the combustion exhaust gas. However, the flow rate of the purging valve 6A and the associated piping is set less than the flow rate of the System C outgoing air valve 5C and its associated piping. Therefore, most of the high-temperature air exhausted from the System C outgoing air valve 5C is still blown to the strip in the preheating section.

A portion of air is supplied from the additional outgoing air piping 17 through the System A purging valve 6A into the System A regenerative heat exchanger 1A. The combustion exhaust gas which filled in the regenerative heat exchanger 1A is exhausted from the System A outgoing exhaust pipe 4A which is still open. Thereby, the regenerative heat exchanger 1A is purged with the high-temperature air. At this point, the regenerator of the System A regenerative heat exchanger 1A is further heated by the high-temperature air.

After the System A regenerative heat exchanger 1A is purged with the high-temperature air, the System A purging valve 6A is closed. After the purging valve 6A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing air valve 5A is opened. When the outgoing air valve 5A is completely opened, the System A incoming air valve 3A is opened to exhaust the high-temperature air from the System A regenerative heat exchanger 1A, which is blown into the strip in the preheating section 100. After the System A incoming air valve 3A is completely open, the System C incoming air valve 3C is closed. After the incoming air valve 3C is completely closed, the System C outgoing air valve 5C is closed. After the air outgoing valve 5C is completely closed, the System C outgoing exhaust valve 4C is opened. After the outgoing exhaust gas valve 4C is completely open, the System C incoming exhaust gas valve 2C is opened. When the System C incoming exhaust gas valve 2C is opened, the System C incoming exhaust gas 2C is opened. After the System A outgoing exhaust gas valve 4A is completely closed, the System A purging valve 6A is closed. After the purging valve 6A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A purging valve 6A is closed. After the purging valve 6A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed. After the outgoing exhaust gas valve 4A is completely closed, the System A outgoing exhaust gas valve 4A is closed.
purging valve 6C is closed. After the purging valve 6C is completely closed, the System C outgoing exhaust gas valve 4C is closed. After the outgoing exhaust gas valve 4C is completely closed, the System C outgoing air valve 5C is opened. When the outgoing air outgoing valve 5C is completely open, the System C incoming air valve 3C is opened to exhaust the high-temperature air from the System C regenerative heat exchanger 1C, which is blown to the strip in the preheating section 100. Subsequently, after the System C air incoming valve 3C is completely open, the system-B incoming air valve 3B is closed. After the incoming air valve 3B is completely closed, the System B outgoing air valve 5B is closed. After the outgoing air valve 5B is completely closed, the System A outgoing exhaust gas valve 4B is opened. After the outgoing exhaust gas valve 4B is completely open, the System B incoming exhaust gas valve 2B is opened, to store the sensible heat of the combustion exhaust gas in the regenerator of the system-B regenerative heat exchanger 1B.

[0037] In the conventional continuous annealing furnace shown in Fig. 8, the combustion exhaust gas from the radiant tubes of the heating section is supplied to the convective heat exchanger, while air is supplied to the tubes in the convective heat exchanger. The air in the tubes is heated by convective heat transmitted from the sensible heat of the combustion exhaust gas, and is blown to the strip in the preheating section to heat (preheat) the strip. The set temperature of the strip supplied from the heating section is 800°C.

[0038] In the heating section, as shown in Fig. 9, the combustion heat of fuel gas or M gas (a mixture of blast-furnace gas and coke-furnace gas) is supplied from the burners and the radiant tubes. Subsequently, heat loss results from the radiant heat from the furnace body and exhaust of NH gas (hydrogen-nitrogen gas mixture in the case of an in-furnace atmosphere being a reduction atmosphere), and further heat loss results from the cooling of the roll chamber which cools the hearth roll and the like. Overall, the radiant heat and the heat loss are small. However, strip sensible heat and heat loss from combustion exhaust gas account for a larger percentage of lost heat. However, the strip sensible heat is disregarded, because it is required to attain the target temperature of the object to be heated. In the conventional continuous annealing furnace, the combustion exhaust gas flow rate is about 63kNm³/hr.

[0039] While the combustion exhaust gas passes through a duct (piping), because of the radiant heat from the duct, its temperature is decreased to 640°C before it reaches the convective heat exchanger. In the convective heat exchanger, only an air sensible heat of 298°C can be recovered from the sensible heat of the combustion exhaust gas. Therefore, even when the air is continuously supplied to the preheating section and blown to the strip, a strip sensible heat which is 40°C on the incoming side of the preheating section is increased only to 120°C on the outgoing side of the preheating section. Therefore, the furnace temperature in the heating section needs to be set to 941°C, and the fuel consumption rate in the heating section is subsequently as high as 996.3MJ/t-steel. Additionally, in the conventional continuous annealing furnace, the flow rate of air supplied or recycled to the preheating section is very high, about 13kNm³/hr. This is because to increase the strip temperature as high as possible, by blowing a low-temperature air to the strip, as seen from the effect of the convective heat, the flow rate of air to be blown to the strip has to be increased.

[0040] In the previously-described regenerative heat exchanger, the recovery efficiency of the combustion exhaust gas sensible heat is so high that the sensible heat of the air to be blown from the regenerative heat exchanger to the strip in the preheating section is increased. Specifically, the temperature of the air blown to the strip is further raised, thereby increasing the temperature of the strip which is supplied to the preheating section. Finally, the temperature of the radiant tubes in the heating section is lowered to lengthen the high-temperature life of the radiant tubes, while the fuel consumption rate in the heating section is reduced to save cost. In this embodiment, as shown in Fig. 5, the temperature of the radiant tubes in the heating section can be set to 926°C, which is 15°C lower as compared with the related art. Additionally, the set temperature of the strip supplied from the heating section remains the same at 800°C.

