

(12) **Patent Application Publication**
WEINZIERL

(43) **Pub. Date:** **Oct. 6, 2016**

(52) **U.S. Cl.**
CPC *B21B 37/76* (2013.01); *B21B 45/0218*
(2013.01); *B21B 2261/20* (2013.01)

(57) **ABSTRACT**

A flat rolled material (1) is transported through a cooling zone (2) such that portions (15) of the rolled material (1) successively pass through effective ranges (8, 9) of cooling installations (6, 7). Virtual rolled material points (P) are assigned to the portions (15). During transportation of the portions (15) through the cooling zone (2), tracking of the portions (15) is carried out by way of an operating cycle ($\delta t'$). The cooling installations (6, 7) are controlled so as to correspond to the respective rolled material points (P) for actual cooling outputs (m_i) which are assigned to the cooling installations (6, 7). On account thereof, that portion (15) that is in each case located in the effective range (8, 9) of the respective cooling installation (6, 7) is impinged with a respective amount of coolant. The cooling installations (6, 7) are subdivided into released and non-released cooling installations. A rolled material point (P) is in each case iteratively selected. Before the corresponding portion (15), proceeding from a starting point (x_A), reaches the effective range (8, 9) of the next released cooling installation (6, 7), a state (E) which the respective rolled material point (P) has at the starting point (x_A) is determined.

(2) Date: **May 18, 2016**

(30) **Foreign Application Priority Data**

Nov. 18, 2013	(EP)	13193234.5
---------------	------------	------------

Publication Classification

(51) **Int. Cl.**
B21B 37/76 (2006.01)
B21B 45/02 (2006.01)

