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(54) METHOD AND DEVICE FOR COOLING HOT-ROLLED PROFILED SECTIONS

(76) Inventors: **Meinert Meyer**, Erkrath (DE); **Uwe Plociennik**, Ratingen (DE)

Correspondence Address:
FRIEDRICH KUEFFNER
SUITE 1921
342 MADISON AVENUE
NEW YORK, NY 10173 (US)

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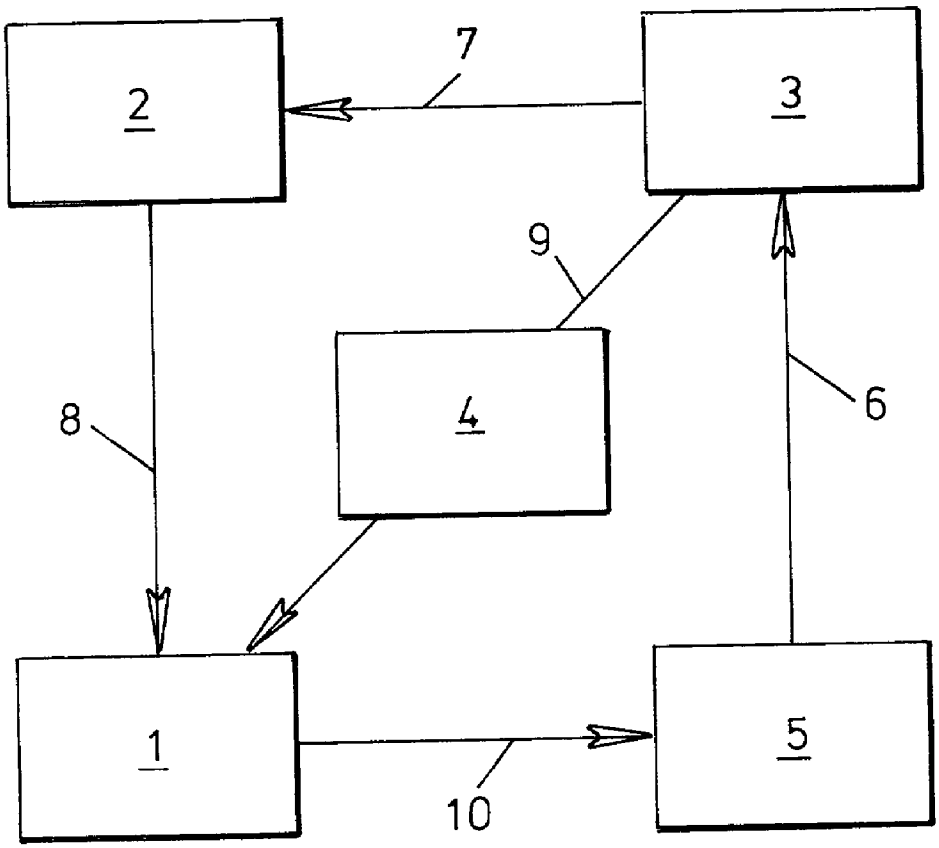
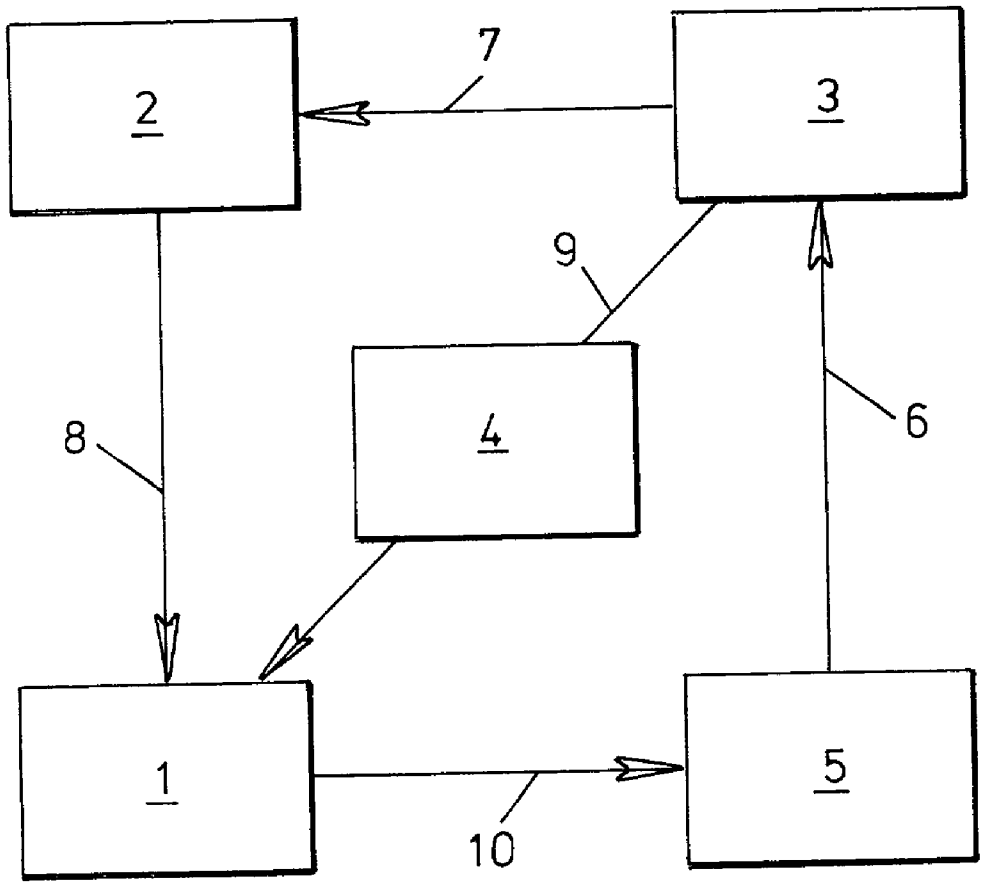
(57) **ABSTRACT**

