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(54) Title: HOT-ROLLING STEEL STRIP (54) Bezeichnung: WARMWALZEN VON STAHLBAND (57) Abstract The invention relates to a method for producing strips of non-alloy and low-alloy steel with homogeneous structures and properties by continuous hot-rolling, by passing several times in the austenite zone and then in the ferrite zone, as well as by reeling. The invention is characterized in that the steel strip that was continuously cast and/or rough rolled in the austenite zone is rolled by passing twice or more in the austenite zone, at a starting temperature $T \geq A_{r3} + 30^\circ \text{C}$ with a total strain of $\epsilon_h \geq 30\%$. After each pass, the rolled product is intensively cooled until completion of the ferrite conversion. The rolled product is then subjected to final rolling by passing several times through the ferrite zone, with a total strain of $\epsilon_n \geq 60\%$, until a final thickness is obtained. (57) Zusammenfassung Die Erfindung betrifft ein Verfahren zur Erzeugung von Bändern mit homogenen Gefügen und Eigenschaften aus unlegiertem und niedriglegiertem Stahl durch kontinuierliches Warmwalzen jeweils in mehreren Stichen im Austenitgebiet und anschließen im Ferritgebiet sowie Haspeln. Kennzeichen der Erfindung ist, daß stranggegossenes und/oder im Austenitgebiet vorgewalztes Stahlband, ausgehend von einer Temperatur $T \geq A_{r3} + 30^\circ \text{C}$ mit einem Gesamtumformgrad $\epsilon_h \geq 30\%$ in zwei oder mehreren Stichen im Austenitgebiet gewalzt wird und das Walzgut nach jedem Stich intensiv gekühlt wird, bis die Ferritumwandlung abgeschlossen ist, worauf das Walzgut in mehreren Stichen mit einem Gesamtumformgrad $\epsilon_n \geq 60\%$ im Ferritgebiet auf Enddicke fertiggewalzt wird.		

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A B S T R A C T

The invention relates to a process for producing strips of homogenous structures and characteristics made of non-alloyed and low-alloyed steel by continuous hot rolling in several roll passes in the austenitic region and subsequently in the ferritic region, as well as coiling. The invention is characterised in that continuous-cast strip and/or strip rough rolled in the austenitic region, starting with a temperature $T \geq A_{r3} + 30\text{ }^{\circ}\text{C}$, with a total degree of deformation of $e_h \geq 30\%$ is rolled in two or several roll passes in the austenitic region and in that the rolling stock is intensively cooled after every roll pass until the ferritic transformation has been completed, after which the rolling stock is end rolled to final thickness in the ferritic range in several passes with a total degree of deformation $e_h \geq 60\%$.



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Hot rolling of steel strip

The invention relates to a process for producing continuous-cast strips and/or strips rough rolled in the austenitic region, of homogenous structures and characteristics made of non-alloyed and low-alloyed steel by continuous hot rolling in two or several roll passes in the austenitic region, starting with a temperature $T \geq A_{r3} + 30 \text{ }^{\circ}\text{C}$, with a total degree of deformation $e_h \geq 30 \%$ and subsequently in several roll passes in the ferritic region with a total degree of deformation $e_h \geq 60 \%$, as well as coiling.

Various printed publications, e.g. EP 0 306 076 B1, DE 692 02 088, WO 96/12573, EP 0 504 999 A3, EP 0 541 574 B1 and EP 0 370 575 B1, disclose processes according to which hot rolling in the austenitic region is separated from hot rolling in the ferritic region by an in-line arrangement of a cooling line, if necessary with a temperature equalisation line, in front of the finishing group. This is associated with the disadvantage of a relatively long cooling period. To this effect either the cooling line between the roughing group and the finishing group must be sufficiently long which requires considerable space, or else the strip needs to be stopped until the structural transformation has been completed. Both require time and extend the production process to an undesirable degree.

It is the object of the present invention by means of increasing the performance of the cooling line in front



of and between the finishing stands, largely to do without additional installations which require additional space, additional time or additional cost.