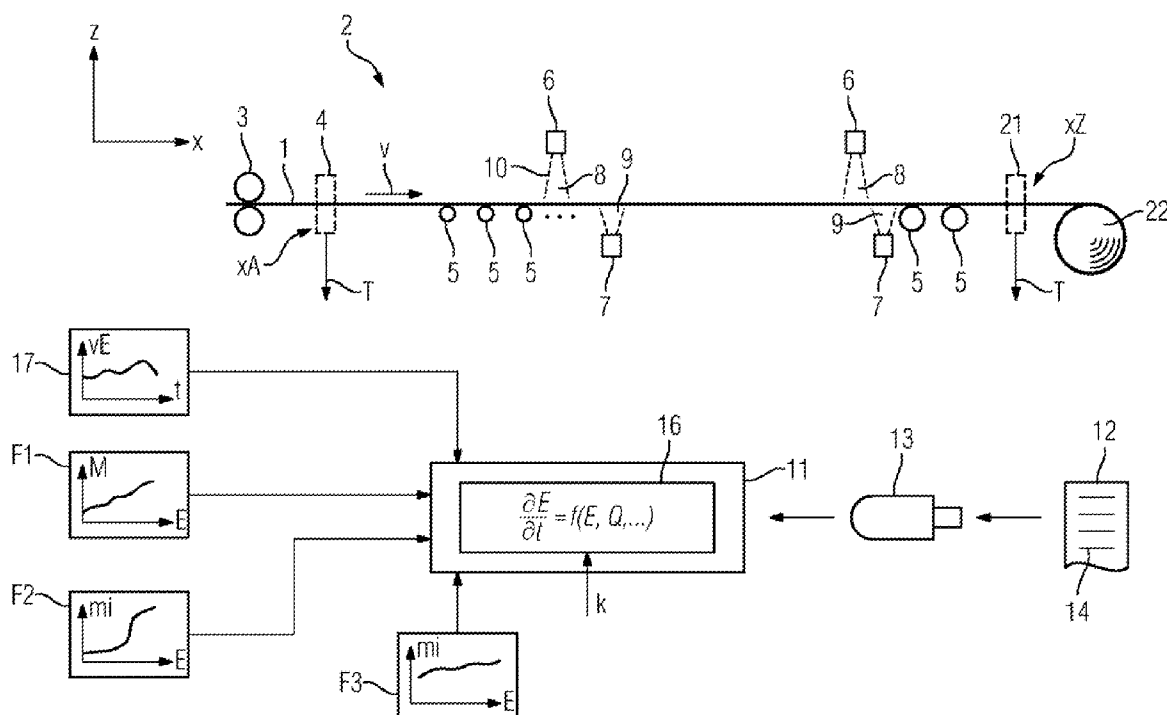


FIG 1

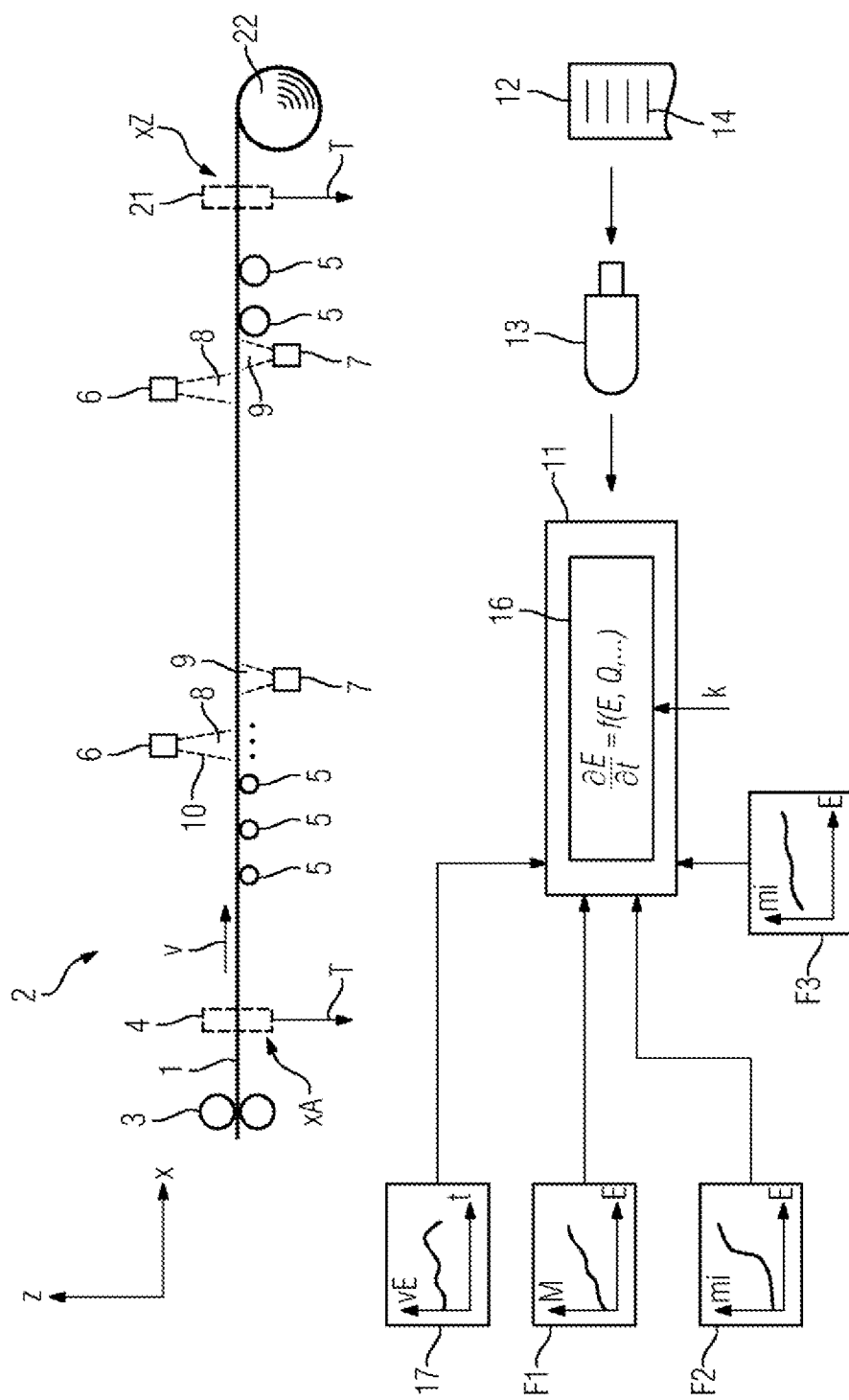


FIG 2

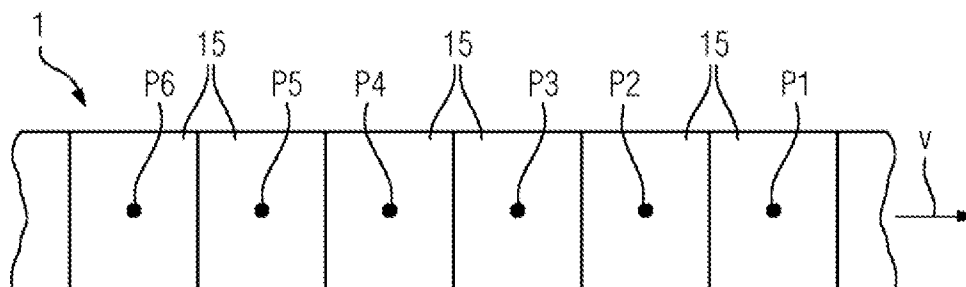


FIG 3

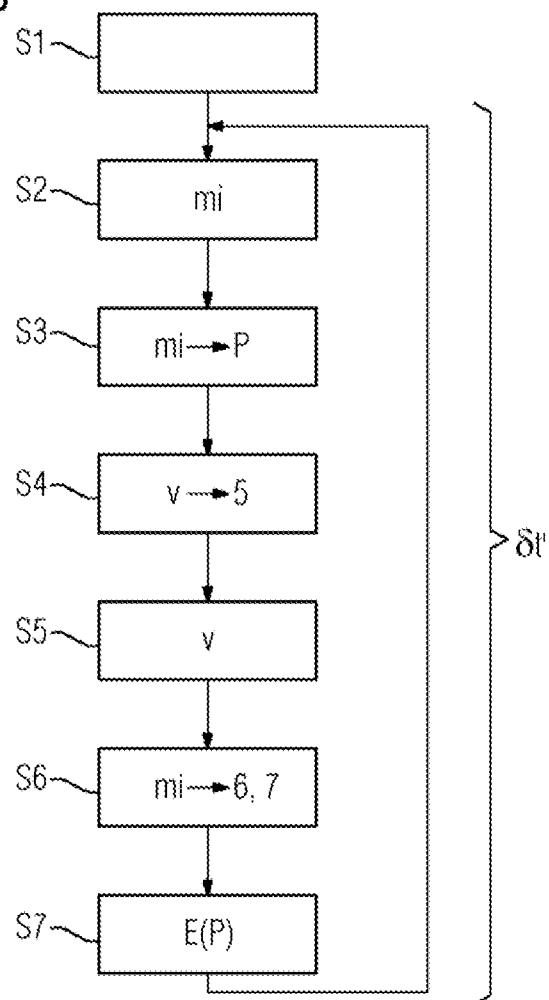


FIG 4

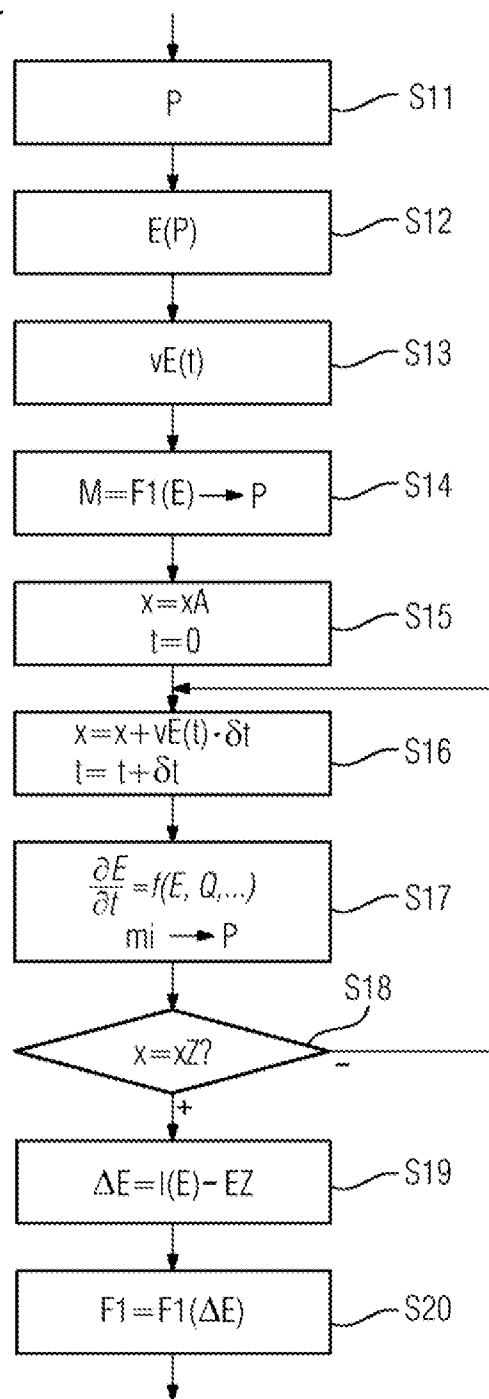


FIG 5

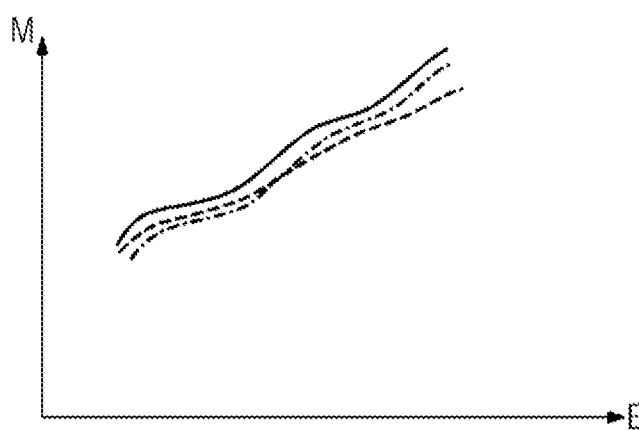


FIG 6