In a method for cooling hot-rolled profiled sections from the rolling heat, wherein the profiled sections are formed of section parts of different mass, wherein, by using measuring-technological means in cooperation with a computer with the aid of a computing program, the quantity of heat to be proportionally removed from the different section parts in accordance with their mass and temperature and the amount of cooling medium required therefor are calculated and controlled, the course of temperature for the rolling stock in the rolling mill is simulated already before the actual rolling and cooling process by performing several simulation calculations by varying the cooling parameters in the simulation calculation to obtain calculated parameters. The actual values are measured upstream and downstream of the cooling stretch. The adjustments of the desired cooling process are controlled based on the calculated parameters obtained from the simulations and the actual values measured upstream and downstream of the cooling stretch. A device for performing the method has a closed active loop of five linked functional units.

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METHOD AND DEVICE FOR COOLING HOT-ROLLED PROFILED SECTIONS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a method for cooling hot-rolled profiled sections from the rolling heat. The profiled sections are formed of section parts of different mass. By using measuring-technological means in cooperation with a computer with the aid of a computing program, the quantity of heat to be proportionally removed from the different section parts in accordance with their mass and temperature and the amount of cooling medium required therefor are calculated and controlled.

[0003] 2. Description of the Related Art

[0004] Profiled rolling stock, for example, rails, are cooled on cooling banks from the rolling heat to a temperature under 80° C. Because of the asymmetric arrangement of the masses of the profiled section, the rail head and the rail foot exhibit different cooling behavior, wherein the rail foot as a result of its larger heat conveying surfaces relative to its mass in comparison to the rail head cools faster then the rail head. This means that the rail will warp during cooling. This warping action can be counteracted to a certain degree by pre-bending the still hot rail. However, this requires disadvantageously a complex hot bending process of uncertain results. In any case, the rails must be straightened after cooling. As a result of the cooling process as well as the straightening process, inherent stresses are caused in the rail which have a detrimental effect on their strength. Numerous proposals are known in order to counteract these problems.

[0005] The German laid-open patent document DE 42 37 991 A1 describes a method for cooling profiled rolling stock hot-rolled in roll stands, in particular, of rails, on a cooling bank, by means of natural convection or forced air cooling. The invention resides in that the rails are suspended with their rail head upside down and transported across a cooling bank. With this measure, the heat transmission conditions are changed in the case of natural convection already so beneficially that the temperature difference between the rail head and the rail foot of the rail of approximately 140° C. for a horizontally positioned rail is reduced to approximately 50° C. for the suspended rail.