This object is met in the generic process in that the rolling stock in the finishing group is intensively cooled after every roll pass in the austenitic region and that intensive cooling ends after the ferritic transformation has been completed.

Fig. 1 shows the time-temperature transformation curve of the rolling process according to the invention compared to that of the state of the art.

It is advantageous if the process according to the invention is carried out with steels comprising (in mass %) max. 0.06 % C, max. 1.5 % Si, max. 0.6 % Mn, 0.005 to 0.25 % P, max. 0.03 % S, max. 0.008 % N as well as if applicable up to a total of 1.5 % of one or several of the elements Al, Ti, Nb, Zr, Cu, Sn, with the remainder being iron including unavoidable impurities.

With hot rolling in the austenitic and ferritic regions according to the invention, the diphasic region austenite/ferrite, which is difficult from the point of view of materials technology and deformation technology, is incorporated into the rolling process but surmounted without any problems by intensive in-line cooling of the rolling stock.

Continuous rolling according to the invention in the austenitic region, in the diphasic region and in the ferritic region, can be applied both in a multi-stand finishing group used for conventional austenitic rolling



and in finishing groups of hot-roll mills which process thin slabs directly from the pouring heat.

The temperature setting in the rolling stock takes place in an unerring and accurate manner by means of the variable and stepped use of cooling groups which for example are provided in the wash descaling plant prior to entering the finishing group and behind the finishing stands. As the hot strip enters the finishing group it is preferably adjusted to an entry temperature in the region of $T \geq A_{r3} + 30 \text{ }^{\circ}\text{C}$ by means of water delivered at high pressure.

Apart from saving space and costs, cooling during continuous finishing rolling provides advantages which have a positive effect on the product quality. By minimising the time during the continuous transition from the austenitic region to the diphasic region and from the diphasic region to the ferritic region, a structural state of high regularity is achieved across the strip width, the strip thickness and the strip length. Hot strip produced according to the invention has a homogenous structure across its cross-section. There is no longer the inhomogeneity across the thickness which can usually be observed with conventional production. The same applies with regard to coarse-grain margins in the region near the surface and in particular in the region of the strip edge. Furthermore, this has a favourable effect on the precipitation state.

The new process is variable within wide limits. By a targeted use of several cooling groups in front of, and in the finishing group, the temperature range of the diphasic region can be differently positioned in the roll-pass plan. By cooling as part of finishing rolling



the transformation kinetics austenite/ferrite are accelerated and the temperature of the diphasic region is narrowed to advantage.

Pendulum time is saved which otherwise would be required for temperature reduction between the roughing line and the finishing line.

Furthermore, with the process according to the invention, the rolling temperatures can be set unerringly and very accurately taking into account the A_{r3} temperature and in particular the A_{r1} temperature. This makes possible ferritic rolling slightly above A_{r1} as well as below A_{r1} . Ferritic rolling close to A_{r1} offers the option of saving rolling forces and thus of carrying out roll passes with high reductions which for example are necessary for thin strip below 2.5 mm and even below 1 mm final thickness. When rolling hot strip within the conventional thickness range, the low rolling forces are advantageously used in the production of strip of large width.

The combination of a high final rolling temperature with a high coiling temperature leads to a soft hot strip, i.e. a hot strip of a largely thermally-softened structural state. To do so it is advantageous to use a coiler at a short distance of for example 20 m towards the exit of the last finishing stand. This hot strip comprises the characteristics which are required for direct use of hot strip as stock.

By combining a high final rolling temperature with a low coiling temperature or by combining a low final rolling temperature with a low coiling temperature, hot strips are either thermally softened by a subsequent annealing process or further processed by cold rolling in order to



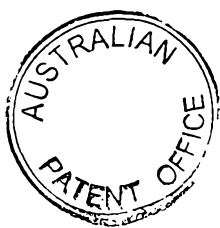
subsequently undergo final heat treatment, with or without a combination of surface refinement.

The above-mentioned combinations of final rolling temperature with coiling temperature offer varied options of exercising a controlling influence on the profile of characteristics of the hot strip for direct consumption or of cold strip produced therefrom. This can easily be proven by texture images.