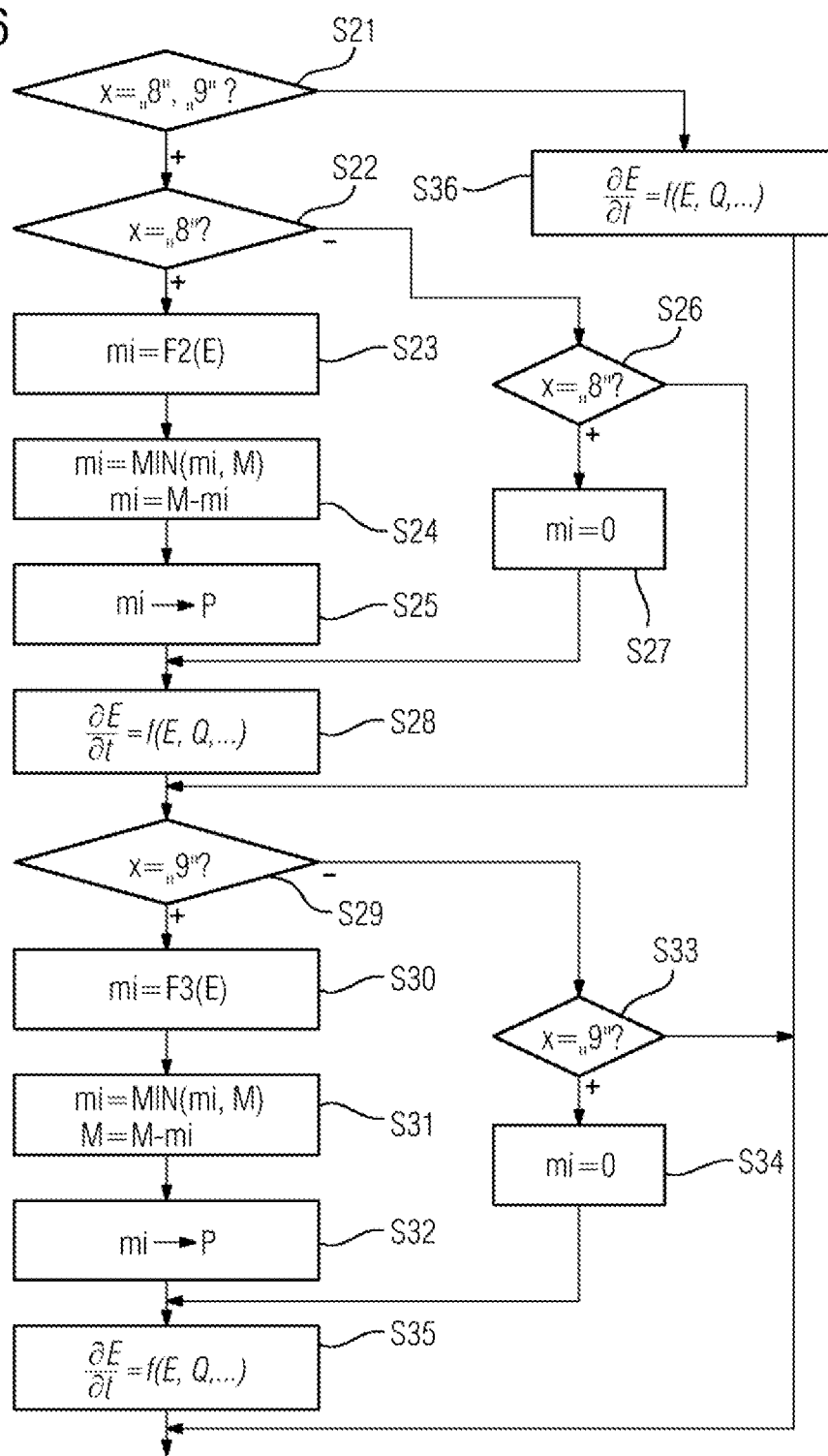


FIG 7

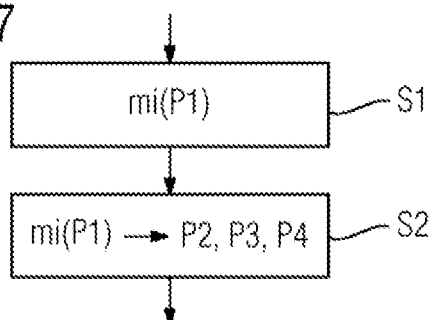


FIG 8

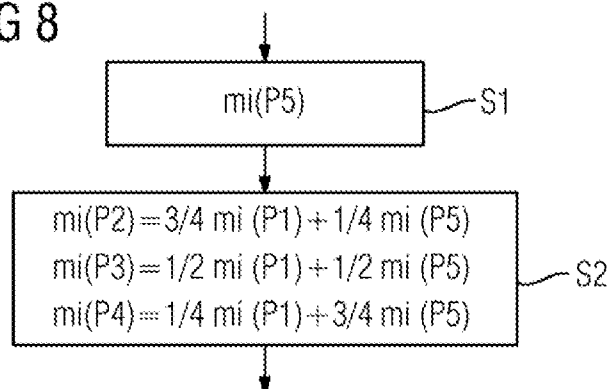


FIG 9

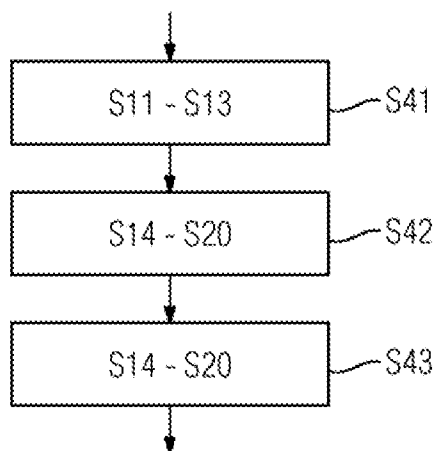


FIG 10

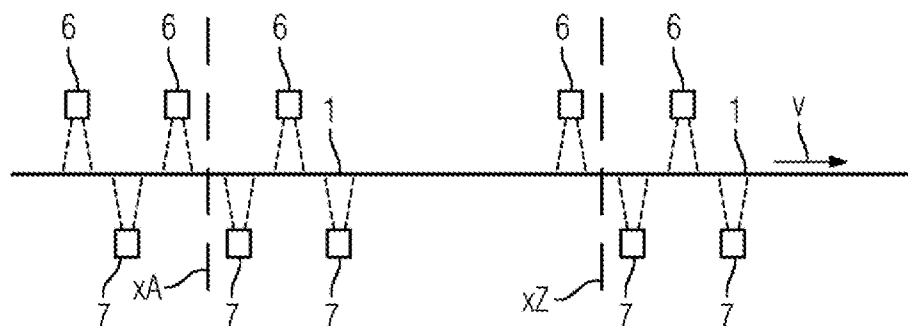


FIG 11

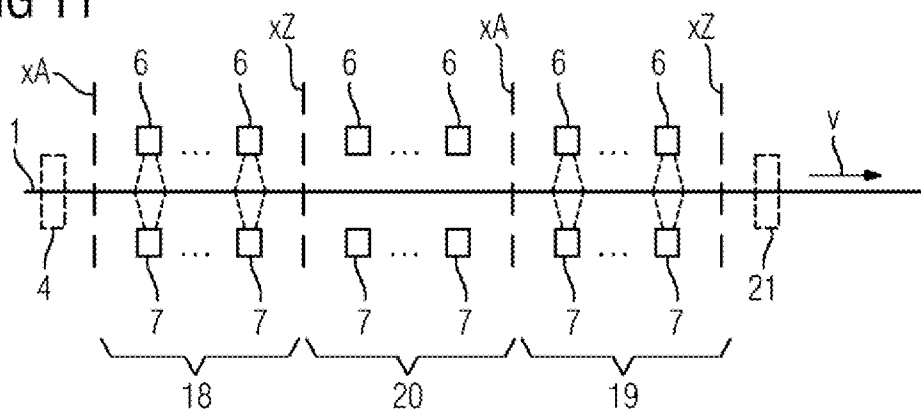