[0041] Since the furnace temperature can be finally lowered, the supply quantity of the fuel gas or M gas is decreased. As a result, the combustion exhaust gas flow rate is decreased by approximately 6000Nm³/hr from the related art to about 57kNm³/hr. In this case, the exhaust gas temperature is 669°C, and the combustion exhaust gas is lowered in temperature to 626°C due to duct radiant heat upon reaching the regenerative heat exchanger. Subsequently, in the regenerative heat exchanger, because of its high heat recovery ratio, the air sensible heat of 570°C can be recovered from the combustion exhaust gas sensible heat, and supplied to the preheating section to be blown to the strip. The strip sensible heat which is 40°C on the incoming side of the preheating section can be increased by 90°C from the related art to 210°C on the outgoing side of the preheating section. The air is then supplied to the heating section, thereby attaining the furnace temperature of 926°C as described above.

[0042] The fuel consumption rate in the heating section can be reduced by 89.6MJ/t-steel from the related art, to 906.7MJ/t-steel. In this embodiment, the flow rate of air supplied or recycled to the preheating section can also be reduced from approximately 68kNm³/hr of the related art down to about 62kNm³/hr. This is because the temperature of air to be blown to the strip is remarkably higher than in the conventional annealing furnace. Even with a small quantity of blown air, the temperature of the strip, as the energy efficiency, can be efficiently raised as well.

[0043] Fig. 6 plots the stress generated on the radiant tube on against the constant value P, which is an inherent property of a material and is calculated as:
can be eliminated. Simultaneously, in the remaining regenerative heat exchangers, the sensible heat of the combustion
opened and closed. Therefore, the high-temperature predetermined gas can be continually blown to the metal strip
in the preheating section, and the sensible heat of the combustion exhaust gas is stored in the regenerator of the large-sized regenerative heat exchanger. By supplying air, or another predetermined gas, to the regenerator, the sensible heat of the combustion exhaust gas is collected and recovered to the sensible heat of the predetermined gas. By blowing the gas to the metal strip in the preheating section, the metal strip is preheated. In this case, the temperature required for the radiant tubes can be lowered. In this lower temperature range, the radiant tubes have a remarkably enhanced lifetime, plus the fuel consumption rate in the burners can be decreased.

From at least one of the regenerative heat exchangers, the sensible heat of the combustion exhaust gas reserved in the regenerator can be recovered as the sensible heat of the predetermined gas. The predetermined gas is blown to the metal strip in the preheating section, and the sensible heat of the combustion exhaust gas is stored in the regenerator of the large-sized regenerative heat exchanger. By blowing the high-temperature gas directly to the metal strip, the temperature of the metal strip, as it leaves the preheating section, is remarkably higher as compared with the conventional annealing furnace. Therefore, the continuous annealing furnace containing a hundred, to several hundreds of radiant tubes, arranged in an integral furnace body, the effect is enlarged. Not only is there a large reduction in the radiant tube material cost, but also a large reduction in maintenance, repair or another operational costs.

As described above, in the metal-strip continuous heat treating furnace, the sensible heat of the combustion exhaust gas supplied from the burners to the radiant tubes in the heating section is collected and stored in the regenerator of the large-sized regenerative heat exchanger. By supplying air, or another predetermined gas, to the regenerator, the sensible heat of the combustion exhaust gas is collected and recovered to the sensible heat of the predetermined gas. By blowing the gas to the metal strip in the preheating section, the metal strip is preheated. In this case, by passing the regenerator in the regenerative heat exchanger, the predetermined gas obtains a sufficiently high temperature. By blowing the high-temperature gas directly to the metal strip, the temperature of the metal strip, as it leaves the preheating section, is remarkably higher as compared with the conventional annealing furnace. Therefore, the increase in temperature of the metal strip required in the heat exchanger section is decreased, and accordingly, the temperature required for the radiant tubes can be lowered. In this lower temperature range, the radiant tubes have a remarkably enhanced lifetime, plus the fuel consumption rate in the burners can be decreased.

Further, only a continuous annealing furnace for continuously annealing the strip has been described. However, the continuous heat treating furnace of the invention can be applied to any continuous heat treating furnace that has at least a heating section and a preheating section.

As described above, in the metal-strip continuous heat treating furnace, the sensible heat of the combustion exhaust gas supplied from the burners to the radiant tubes in the heating section is collected and stored in the regenerator of the large-sized regenerative heat exchanger. By supplying air, or another predetermined gas, to the regenerator, the sensible heat of the combustion exhaust gas is collected and recovered to the sensible heat of the predetermined gas. By blowing the gas to the metal strip in the preheating section, the metal strip is preheated. In this case, by passing the regenerator in the regenerative heat exchanger, the predetermined gas obtains a sufficiently high temperature. By blowing the high-temperature gas directly to the metal strip, the temperature of the metal strip, as it leaves the preheating section, is remarkably higher as compared with the conventional annealing furnace. Therefore, the increase in temperature of the metal strip required in the heat exchanger section is decreased, and accordingly, the temperature required for the radiant tubes can be lowered. In this lower temperature range, the radiant tubes have a remarkably enhanced lifetime, plus the fuel consumption rate in the burners can be decreased.

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exhaust gas can be efficiently stored in the regenerators.