[0006] The German patent 21 61 704 describes a method as well as a device for a stress-free and warp-free cooling of railroad rails which resides in that identical profiled rail sections to be cooled are symmetrically clamped together in pairs, rail foot against rail foot which thus provide abutments for one another, and are transported by a transverse conveyor across a cooling bank. Since each rail head has substantially the same mass as the rail foot, but the peripheral surface of the rail foot is twice that of the rail head, the peripheral surface of the rail feet in their clamped position in comparison to their mass is approximately of the same magnitude as the ratio of the peripheral surface and mass of the rail head. This provides a uniform cooling of the rail heads and the rail feet.

[0007] In U.S. Pat. No. 468,788 a method for cooling rails is disclosed wherein the rails are suspended in a device with their rail heads upside down and completely or partially immersed in a tank filled with water to thus be cooled, wherein they are simultaneously pressed by means of pressure screws against a stationary abutment.

[0008] In German patent 404 127 a method for straightening metal rods of asymmetric cross-section, in particular, of railroad rails, is disclosed wherein the thick parts of the cross-section are subjected to such a controlled artificial cooling that all parts, despite their non-uniform thickness, shrink by the same amount and the rods, during cooling to ambient temperature, remain straight. This is achieved in that the artificial cooling is realized either by immersion into a liquid, wetting or spraying, by blowing atomized liquid, by steam, air or other gases, wherein the employed medium acts continuously or intermittently during the entire cooling period or only during a portion of the cooling period.

[0009] The German patent 19 42 929 describes a method for cooling rails, wherein the rails, before reaching the austenite transformation temperature, are placed on the rail foot at a spacing above a heat-reflecting layer. In addition, a solid insulation material can be placed onto the running surface of the rails during the further course of cooling. A mutual positive effect by radiation is moreover achieved in this method in that the rails are positioned directly adjacent to one another so that the rail feet contact one another laterally. This results in a beneficial stress compensation in the rail cross-section. The placement of the rails on the rail foot before reaching the austenite transformation temperature at a spacing above a heat-reflecting layer has the advantage that a premature beginning of the austenite transformation in the rail foot and rail stay is prevented.

[0010] The opposite approach, i.e., through-hardening of the rail head as a result of a corresponding rapid cooling process is achieved according to French patent 543.461 in that the rail is suspended upside-down, with the rail foot facing upwardly, and subjected to a series of defined immersion processes of very short duration in a reservoir filled with water.

[0011] The known methods have the common disadvantage that they are more or less empirical, i.e., it is first necessary by means of time-consuming experiments to determine which parameters have to be observed when performing the method in order to ensure the desired cooling results. Accordingly, for each batch at least test samples of hot-rolled profiled sections are used and, in the case of results that are not immediately satisfying, tests must be repeated and scrap metal is produced in many cases.

[0012] The knowledge of the temperature distribution during the forming process across the entire cross-section and across the length of the rolling stock is required for a directed cooling of profiled rolling stock. In German laid-open patent document DE 195 03 747 A1 it is therefore suggested that first, by using measuring-technological means in cooperation with a computer with the aid of a computing program, the quantity of heat to be proportionally removed from the different profiled sections in accordance with their mass and temperature and the amount of cooling medium required for this purpose are determined and calculated and that, subsequently, the cooling of the different section parts or their masses is carried out in a controlled fashion such that they reach the conversion line A_{r3}/A_{r1} for the decomposition of the gamma mixed crystals into ferrite and/or pearlite with release of transformation heat with as little time lag as possible between the section parts. Advan-

tageously, this method makes it possible that for different batches a perfect cooling result without warping of the profiled sections can be obtained without requiring costly empirical experiments.

SUMMARY OF THE INVENTION

[0013] It is an object of the present invention to provide a method for cooling hot-rolled profiled section of the aforementioned kind and to improve it such that the aforementioned difficulties are overcome and a warp-free cooling result during cooling from the rolling heat can be achieved without costly and time-consuming experiments and without producing scrap metal resulting from such experiments.

[0014] In accordance with the present invention, this is achieved in that the course of temperature in the rolling mill is simulated for the rolling stock already before the actual rolling and cooling process, wherein in several simulation calculations the cooling parameters in the simulation are varied such that the adjustments of the desired cooling process, for example, cooling by quenching or cooling with minimal temperature differences, can be controlled by the parameters obtained from the simulations taking into account the actual values measured upstream and downstream of the cooling stretch.

[0015] According to an advantageous embodiment of the invention the required control parameters (for example, amplification factors) required for changing the cooling parameters are also calculated during the simulation calculation and are made available to the control.