FIG 12

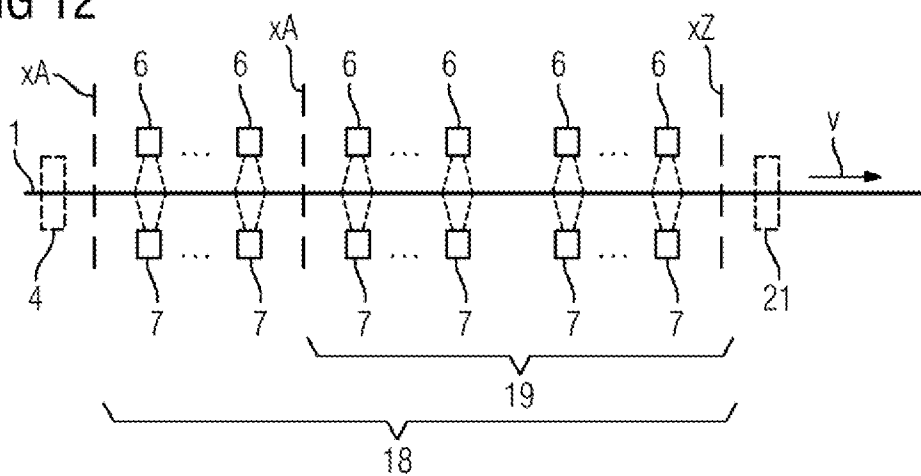


FIG 13

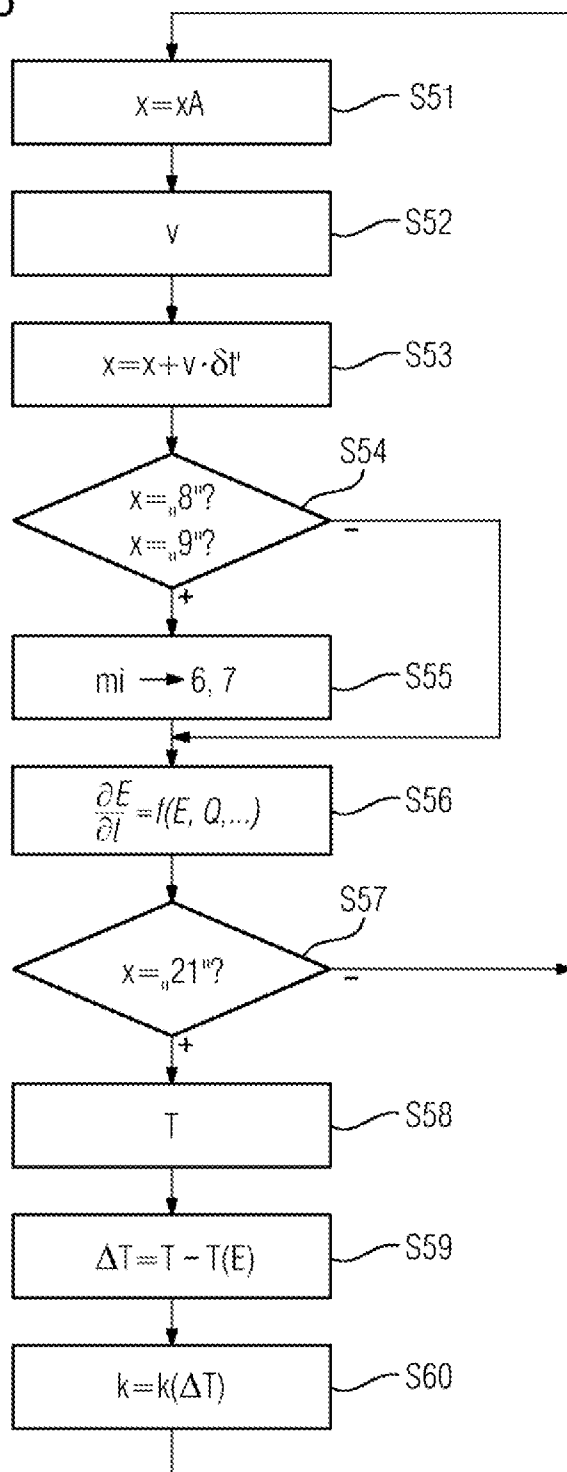


FIG 14

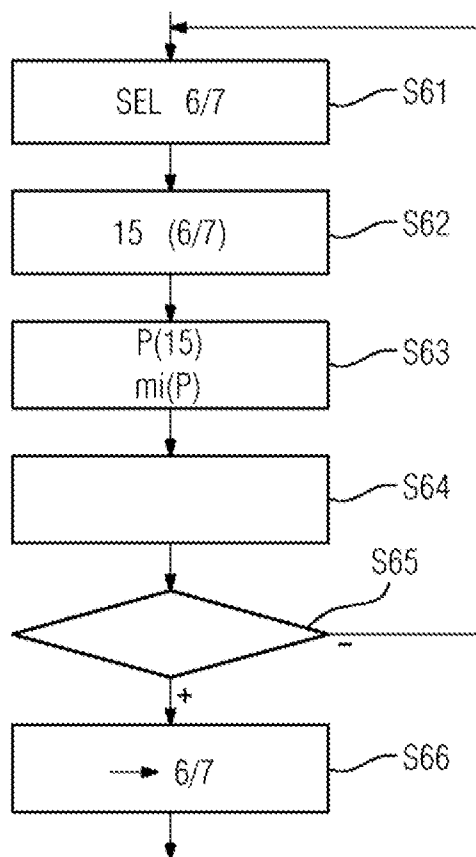
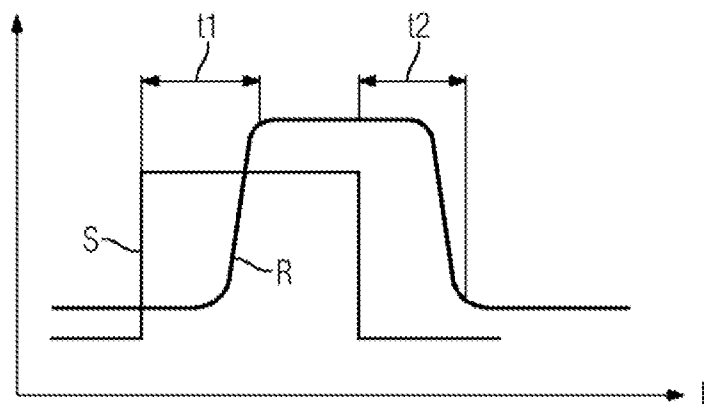


FIG 15



OPERATING METHOD FOR A COOLING ZONE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a 35 U.S.C. §§371 national phase conversion of PCT/EP2014/074112, filed Nov. 10, 2014, which claims priority of European Patent Application No. 13193234.5, filed Nov. 18, 2013, the contents of which are incorporated by reference herein. The PCT International Application was published in the German language.