[0051] Further, in another metal-strip continuous heat treating while the valve for purging the predetermined gas is open, the valve for exhausting the combustion exhaust gas is opened. Thereby, the combustion exhaust gas is exhausted from the relevant regenerative heat exchanger, and the heat exchanger is purged with the predetermined gas. Subsequently, after closing the valve for purging the predetermined gas, the valve for exhausting the combustion exhaust gas is closed. Then, the valve for exhausting the predetermined gas is opened. This allows the metal strip in the preheating section to be accurately blown by the predetermined gas.

[0052] Also, in another metal-strip continuous heat treating the flow rate of the system for purging the predetermined gas is set less than the flow rate of the system for exhausting the predetermined gas into the preheating section. Thereby, the high-temperature predetermined gas from the relevant regenerative heat exchangers is continually exhausted into the preheating section. Using a portion of the predetermined gas, the relevant regenerative heat exchanger can be securely purged.

[0053] According to an embodiment of the invention, the regenerator is divided into at least three sections: a regenerating zone (heating section combustion exhaust gas path), which supplies the sensible heat of the exhaust gas to the regenerator; a purging zone (purging gas path), which removes the exhaust gas residing in the regenerator after the temperature of circulating gas has risen closer to the limit temperature in the regenerating zone; and a heating zone (circulating gas path), which raises the temperature of the circulating gas by passing the gas through the purged regenerator. These zones are repeatedly cycled, allowing the sensible heat of the high-temperature exhaust gas to be efficiently recovered. Additionally, since the regenerator itself rotates, the number of pipes and valves can be reduced.

[0054] Fig. 10 schematically shows a heat exchanger for the metal-strip annealing furnace according to a first embodiment of the invention. In Fig. 10, a heat exchanger body 21 (shown by a two-dotted line) is rotatable about a rotation axis 28, in which three regenerators 22 are disposed. The regenerators 22 are provided with a heating section exhaust gas path 23 connected from the heating section 200 of the continuous annealing furnace or the like, a purging gas path 24 and a circulating gas path 25 connected to the preheating section 100 of the continuous annealing furnace or the like.

[0055] As the heat exchanger body 21 is continuously rotated, the sensible heat of the exhaust gas from the heating section is recovered.

[0056] As the heat exchanger body 21 rotates, a first regenerator 22a shifts into the purging gas path 24. Purging gas is blown through the first regenerator 22a, forcing the exhaust gas and debris which remain after the combustion exhaust gas has passed to be removed. If the regenerator 22, after its temperature has been increased by the exhaust gas, is not purged, the circulating gas passed through the regenerator is blown to the metal, and any debris or the like included in the exhaust gas will stick to the metal strip. This results in a deterioration of the surface quality of the product.

[0057] As the first regenerator 22a shifts to the circulating gas path 25, circulating gas is blown into a first regenerator 22a allowing the circulating gas to recover the heat of the first regenerator 22a, thereby raising its temperature. The circulating gas is then supplied to the preheating section 100 of the continuous annealing furnace or the like.

[0058] As the first regenerator 22a is switched from the heating section exhaust gas path 23 to the purging gas path 24, the second regenerator 22b is switched from the purging gas path 24 to the circulating gas path 25. At the same time, the third regenerator 22c switches from the circulating gas path 25 to the heating section exhaust gas path 23. This method of raising the circulating gas temperature is repeated in a cycle as long as the heat exchanger body 21 rotates and gasses are supplied from the paths 23, 24 and 25. Alternatively, the heat exchanger body 21 can be fixed and the chambers shown in Fig. 11, or another peripheral device can be rotated, to achieve the same effect.

[0059] In this type of heat exchanger, the gas pressure is set in such a manner that:

\[ P_e < P_p \leq P_c \]

where:

- \( P_e \) is the pressure of the heating section exhaust pipe;
- \( P_p \) is the pressure of the purging gas; and
- \( P_c \) is the pressure of the circulating gas.

[0060] Even if one section is continuously rotated, the other sections are not largely influenced. However, especially when there is a strict accuracy requirement, buffer areas can be provided adjacent to the regenerators 22a-22c. The time during which one of the first regenerators 22a-22c stays in the heating section combustion exhaust gas path 23, the purging gas path 24 or the circulating gas path 25 is described by Eq. 3. As shown in Eq. (3), the cycle pitch \( t_2 \) is:
where:

\[ P_2 \] is a length of the section as shown in Fig. 10, in meters; and
\[ V_2 \] is a rotational speed in meters per second.

[0061] Therefore, by changing the rotational speed, the pitch can be adjusted. Additionally, the heat exchanger body 21 can be continuously rotated by an electric motor or non-continuously rotated by using a cylinder and rod configuration. However, one skilled in the art will appreciate that there are other means of rotation. In any case, the rotational speed is set to about 0.5 to 4 rpm.

[0062] The sectional areas of the purging gas passing section and the circulating gas passing section preferably satisfy:

\[ \frac{S_1}{S_2} \geq \frac{1}{[Q_a/(V_1) - 1]} \] (4)

where:

\[ S_1 \] is the sectional area of the purging gas passing section in square meters (m²);
\[ S_2 \] is the sectional area of the circulating gas passing section in square meters (m²);
\[ Q_a \] is an average flow rate of the air passing the regenerator connected to the purging gas path 24 in cubic meters per second (m³/s); and
\[ V_1 \] is an approach volume of the circulating gas passing section in cubic meters per second (m³/s).

[0063] When those conditions are satisfied, the circulating gas can be passed and the exhaust gas is completely purged.

[0064] Fig. 16 shows a third embodiment of the heat exchanger body 21 in which the purging gas path 24 branches from the incoming path 25a of the circulating gas path 25. With this configuration, the circulating gas can be used also as the purging gas. While simplifying the purging gas path this leads to an overall reduction in cost for the device.