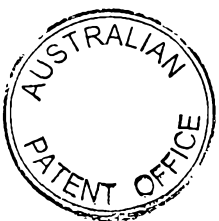
It is advantageous if in the process according to the invention, the hot strip is finish-rolled in the ferritic range at a temperature ranging from the final transformation temperature of the ferrite to up to 200 °C below it, preferably less than 100 °C below it, and is subsequently coiled at a temperature of ≥ 650 °C.

According to a further embodiment of the process according to the invention, at the latest 2 s after completion of rolling, the hot strip can be cooled to coiling temperature, with liquid and/or gaseous coolants such as water and/or a water-air mixture, at a cooling rate in the core exceeding 10 K/s, with said coiling temperature being more than 200 °C below the A_{r1} temperature.

The advantages stated apply both to hot strip for direct consumption and for cold strip produced thereof by subsequent cold rolling at a degree of deformation of ≥ 30 %, preferably ≥ 60 %, and continuous recrystallising annealing or recrystallising annealing in a hood-type furnace.



Thin strip below 3 mm final thickness should be rolled in the ferritic region, preferably with lubricants being applied.



THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for producing hot strip made of continuous-cast rolling stock and/or rolling stock rough rolled in the austenitic region, of homogenous structures and characteristics made of non-alloyed and low-alloyed steel in which the rolling stock is hot rolled in a finishing group in two or several roll passes in the austenitic region, starting with a temperature $T \geq A_{r3} + 30^{\circ}\text{C}$, with a total degree of deformation of $e_h \geq 30\%$ and subsequently in several roll passes in the ferritic region with a total degree of deformation $e_h \geq 60\%$, and subsequently coiled, characterised in that the rolling stock in the finishing group is hot-rolled in continuous succession in the austenitic region, in the diphasic region and in the ferritic region; in that the rolling stock during hot rolling, by targeted use of cooling groups arranged in the finishing group, is intensively cooled after every roll pass and in that the intensive cooling ends after the ferritic transformation has been completed.
2. A process according to claim 1, characterised in that intensive cooling is undertaken after every roll pass until completion of the ferritic transformation, by applying water or a water-air mixture or a water-steam mixture at a pressure of ≥ 3 bar.
3. A process according to claim 1 or 2, characterised in that the strips are hot rolled from a steel comprising (in mass %) max. 0.06 % C, max. 1.5 % Si, max. 0.6 % Mn, 0.005 to 0.25 % P, max. 0.03 % S, max. 0.008 % N as well as if applicable up to a total of 1.5% of one or more of the elements Al, Ti, Nb, Zr, Cu, Sn, with the remainder being iron including unavoidable impurities.



4. A process according to any one of claims 1 to 3, characterised in that the hot strip is finish-rolled in the ferritic range at a temperature ranging from the final transformation temperature of the ferrite to 200 °C below it, and is subsequently reeled at a temperature of ≥ 650 °C.
5. A process according to claim 4, characterised in that finish rolling takes place at a temperature ranging from the final transformation temperature of the ferrite to 100 °C below it in the ferritic range.
6. A process according to any one of claims 1 to 3, characterised in that at the latest 2 s after completion of rolling, the hot strip is cooled to coiling temperature with liquid and/or gaseous coolants such as water and/or a water-air mixture, at a cooling rate in the core exceeding 10 K/s, with said coiling temperature being more than 200 °C below the A_{r1} temperature.
7. A process according to any one of claims 1 to 6, characterised in that the hot strip is cold rolled at a degree of deformation of ≥ 30 %.
8. A process according to claim 7, characterised in that the hot strip is cold rolled at a degree of deformation of ≥ 60 %.
9. A process according to any one of claims 4 to 7, characterised in that the hot strip or cold strip is subjected to continuous recrystallising annealing or



recrystallising annealing in a hood-type furnace and/or to surface refinement.

10. A process according to any one of claims 1 to 9, characterised in that the steel strip is end rolled in the ferritic region, with the addition of lubricants, to thicknesses below 3 mm.

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