TECHNICAL BACKGROUND

[0002] The present invention relates to an operating method for a cooling zone for cooling a flat rolled material

[0003] wherein the cooling zone has a multiplicity of cooling installations;

[0004] wherein the rolled material is transported through the cooling zone such that portions of the rolled material successively pass through effective ranges of the cooling installations;

[0005] wherein each of the portions of the rolled material is assigned one virtual rolled material point;

[0006] wherein tracking of the portions of the rolled material is carried out during transportation of the portions of the rolled material through the cooling zone at an operating cycle, and the cooling installations are controlled according to the actual cooling outputs assigned to the respective rolled material points for the respective cooling installations and, on account thereof, that portion of the rolled material that is in each case located in the effective range of the respective cooling installation is impinged with a respective amount of coolant.

[0007] The present invention furthermore relates to a computer program comprising machine code which is processable by a control installation for a cooling zone, wherein processing of the machine code by the control installation causes the control installation to operate the cooling zone according to an operating method of this type.

[0008] The present invention furthermore relates to a control installation for a cooling zone, wherein the control installation is programmed using a computer program of this type.

[0009] The present invention furthermore relates to a cooling zone for cooling a flat rolled material,

[0010] wherein the cooling zone has a multiplicity of cooling installations by means of which a portion of the rolled material that is in each case located in an effective range of the respective cooling installation is impinged with a respective amount of coolant;

[0011] wherein the cooling zone has a transport installation by which the rolled material is transported through the cooling zone such that the portions of the rolled material successively run through the effective ranges of the cooling installations;

[0012] wherein the cooling zone has a control installation of the type which operates the cooling zone according to an operating method of this type.

[0013] In the manufacturing of flat rolled material from metal, cooling in a cooling zone is performed in most cases after rolling in a processing line. The flat rolled material is

cooled in a pre-defined manner in the cooling zone. The material properties of the flat rolled material are influenced in particular by cooling. In order for particularly favorable material properties to be achieved, it is in many cases not sufficient for a temperature to be set only at the exit of the cooling zone. Rather, a precisely defined profile of the temperature (or of the enthalpy, or of another variable which is characteristic of the energy content) is to be adhered to in many cases. The flat rolled material may be a metal strip, for example, in particular a steel strip. Alternatively, this may be what is referred to as a plate.

[0014] In order for the flat rolled material to be cooled, the cooling zone has a multiplicity of individually controllable cooling installations by which the rolled material is impinged with a coolant (typically a liquid coolant, most often water or water having additives). In many cases, it is the upper side of the rolled material that is exclusively impinged with the coolant by the cooling installations. In other cases, the upper side is impinged by a first part of the cooling installations, and the lower side of the rolled material is impinged with the coolant by a second part of the cooling installations. The cooling installations may be continuously adjustable or be provided with (on/off) switch valves.

[0015] Various approaches to operating a cooling zone are known in the prior art.

[0016] For example, it is known from EP 0 997 203 B1, or corresponding U.S. Pat. No. 6,185,970 B1, to continuously calculate and observe the temperature state of a metal strip along the length of the cooling zone, to compare this temperature curve with a temperature reference curve, and to individually level out the deviations from the norm along the length of the cooling zone.

[0017] It is known from DE 199 63 186 A1, or corresponding US 2003/0089 431 A1, to pre-define a dedicated temporal cooling profile for each of the rolled material points, to perform tracking of the rolled material points through the cooling zone, and to actuate the cooling installations in each case so as to correspond to the temporal cooling profile of that rolled material point on which the respective cooling installation is currently acting.

[0018] A method for cooling a plate is known from EP 2 361 699 A1, or corresponding US 2012/0 318 478 A1, in which method a pre-defined target state of the plate at the exit of the cooling zone or beyond the exit is set by means of cooling. A targeted subdivision of the applied amount of coolant into a partial amount which is applied from above and a partial amount which is applied from below onto the plate is in particular performed in this method. A non-planar characteristic of the plate is to be counter-acted in particular by this measure. The cooling installations are individually actuated.

[0019] Particular types of steel have particularly strict requirements pertaining to the temporal cooling profile. The former in some cases have to be cooled to comparatively low temperatures. However, the vapor film which usually separates the coolant from the surface of the rolled material collapses at temperatures below approx. 350° C. On account thereof, the heat transfer from the rolled material to the coolant becomes highly non-linear. The process is difficult to model, causes significantly non-uniform cooling in particular between the upper side and the lower side of the rolled material, and in some cases even leads to plastic deformation

of the cooled rolled material. On account thereof, the quality of the rolled material is negatively influenced.

SUMMARY OF THE INVENTION

[0020] The object of the present invention lies in providing possibilities by means of which improved operation of the cooling zone is enabled.