[0065] Fig. 17 shows a fourth embodiment of the heat exchanger body 21 in which the incoming path 24a of the purging gas path 24 is connected to an outgoing path 25b of the circulating gas path 25 and the outgoing path 24b is connected to the outgoing path 23b of the exhaust gas passing section. In this constitution, no outgoing path is required for the purging gas path 24.

[0066] Figs. 18 and 19 show the heat exchanger body 21 of Fig. 17 in greater detail. Specifically, Fig. 18 shows in detail the device including the preheating section 43 of the annealing furnace, the circulating air fans 44, the exhaust fans 45 and a funnel 46. Fig. 19 is a plan view of the heat exchanger according to the fourth embodiment of the heat exchanger body 21 of this invention, as shown in Fig. 17. In Fig. 19, numeral 47 denotes a sector plate which rotatably holds the heat exchanger body 21. Adjacent to the sector plate 47 an inlet 48 for purging gas can be provided.

[0067] Figs. 11 through 14 show a heat exchanger for the annealing furnace according to the second embodiment of the invention. In Figs. 11 through 14, in the heat exchanger casing 29, the regenerator 22 (Al₂O₃ or other balls) is fixed and held. On the upper and lower faces of the regenerator 22, plate members are disposed. The plate members have numerous holes therein to facilitate gas distribution.

[0068] A rotation axis 28 which holds the regenerator 22 is supported by bearings on the upper and lower faces of the casing 29. The circulating gas path 25 is a duct which has an open end covering almost half of the lower periphery of the regenerator 22, while the heating section combustion exhaust gas path 23 is a duct which has an open end covering almost half the upper periphery of the regenerator 22. Paths 25 and 23 partially constitute the regenerator 22.

[0069] A chamber 31 hermetically surrounds the lower open end of the circulating gas distribution duct 41 and is connected to the circulating gas supply path 25. A chamber 32 hermetically surrounds the upper open end of the heating section combustion exhaust gas distribution duct 42 and is connected to the heating section combustion exhaust gas supply path 23.

[0070] A drive mechanism 33 is formed by a motor 33a, a speed reducer 33b and a gear 33c. The gear 33c of the drive mechanism 33 engages a rack (not shown) which is provided on a lower-end outer periphery of the circulating gas distribution duct 41. Similarly, a drive mechanism 34 is formed of a motor 34a, a speed reducer 34b and a gear 34c. The gear 34c of the drive mechanism 34 engages a rack (not shown) which is provided on an upper-end outer periphery of the heating section combustion exhaust gas distribution duct 42. By operating the drive mechanisms 33
and 34, the ducts 41 and 42 are rotated in the direction illustrated by arrows in Fig. 11.

[0071] A partition 35 forms a local region d₁ (shown in Fig. 14) in the circulating gas distribution duct 41, while a partition 36 forms a local region d₂ (shown in Fig. 13) in the heating section combustion exhaust gas distribution duct 42. The purging gas path 24 is formed in such a manner that the purging gas passes from the local region d₁ via the regenerator 22, is exhausted from a heating section exhaust gas outlet 37. The heating section exhaust gas enters an inlet 38. The circulating gas which has passed the regenerator 22, thus raising its temperature, is exhausted from a circulating air outlet 39 which is connected to the preheating section of the annealing furnace or the like. The circulating gas enters an inlet 40.

[0072] In the regenerative heat exchanger having the above-described structure, the sensible heat of the heating section exhaust gas is recovered as follows. First, the regenerator 22 is divided into a first portion 22a, a second portion 22b, and a third portion 22c. The first portion 22a is opposed to the heating section combustion exhaust gas distribution duct 42. The second portion 22b is opposed to the purging gas path 24. The third portion 22c is opposed to the circulating gas distribution duct 41. Exhaust gas passes from the inlet 38 into the heating section combustion exhaust gas distribution duct 42, the heat of the first portion 22a, the heating section exhaust gas is stored in the regenerator 22, and the heating section exhaust gas is exhausted from the exhaust gas outlet 37. In this case, as the heating section combustion exhaust gas distribution duct 42 rotates, the region changes at a predetermined speed with an elapse of time.

[0073] Simultaneously, in the second portion 22b, the purging gas passes through the regions d₁ and d₂. The heating section exhaust gas residual in the regenerator 22, and the debris in the gas sticking to the regenerator 22, are removed. The purging gas is blown in because if the circulating gas passed through the regenerator is raised in temperature by the exhaust gas, then blown directly to the metal strip in the preheating section, debris or the like included in the exhaust gas could stick to the strip deteriorating the surface quality of the product. Also simultaneously, the third portion 22c circulating gas flows in, its temperature is increased by the regenerator 22, and the circulating gas is supplied via the outlet 39 to the preheating section of the annealing furnace or the like. As described above, storing the heat from the heating section exhaust gas, and the purging and raising of the circulating gas temperature are repeated in a cycle as long as the circulating gas distribution duct 41 and the heating section combustion exhaust gas distribution duct 42 are rotated in the directions indicated by the arrows in Fig. 11, thereby allowing the heat of 200 exhaust gas to be efficiently recovered.

[0074] In this type of heat exchanger, in the same manner as the third embodiment, to prevent the heating section exhaust gas from flowing into the preheating section circulating air, a gas pressure is set in such a manner that:

\[
P_e < P_p \leq P_c
\]

where:

- \(P_e\) is the pressure of the heating section exhaust pipe;
- \(P_p\) is the pressure of the purging gas; and
- \(P_c\) is the pressure of the circulating gas.