[0016] Moreover, it is advantageously provided that for the simulation of the temperature course of the rolling stock the entire surface of the rolling stock is divided into different zones with correspondingly assigned boundary conditions and these zones are loaded with the calculated cooling parameters.

[0017] The measures of the invention make it possible to set the cooling parameters such as cooling medium pressure, cooling medium volume flow, arrangement of the cooling zones and of the profiled sections to be cooled, also for changing profile shapes, such that an optimal cooling result will be obtained.

[0018] The simulation calculations are controlled and supplemented by measuring the rolling stock temperature across the periphery and the length of the profiled section upstream and downstream of the cooling zones. Should the temperatures deviate already before entry of the rolling stock into the cooling zone, a change of the preadjustment of the cooling zone still before entry of the rolling stock into the cooling zone is carried out. Should the temperatures of the rolling stock deviate from the nominal temperatures downstream of the cooling zone, the parameters resulting from the simulation are also used for a correction of the adjustments of the cooling stretch.

[0019] For performing the method of the invention, several functional units are linked to one another to a closed active loop illustrated in the drawing in an exemplary fashion.

BRIEF DESCRIPTION OF THE DRAWING

[0020] The only FIGURE of the drawing shows an embodiment according to the invention of a closed active loop for controlling the cooling process.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] The closed active loop is comprised of five linked functional units **1**, **2**, **3**, **4**, **5** whose tasks and functions will be explained in the following.

[0022] In the simulation unit **1** the following tasks are performed:

[0023] simulation of the temperature course for the rolling and cooling process;

[0024] generation of the cooling programs with the adjusting values for the water cooling stretches and the air cooling stretches, namely:

[0025] storage of the pass schedule,

[0026] calculation of the rolling force, the rolling output, and the rolling moment,

[0027] calculation of the forming energy and temperature distribution within the rolling stock,

[0028] calculation of the water pressures and water quantities,

[0029] determination of the number and switching sequence of the water cooling zones,

[0030] calculation of the control parameters,

[0031] determination of the yield strength as a function of the forming conditions, the forming speed, and the forming temperature,

[0032] determination of the caloric data as a function of the temperature,

[0033] calculation of the temperature losses between the stands, in the water cooling stretch, and on the air cooling stretches;

[0034] representation of the courses of temperature in the rolling mill, in the water cooling stretches, and in the air cooling stretches;

[0035] representation of the courses of cooling in the TTT (time-temperature-transformation) diagram,

[0036] representation of the cooling rate course in the air cooling stretches,

[0037] representation of the microstructure proportions as well as the hardness corresponding to the TTT diagram and input of the calculated cooling rates,

[0038] output of the adjusting values for the water cooling stretch and the air cooling stretches,

[0039] output of the plotter diagrams for

[0040] temperature course in the rolling mill and the cooling stretches as a function of time,

[0041] temperature course in the rolling mill and the cooling stretches across the length,

[0042] temperature profile of the rolling stock cross-section in the cooling stretches,

[0043] cooling rate courses in the cooling stretches,

[0044] cooling course in the TTT diagram,

[0045] microstructure proportions and hardness,

[0046] comparison nominal/actual values in the temperature course.

[0047] Via the link **10** a communication with the control unit **5** takes place. The cooling programs generated in the simulation unit **1** are input in the control unit **5**. In the control unit **5** the following tasks are performed:

[0048] administration of the cooling programs, of the production data, the product data and the process data,

[0049] pre-setting the adjusting values for the water cooling stretches and the air cooling stretches,

[0050] controlling and governing the cooling stretches (water cooling stretches, air cooling stretches),

[0051] measuring the actual production values, actual product values, and actual process values,

[0052] storing the production data, product data, and process data for a temporally delayed output,

[0053] visualization of the cooling processes,

[0054] graphic illustration for

[0055] final rolling temperature,

[0056] entry temperature cooling stretch,

[0057] cooling time $t_{8/5}$.