[0021] According to the invention, an operating method of the type mentioned at the outset is designed in

[0022] that the cooling installations are subdivided into released cooling installations and non-released cooling installations;

[0023] that a virtual rolled material point is iteratively selected in each case and, in relation to the respective virtual rolled material point, the following steps are carried out prior to the respective portion of the real rolled material, proceeding from a pre-defined starting point, reaching the effective range of the next released cooling installation:

[0024] a state which the respective portion of the rolled material has at the starting point of the cooling zone is determined;

[0025] a total amount of coolant for the rolled material point is determined by means of a defined total cooling function and assigned as a residual amount of coolant to the rolled material point;

[0026] mathematically simulating transportation of the rolled material point through the cooling zone up to a pre-defined destination by using a motion diagram;

[0027] conjointly calculating the temporal development of the state of the rolled material point during the simulation by means of a model;

[0028] each time the rolled material point reaches the effective range of one of the released cooling installations a respective temporary cooling output is determined by means of the then-current state of the rolled material point while using a cooling curve which is assigned to the respective released cooling installation, the rolled material point for the respective released cooling installation is assigned the lower of the two values of temporary cooling output and residual amount of coolant as the final cooling output, and the residual amount of coolant is reduced by the final cooling output;

[0029] an actual variable of the rolled material point at the destination is determined by means of the state of the rolled material point at the destination and is compared with a pre-defined target variable, the total cooling function being adapted by means of the comparison; and

[0030] that the actual cooling outputs for a number of rolled material points are determined while using the final cooling outputs which have been determined for the selected rolled material point, and are assigned to the respective rolled material points, the respective released cooling installation being assigned thereby.

[0031] The subdivision of the cooling installations into released and non-released cooling installations may be performed on demand. For example, cooling installations may not be released because they are defective and/or because they are too close to the starting point. However, in principle, arbitrary blocking (i.e. denial of release) of cooling installations is also possible and conceivable. The propor-

tion of released cooling installations in an extreme case may be up to 100% of the cooling installations such that all cooling installations are thus released.

[0032] To the extent that cooling installations that have not been released are passed by the rolled material point, the cooling outputs which are applied by these cooling installations are indeed considered in the context of the development of the state of the rolled material point. However, the cooling outputs of these cooling installations are not determined in the context of the approach according to the invention but elsewhere. To the extent that the approach according to the invention is affected, the cooling outputs of these cooling installations are accepted as a given.

[0033] In particular, the actual variable and the target variable may be temperatures.

[0034] The state of the rolled material point comprises at least one energy variable. The energy variable may be the enthalpy or the temperature, for example. In the simplest case, the energy variable may be a scalar. However, said energy variable will typically be a distribution at least in the direction of the thickness of the rolled material. Furthermore, in addition to the energy variable, the selected rolled material point may be assigned further variables which describe the state of the respective portion of the rolled material. In this case, the further variables are considered when carrying out those steps that follow selecting of the rolled material point. Examples of variables of this type may be the phase fractions of the respective portions of the rolled material in particular.

[0035] The cooling outputs may be characteristic of an absolute or relative amount of coolant, or of a relative valve opening position of the respective cooling installation, for example. The model may in particular comprise a thermal conductivity equation with or without a coupled phase transformation equation. The operating cycle of tracking is usually 100 ms to 500 ms. Said operating cycle in particular may be approx. 250 ms to 300 ms.

[0036] It is possible that selecting (including the steps following selecting) is performed for each rolled material point. In this case, the number of rolled material points for which the actual cooling outputs are then determined is equal to 1, specifically to the respective rolled material point per se. Determining the actual cooling outputs in this case is furthermore reduced to directly acquiring the final cooling outputs as actual cooling outputs.

[0037] Alternatively, it is possible for at least one further virtual, non-selected rolled material point to lie between two directly successive selected virtual rolled material points. In this case, the number of rolled material points for which the actual cooling outputs are then determined is greater than 1, specifically being the respective rolled material point per se and at least one further rolled material point.

[0038] For the respective rolled material point per se, for which the final cooling outputs have been determined, determining the actual cooling outputs in this case is also reduced to directly acquiring the final cooling outputs as actual cooling outputs. Various approaches are possible in terms of the other rolled material points, that is to say for those rolled material points that lie between two directly successive selected virtual rolled material points. In this way, it is possible to acquire those final cooling outputs as actual cooling outputs for these rolled material points, that were determined for the first selected virtual rolled material point, for example. Preferably, however, selecting the later

selected virtual rolled material point and carrying out of the calculations in relation to this virtual rolled material point are completed before those portions of the rolled material that correspond to the non-selected rolled material points, proceeding from the starting point, reach the effective range of the next released cooling installation. In this case, it is possible for the actual cooling outputs for the non-selected rolled material points to be determined by interpolation of the final cooling outputs which have been determined for the two adjacent selected rolled material points.

[0039] As in the prior art, at least one part of the cooling installations usually acts on the upper side of the rolled material. In this case, the cooling curves for the cooling installations which act on the upper side of the rolled material are preferably mutually congruent. In a complementary manner thereto, it is possible that a further part of the cooling installations acts on the lower side of the rolled material. In this case, the cooling curves for the cooling installations which act on the lower side of the rolled material are preferably mutually congruent.

[0040] In the case last mentioned, specifically where one part of the cooling installations each acts on the upper side and on the lower side of the rolled material, and the respective cooling curves for the upper side are mutually congruent and the respective cooling curves for the lower side are mutually congruent, it is possible that the cooling curves for those cooling installations that act on the upper side of the rolled material, on the one hand, and the cooling curves for those cooling installations that act on the lower side of the rolled material, on the other hand, are mutually congruent, that thus in total only one single cooling curve is used that is uniform for all cooling installations. Alternatively, it is possible that a dedicated cooling curve each is pre-defined for those cooling installations that act on the upper side of the rolled material, on the one hand, and for those cooling installations that act on the lower side of the rolled material, on the other hand, said dedicated cooling curves being mutually dissimilar.

[0041] The manner in which the total cooling function is adapted by means of the comparison of the actual variable which is determined by means of the state determined at the destination with the target variable may be designed in various manners. For example, the total cooling function may be scaled by a factor and/or be displaced by an offset. In some circumstances, the offset may be vectorial, that is to say have a displacement in the x-coordinate and/or a displacement in the y-coordinate.