[0075] Even if the circulating gas is used as the purging gas, the other sections are not largely affected. However, if the difference in pressure from the heating section exhaust gas is excessively large, the supply efficiency of circulating gas is dropped. To prevent the supply efficiency from greatly reducing, the differential pressure is preferably set in a range of 4,900 to 7,000 Pa.

[0076] When the cycle pitch of the heating section combustion exhaust gas distribution duct 42 is \(L_1\), the cycle pitch of the circulating gas distribution duct 41 is \(L_2\), the peripheral length shown in Figs. 13 and 14 is \(P_2(P_2-1=P_2-2)\) in meters (m), and the rotational speed is \(V_2\) in meters per second (m/sec). The cycle pitch \(t_2\) is then:

\[
t_2 = \frac{L_2}{V_2}
\]

[0077] Therefore, by changing the rotational speed, the pitch can be adjusted. In the present invention, the duct rotational speed is set to about 0.4 to 4 rpm. The duct can be continuously rotated by an electric motor or non-continuously rotated by using a cylinder and rod, however. The method of rotation is not especially restricted.

[0078] Fig. 15 schematically shows an embodiment in which the heat exchanger body 21 is incorporated into the preheating section 100 of the continuous annealing furnace according to the fifth embodiment of the invention. In Fig. 15, a hot air circulating fan 26 for circulating gas and a conventional convective heat exchanger 27 are incorporated.

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into the preheating section 100. When the circulating gas is used as the purging gas, its supply path is not especially required. However, if argon (Ar) gas or the like is used separately, a separate path can be provided, as shown in Fig. 15. Alternatively, plural heat exchangers, as previously disclosed, could be arranged in parallel. In this case, all the heat exchangers, including the conventional convective heat exchanger, could be used. In this case, at least one of the heat exchangers would be on standby, and can be used as a spare heat exchanger.

The regenerator 22 is preferably formed of Al₂O₃, SUS310 or SUS316 according to Japanese Industrial Standards, or another material superior in heat resistance and corrosion resistance. The regenerator 22 can be formed in a ball, a honeycomb structure body or the like. However, to ensure heating section exhaust gas does not flow into the circulating gas, a regenerator having a honeycomb structure body having directivity is preferably used.

In the device shown in Fig. 15, a cold rolled steel plate 0.5 to 2.3mm thick and 700 to 1850mm wide is continuously annealed. To comparatively illustrate the advantages of the present invention the following variables are realized: the heat recovery ratio from a heating section exhaust gas (raised heat of preheating section circulating air/ exhaust gas sensible heat), the steel strip temperature on the heating section incoming side, the fuel consumption rate, the furnace temperature in the heating section, the burner combustion load in the heating section, the radiant tube life, the number of switching valves, and the device cost in relation to the conventional convective heat exchanger.

treatment condition:

heating section exhaust gas
flow rate: 35310Nm³/hr
fluid: M gas combustion exhaust gas
heat exchanger incoming-side temperature: 627°C
heat exchanger outgoing-side temperature: 403°C
heat exchanger incoming-side pressure: -3,240 Pa

preheating section circulating gas
flow rate: 66365Nm³/hr
fluid: air
heat exchanger incoming-side temperature: 360°C
heat exchanger outgoing-side temperature: 575°C
heat exchanger incoming-side pressure: +2,350 Pa purging gas

circulating gas

heat exchanger specification
embodiment: rotary regenerative heat exchanger (exchanger quantity 20,093MJ/hr)
comparative example: plate heat exchanger (exchanger quantity 5,860MJ/hr)
Regenerator: SUS 304 (honeycomb structure body)

As clearly seen from Table 1, the regenerative heat exchanger according to the invention is negligibly adversely affected by the combustion exhaust gas. As compared with the conventional convective heat exchanger, the exhaust gas recovery ratio can be improved by 15% or more (as compared with the conventional regenerative heat exchanger, about 15%), and the heating section incoming-side temperature of the steel strip can be raised by about 90°C. It can further be seen that all the remainder of the variables tend to be improved.

When a rotary regenerator as shown in Fig. 20 is operated under the condition that the average air flow rate Qₐ in a regenerator is 47m³/sec and the rotational speed of the regenerator is 1.35rpm, then the air piping approach...
volume of the regenerator, the approach volume in the circulating gas passing section, \( V_r \) is:

\[
V_r = 1.345 \cdot p \left( (3.35/2)^2 - (0.92/2)^2 \right)^{1/2} p^2 (2p' 1.35/60)
\]

\[
= 2.47 \cdot 10^{-1} \text{[m}^3/\text{sec]}\]

The ratio of the sectional area \( S_1 \) of the purging gas passing section and the sectional area \( S_2 \) of the circulating gas passing section, including a safety factor of 50%, is:

\[
S_1 / S_2 = \left( \frac{1}{(47/0.247) - 1} \right) 1.5 = 0.8\%
\]

[0082] According to the present invention, the number of pipes and valves associated the heat exchanger is minimized, and the device itself can be made more compact. Further, the heat loss of the combustion exhaust gas can be recovered efficiently. Also, by efficiently recovering the heat loss of the combustion exhaust gas, the temperature of the metal strip can be effectively raised in the preheating section. Therefore, the set temperature of the heating section can be set to the minimum temperature required for treating the steel plate. Since the invention can be applied to devices other than the heating furnace with the radiant tubes, the equipment cost can be saved while the consumption load of the burner can be advantageously reduced. For the radiant tube especially, its life can be remarkably prolonged, while changing the hoods on the outgoing or incoming side of the heat exchanger, the passing area of exhaust gas and air can be optionally regulated.