[0058] Via a link **6** the obtained product and process data are sent to the process data unit **3** in which the obtained data are processed and represented. In detail, the following functions are performed:

[0059] processing the actual values stored in the "KOMP file", namely:

[0060] temperatures with representation of

[0061] average values

[0062] minimum and maximum values

[0063] standard deviation (1 sigma and 2 sigma)

[0064] frequency distribution curve

[0065] summation curve,

[0066] pressures,

[0067] volume flows,

[0068] cooling time on the cooling stretches (from 800° C. to 500° C.=$t_{8/5}$)

[0069] only actual values,

[0070] mechanical properties such as, for example,

[0071] tensile strength—R_m

[0072] tensile yield strength—R_e

[0073] extension—A_{10}

[0074] constriction—Z

[0075] representation of the results for

[0076] a billet

[0077] a rolling batch

[0078] a cooling program

[0079] a time interval.

[0080] For optimizing the quality, a data transfer from the process data unit **3** to the technology data unit **2** is carried out via a corresponding link **7**, wherein the technology data unit has the following functions:

[0081] combining and compressing the cooling programs for a quick review,

[0082] setting guide values for the cooling strategies,

[0083] automatic adjustment of cooling programs for the pre-set values of the nominal temperatures,

[0084] setting the desired mechanical properties as well as performing feedback of the properties obtained by the rolling process for quality optimization.

[0085] For determining the optimal cooling strategy the technology data unit **2** is connected to the simulation unit **1** by means of a link **8** so that the active loop is closed.

[0086] For optimizing the determined cooling model a control unit **4** is connected between the process data unit **3** and the simulation unit **1** by means of the link **9**, wherein the control unit **4** performs the following functions:

[0087] recalculation of the cooling programs with the actual values measured during the rolling process for optimizing the simulation model,

[0088] representation of the temperature course based on the recalculation,

[0089] comparison of the simulated and measured temperature values with output of deviations in ° C. and %.

[0090] With the features and measures of the invention the cooling of rolled profiled sections which are usually difficult to cool can be carried out in an optimized fashion because according to the invention the actual rolling stock temperatures are adjusted quickly to the desired nominal temperatures by correction of the cooling program, wherein the functional units explained in connection with the embodiment can be simplified or can be supplemented by additional functional units in the spirit of the invention.

[0091] While specific embodiments of the invention have been shown and described in detail to illustrate the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A method for cooling hot-rolled profiled sections from the rolling heat, wherein the profiled sections are formed of section parts of different mass, wherein, by using measuring-technological means in cooperation with a computer with the aid of a computing program, the quantity of heat to be proportionally removed from the different section parts in accordance with their mass and temperature and the amount of cooling medium required therefor are calculated and controlled, the method comprising the steps of:

simulating the course of temperature for the rolling stock in the rolling mill already before the actual rolling and cooling process by performing several simulation calculations by varying the cooling parameters in the simulation calculation to obtain calculated parameters;

measuring actual values upstream and downstream of the cooling stretch

controlling the adjustments of the desired cooling process based on the calculated parameters obtained from the simulations and the actual values measured upstream and downstream of the cooling stretch.

2. The method according to claim 1, wherein the cooling parameters are based on cooling by quenching or cooling with minimal temperature differences.

3. The method according to claim 1, wherein, in the step of simulating, control parameters for changing the cooling parameters are calculated and employed in the step of controlling.

4. The method according to claim 3, wherein the control parameters are amplification factors.

5. The method according to claim 1, wherein, in the step of simulating, the entire surface of the rolling stock is divided into different zones having corresponding boundary conditions and wherein the different zones are loaded with calculated cooling parameters.

6. A device for performing the method according to claim 1, comprising a closed active loop of functional units linked with one another, wherein:

a first one of the functional units is a simulation unit configured to simulate a course of temperature of the rolling and cooling process and to generate cooling programs for the cooling stretches with cooling parameters and control parameters for the controlling step;

a second one of the functional units is a technology data unit containing data for cooling strategies, data for automatic generation of cooling programs, data of desired mechanical properties, and feedback data of properties obtained in the rolling process for optimizing the product quality;

a third one of the functional units is a process data unit for processing actual values;

a fourth one of the functional units is a control unit configured to recalculate the cooling programs with the measured actual values and to compare the simulated and the measured temperature values; and

a fifth one of the functional units is a control unit configured to manage the cooling programs and pre-set values of the adjustments of the cooling stretches, to control and govern the cooling zones, and to measure the actual values.

7. The device according to claim 6, wherein the cooling parameters are pressure, volume flow, and the number of cooling zones.

8. The device according to claim actual values are temperatures, cooling medium pressures, and cooling medium volume flows, cooling times, and mechanical properties.

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