**Claims**

1. A continuous heat treating furnace for a metal strip having a regenerative heat exchanger which raises through a regenerator (22) a temperature of a circulating gas wherein:
   - the regenerator (22) is constituted of three sections (23, 24, 25):
     - a heating section combustion exhaust gas path (23) for passing a heating section combustion exhaust gas to apply to the regenerator (22) a sensible heat of the heating section combustion exhaust gas of the furnace,
     - a purging gas path (24) for passing a purging gas to remove debris sticking to a sensible heat recovery path when applying the sensible heat of the heating section exhaust gas, and
     - a circulating gas path (25) for heating the circulating gas wherein the regenerator (22) is continuously or intermittently rotated in such a manner that the sections (23, 24, 25) of the regenerator (22) change roles with rotation from the heating section combustion exhaust gas path (23), then the purging gas path (24) to the circulating gas (25) path sequentially and repeatedly.

2. The continuous heat treating furnace according to claim 1, wherein:
   - the circulating gas is used as the purging gas,
   - the circulating gas and the purging gas are caused to flow in the same direction, and
   - the circulating gas and the heating section combustion exhaust gas are caused to flow in opposite directions.

3. The continuous heat treating furnace according to claim 1 or 2, wherein:
   - the regenerator (22) is fixed while a circulating gas distribution duct (41) and a heating section combustion exhaust gas distribution duct (42) are rotated.

4. The continuous heat treating furnace according to at least one of claims 1-3, wherein:
   - the regenerator (22) is a refractory mainly constituted of alumina.

5. The continuous heat treating furnace according to at least one of claims 1-3, wherein:
the regenerator (22) is formed of stainless steel.

6. The continuous heat treating furnace according to at least one of the preceding claims, wherein:

the purging gas is passed from a region of the circulating gas distribution duct (41) via the regenerator (22) to a region of the heating section combustion exhaust gas distribution duct (42).

7. The continuous heat treating furnace according to at least one of the preceding claims, wherein:

a relationship between a sectional area of a purging gas passing section and a sectional area of a circulating gas passing section satisfies the following expression:

\[ \frac{S_1}{S_2} \geq 1/\left[ \left( \frac{Q_a}{V_1} \right) - 1 \right] \]

wherein:

- \( S_1 \) is the sectional area (m²) of the purging gas passing section;
- \( S_2 \) is the sectional area (m²) of the circulating gas passing section;
- \( Q_a \) is an average flow rate (m³/s) of air passing through the regenerator; and
- \( V_1 \) is an approach volume (m³/s) of the circulating gas passing section.

8. The continuous heat treating furnace according to at least one of the preceding claims, wherein:

a static pressure of the circulating gas is higher than a static pressure of the exhaust gas.

9. The continuous heat treating furnace according to at least one of the preceding claims, wherein:

an incoming path of the purging gas passing section is branched from an incoming path of the circulating gas passing section.

10. The continuous heat treating furnace according to at least one of the preceding claims, wherein:

an incoming path of the purging gas passing section is connected to an outgoing path of the circulating gas passing section; and

an outgoing path of the purging gas passing section is connected to an outgoing path of the exhaust gas passing section.

11. The continuous heat treating furnace according to at least one of the preceding claims, wherein:

the regenerator (22) is provided in a preheating section (100) of the furnace for preheating a metal strip.

12. The continuous heat treating furnace according to at least one of the preceding claims, wherein:

the furnace is an annealing furnace.

13. A metal strip annealing heat exchanger for use in a furnace for a metal strip which raises through a regenerator (22) a temperature of a circulating gas wherein:

the regenerator (22) is constituted of three sections (23,24,25):

- a heating section combustion exhaust gas path (23) for passing a heating section combustion exhaust gas to apply to the regenerator a sensible heat of the heating section combustion exhaust gas of the furnace,
- a purging gas path (24) for passing a purging gas to remove debris sticking to a sensible heat recovery path when applying the sensible heat of the heating section exhaust gas, and
- a circulating gas path (25) for heating the circulating gas, wherein the regenerator (22) is continuously or intermittently rotated in such a manner that the sections of the regenerator change roles with rotation from
the heating section combustion exhaust gas path (23), then the purging gas path (24) to the circulating
gas path (25) sequentially and repeatedly.

**Patentansprüche**

1. Durchlaufwärmebehandlungsofen für ein Metallband, der einen regenerativen Wärmeaustauscher besitzt, der
über einen Regenerator (22) eine Temperatur eines zirkulierenden Gases anhebt, wobei:

der Regenerator (22) aus drei Abschnitten (23,24,25) gebildet ist:

   einem Heizabschnitt-Verbrennungsabgasweg (23) zum Hindurchführen eines Heizabschnitt-Verbren-
nungsabgases, um zu dem Regenerator (22) eine fühlbare Wärme des Verbrennungsabgases des Hei-
zabschnitts des Ofens zuzuführen;

einem Spülgasweg (24) zum Hindurchführen eines Spülgases, um Partikel, die an einem Zurückgewin-
nungsweg für fühlbare Wärme anhaftet, zu entfernen, wenn die fühlbare Wärme des Heizabschnittabga-
ses angelegt wird, und

einem Zirkulationsgasweg (25) zum Erwärmen des Zirkulationsgases, wobei der Regenerator (22) kon-
tinuierlich oder intermittierend derart gedreht wird, dass die Abschnitte (23,24,25) des Regenerators (22)
bei Drehung die Positionen vom Heizabschnitt-Verbrennungsabgasweg (23), dann dem Spülgasweg (24)
zum Zirkulationsgasweg (25) abfolgend und wiederholt wechseln.

2. Durchlaufwärmebehandlungsofen nach Anspruch 1, wobei:

das zirkulierende Gas als das Spülgas verwendet wird,
das zirkulierende Gas und das Spülgas dazu gebracht werden, in derselben Richtung zu fließen, und
das zirkulierende Gas und das Heizabschnitt-Verbrennungsabgas dazu gebracht werden, in entgegengesetz-
ten Richtungen zu fließen.

3. Durchlaufwärmebehandlungsofen nach Anspruch 1 oder 2, wobei:

der Regenerator (22) festgelegt ist, während ein Zirkulationsgas-Verteilungskanal 41 und
ein Heizabschnitt-Verbrennungsabgasabgas-Verteilungskanal (42) gedreht werden.

4. Durchlaufwärmebehandlungsofen nach mindestens einem der Ansprüche 1-3, wobei der Regenerator (22) ein
Feuerfest-Material, hauptsächlich gebildet aus Aluminiumoxid, ist.

5. Durchlaufwärmebehandlungsofen nach mindestens einem der Ansprüche 1-3, wobei der Regenerator (22) aus
rostfreiem Stahl gebildet ist.

6. Durchlaufwärmebehandlungsofen nach mindestens einem der vorhergehenden Ansprüche, wobei:

das Spülgas von einem Bereich des Zirkulationsgas-Verteilungskanals (41) über den Regenerator (22) zu
einem Bereich des Heizabschnitt-Verbrennungsabgas-Verteilungskanals (42) geführt wird.

7. Durchlaufwärmebehandlungsofen nach mindestens einem der vorhergehenden Ansprüche, wobei:

   eine Beziehung zwischen einem Querschnittsflächenbereich eines Spülgas-Hindurchführungsabschnitts und
einem Querschnittsflächenbereich eines Zirkulationsgas-Hindurchführungsabschnitts den folgenden Aus-
druck erfüllt:

   \[ \frac{S_1}{S_2} \geq \frac{1}{[(Q_a/V_1)-1]} \]

   wobei:

   \( S_1 \) der Querschnittsflächenbereich (m²) des Spülgas-Hindurchführungsabschnitts ist;

   \( S_2 \) der Querschnittsflächenbereich (m²) des Zirkulationsgas-Hindurchführungsabschnitts ist;
Qₜ eine durchschnittliche Strömungsrate (m³/S) der Luft, die durch den Regenerator hindurchführt, ist; und

V₁ ein Näherungsvolumen (m³/S) des Zirkulationsgas-Hindurchführungsabschnitts ist.


9. Durchlaufwärmebehandlungsofen nach mindestens einem der vorhergehenden Ansprüche, wobei:

10. Durchlaufwärmebehandlungsofen nach mindestens einem der vorhergehenden Ansprüche, wobei:
ein Einlassweg des Spülgas-Hindurchführungsabschnitts mit einem Auslassweg des Zirkulationsgas-Hindurchführungsabschnitts verbunden ist; und
ein Auslassweg des Spülgas-Hindurchführungsabschnitts mit einem Auslassweg des Abgas-Hindurchführungsabschnitts verbunden ist.

11. Durchlaufwärmebehandlungsofen nach mindestens einem der vorhergehenden Ansprüche, wobei der Regenerator (22) in einem Vorheizabschnitt (100) des Ofens zum Vorheizen eines Metallbands vorgesehen ist.

12. Durchlaufwärmebehandlungsofen nach mindestens einem der vorhergehenden Ansprüche, wobei der Ofen ein Glühofen ist.

13. Metallbandglühwärmetauscher zur Verwendung in einem Ofen für ein Metallband, der über einen Regenerator (22) eine Temperatur eines zirkulierenden Gases anhebt, wobei:
der Regenerator (22) aus drei Abschnitten (23,24,25) gebildet ist:
einem Heizabschnitt-Verbrennungsabgasweg (23) zum Hindurchführen eines Heizabschnitt-Verbrennungsabgases, um zu dem Regenerator (22) eine fühlbare Wärme des Verbrennungsabgases des Heizabschnitts des Ofens zuzuführen;
einem Spülgasweg (24) zum Hindurchführen eines Spülgases, um Partikel, die an einem Zurückgewinnungsweg für fühlbare Wärme anhafteten, zu entfernen, wenn die fühlbare Wärme des Heizabschnitts abgezogen wird,
einem Zirkulationsgasweg (25) zum Erwärmen des Zirkulationsgases, wobei der Regenerator (22) kontinuierlich oder intermittierend derart gedreht wird, dass die Abschnitte des Regenerators (22) bei Drehung die Positionen vom Heizabschnitt-Verbrennungsabgasweg (23), dann dem Spülgasweg (24) zum Zirkulationsgasweg (25) abfolgend und wiederholt wechseln.

Revendications

1. Four de traitement thermique continu pour bandes de métal, ayant un échangeur de chaleur régénératif qui élève la température d'un gaz circulant, à travers un régénérateur (22), dans lequel :
le régénérateur (22) est constitué de trois sections (23, 24, 25) :
un chemin (23) pour le gaz d'échappement de la combustion dans la section chauffage, servant à faire passer le gaz d'échappement de la combustion dans la section chauffage de manière à appliquer au régénérateur (22) la chaleur sensible du gaz d'échappement de la combustion dans la section chauffage du four,
un chemin de gaz de purge (24), servant au passage d'un gaz de purge pour éliminer les débris collants à un chemin de récupération de chaleur sensible, lors de l'application de la chaleur sensible du gaz d'échappement de la section chauffage, et
un chemin de gaz circulant (25), pour le chauffage du gaz circulant,
'où le régénérateur (22) est entraîné en rotation de manière continue ou intermittente, de telle sorte que les
sections (23, 24, 25) du régénérateur (22) changent de rôle avec la rotation, pour passer de manière séquentielle et répétitive du chemin (23) pour le gaz d'échappement de la combustion dans la section chauffage, au chemin de gaz de purge (24), puis au chemin de gaz circulant (25).

2. Four de traitement thermique continu selon la revendication 1, dans lequel :
   le gaz circulant est utilisé en tant que gaz de purge ;
   le gaz circulant et le gaz de purge sont entraînés à s'écouler dans le même sens ; et
   le gaz circulant et le gaz d'échappement de la combustion dans la section chauffage sont entraînés à s'écouler en sens contraires.

3. Four de traitement thermique continu selon la revendication 1 ou 2, dans lequel :
   le régénérateur (22) est fixe, tandis qu'une conduite de distribution (41) du gaz circulant et une conduite de distribution (42) du gaz d'échappement de la combustion dans la section chauffage sont entraînées en rotation.

4. Four de traitement thermique continu selon au moins l'une des revendications 1 à 3, dans lequel :
   le régénérateur (22) est un matériau réfractaire principalement constitué d'alumine.

5. Four de traitement thermique continu selon au moins l'une des revendications 1 à 3, dans lequel :
   le régénérateur (22) est formé d'acier inoxydable.

6. Four de traitement thermique continu selon au moins l'une des revendications précédentes, dans lequel :
   le gaz de purge est entraîné à passer depuis une région de la conduite de distribution (41) du gaz circulant vers une région de la conduite de distribution (42) du gaz d'échappement de la combustion dans la section chauffage, par l'intermédiaire du régénérateur (22).

7. Four de traitement thermique continu selon au moins l'une des revendications précédentes, dans lequel :
   une relation entre l'aire en section transversale d'une section de passage du gaz de purge et l'aire en section transversale d'une section de passage du gaz circulant satisfait à l'expression ci-après :

   \[
   \frac{S_1}{S_2} \geq 1 / \left[ \left( \frac{Q_a}{V_1} \right) - 1 \right],
   \]

   où :
   
   * \(S_1\) est l'aire en section transversale (m²) de la section de passage du gaz de purge ;
   * \(S_2\) est l'aire en section transversale (m²) de la section de passage du gaz circulant ;
   * \(Q_a\) est le débit moyen (m³/S) du passage d'air à travers le régénérateur ; et
   * \(V_1\) est un volume d'approche (m³/S) de la section de passage du gaz circulant.

8. Four de traitement thermique continu selon au moins l'une des revendications précédentes, dans lequel :
   la pression statique du gaz circulant est supérieure à la pression statique du gaz d'échappement.

9. Four de traitement thermique continu selon au moins l'une des revendications précédentes, dans lequel :
   un chemin entrant de la section de passage de gaz de purge est dérivé d'un chemin entrant de la section de passage de gaz circulant.

10. Four de traitement thermique continu selon au moins l'une des revendications précédentes, dans lequel :
    un chemin entrant de la section de passage de gaz de purge est connecté à un chemin sortant de la section de passage de gaz circulant ; et
un chemin sortant de la section de passage de gaz de purge est connecté à un chemin sortant de la section de passage de gaz d'échappement.

11. Four de traitement thermique continu selon au moins l'une des revendications précédentes, dans lequel :

le régénérateur (22) est disposé dans une section préchauffage (100) du four, pour préchauffer une bande de métal.

12. Four de traitement thermique continu selon au moins l'une des revendications précédentes, dans lequel :

le four est un four de recuit.

13. Echangeur de chaleur pour le recuit de bandes métalliques, à utiliser dans un four pour bandes métalliques, qui élève la température d'un gaz circulant, à travers un régénérateur (22), dans lequel :

le régénérateur (22) est constitué de trois sections (23, 24, 25) :

un chemin (23) pour le gaz d'échappement de la combustion dans la section chauffage, servant à faire passer le gaz d'échappement de la combustion dans la section chauffage de manière à appliquer au régénérateur (22) la chaleur sensible du gaz d'échappement de la combustion dans la section chauffage du four,

un chemin de gaz de purge (24), servant au passage d'un gaz de purge pour éliminer les débris collants à un chemin de récupération de chaleur sensible, lors de l'application de la chaleur sensible du gaz d'échappement de la section chauffage, et

un chemin de gaz circulant (25), pour le chauffage du gaz circulant,

où le régénérateur (22) est entraîné en rotation de manière continue ou intermittente, de telle sorte que les sections (23, 24, 25) du régénérateur (22) changent de rôle avec la rotation, pour passer de manière séquentielle et répétitive du chemin (23) pour le gaz d'échappement de la combustion dans la section chauffage, au chemin de gaz de purge (24), puis au chemin de gaz circulant (25).
Fig. 3
Fig. 5
**Fig. 6**

**Fig. 7**
**Fig. 8**

PRIOR ART
Fig.9 PRIORART
PREHEATING SECTION OF CONTINUOUS
Annealing Furnace or the Like

Fig. 10
Fig. 11
HEATING SECTION
EXHAUST GAS (Ope SIDE)
TO CONVECTIVE HEAT EXCHANGER 27

HEATING SECTION
EXHAUST GAS (Ope SIDE)
TO REGENERATIVE HEAT EXCHANGER 21

HEATING SECTION
EXHAUST GAS (TO FUNNEL)

METAL STRIP S

PLATE PASSING DIRECTION

Fig. 15