[0042] The starting point may be defined according to requirements. In particular, the former may lie ahead of the cooling zone or in the cooling zone. It is furthermore possible that a temperature measurement spot by means of which a temperature of the respective portion of the rolled material is detected is disposed at the starting point. In this case, the state of the rolled material point at the starting point is preferably determined by means of the detected temperature. Disposing a temperature measurement spot at the starting point is possible in particular when the starting point lies ahead of the cooling zone. The temperature measurement spot in this case may be, for example, the usual so-called processing line measurement spot at which the final rolling temperature of the rolled material is detected. Alternatively thereto, it is possible that no temperature measurement spot is disposed at the starting point. In this

case, the state of the rolled material point is determined in another manner at the starting point.

[0043] In an analogous manner, the destination may also be defined according to requirements. In particular, said destination may lie in the cooling zone or behind the cooling zone. However, it is self-evident that said destination, when viewed in the transportation direction of the rolled material, must lie behind the starting point.

[0044] It is possible that upon adapting the total cooling function, the adapted total cooling function is first exploited for the next selected rolled material point. Alternatively, it is possible that those steps that follow selecting the rolled material point are carried out once again upon adapting the total cooling function for the same rolled material point. In this case, a new and improved prognosis is therefore established for this rolled material point. This approach is in particular possible when a sufficiently high computing capacity is available.

[0045] The cooling installations in many instances have significant time lags. The time lags may be in the range of a plurality of seconds. The time lags of the cooling installations are preferably considered when actuating the cooling installations. This, in an advantageous manner, leads to the result that the cooling installations are controlled in a timely manner, so as to correspond to the actual cooling outputs which are assigned to the respective cooling installations for the corresponding rolled material points, while the portions of the rolled material are transported through the cooling zone.

[0046] On account of the situation that the cooling installations have time lags, the cooling installations should preferably be actuated in a timely advanced manner. However, actuating may only be performed once the corresponding cooling output has been determined for the respective cooling installation. Those steps that follow selecting the respective rolled material point are completed at a completion time point. The respective portion of the real rolled material, proceeding from the starting point, reaches the effective range of the next released cooling installation at a cooling start time point. In order for it to be possible for the next released cooling installation to be actuated in a timely manner, a temporal difference between the completion time point and the cooling start time point is preferably at least the size of the time lag of the next released cooling installation. In order for this actual situation to be guaranteed, all cooling installations for which this criterion has not been met may be blocked (=not released), for example.

[0047] One particularly preferred design embodiment of the present invention consists in

[0048] that the states of those portions of the rolled material that are transported through the cooling zone are conjointly calculated in real time during transportation of the portions of the rolled material through the cooling zone at the operating cycle, while considering actuation of the cooling installations;

[0049] that at a temperature measurement spot an actual temperature of that respective portion of the rolled material that passes the temperature measurement spot is detected; and

[0050] that the respective temperature detected is compared with an expected temperature for this portion that has been determined by means of the conjointly calculated state, and at least one parameter of the model is updated by means of the comparison.

[0051] On account thereof, the model may be steadily more closely approximated toward the actual behavior of cooling in particular.

[0052] In the simplest case, the operating method according to the invention, in terms of the extent of the cooling zone, is applied once within the cooling zone. However, alternatively it is likewise possible that the operating method, in terms of the extent of the cooling zone, is applied multiple times in respective regions of the cooling zone. An approach of this type may be of advantage in particular when a so-called dual-phase type steel is to be cooled. In this case, the starting point of the rear region in terms of location, when viewed in the transportation direction of the rolled material, lies behind the destination of the front region in terms of location.

[0053] In the case in which a dual-phase type steel is to be cooled, an intermediate portion in which the rolled material is not actively cooled lies between those regions of the cooling zone in which the operating method is in each case applied. Pure air cooling by convection and radiation, and contact cooling by way of contact with the transport rollers, but no cooling by means of a liquid coolant, is thus performed in the intermediate portion. Alternatively, it is possible that those regions of the cooling zone in which the operating method is in each case applied are mutually overlapping. For example, the destinations of the two regions may be mutually congruent, while the starting points are disparate. In this case, a determination of the actual cooling outputs which in relation to the first application of the operating method is improved may be performed by the second application of the operating method for the remaining part of the cooling zone.

[0054] It is possible that the total cooling function is dependent or independent of the state of the selected rolled material point at the starting point. Which of these two approaches is more advantageous depends on the circumstances of the individual case.

[0055] The object is furthermore achieved by a computer program with machine code. According to the invention, processing of the machine code by the control installation causes the control installation to carry out an operating method according to the invention, as has been discussed above.

[0056] The object is furthermore achieved by a control installation for a cooling zone. According to the invention, the control installation is programmed using a computer program according to the invention.

[0057] The object is furthermore achieved by a cooling zone for cooling a flat rolled material, wherein the cooling zone has a control installation according to the invention, which operates the cooling zone according to an operating method according to the invention.

[0058] The properties, features, and advantages of this invention that have been described above, and the manner in which the former are achieved, will be more readily and clearly understood in conjunction with the following description of the exemplary embodiments which will be discussed in more detail in conjunction with the drawings. Herein, in a schematic illustration:

DESCRIPTION OF THE DRAWINGS

[0059] FIG. 1 shows a cooling zone;

[0060] FIG. 2 shows a fragment of a flat rolled material;

[0061] FIG. 3 shows a flow diagram;

[0062] FIG. 4 shows a further flow diagram;

[0063] FIG. 5 shows a total cooling function;

[0064] FIGS. 6 to 9 show flow diagrams;

[0065] FIGS. 10 and 12 each show a fragment of a cooling zone;

[0066] FIGS. 13 and 14 show flow diagrams; and

[0067] FIG. 15 shows a time diagram.

DESCRIPTION OF EMBODIMENTS

[0068] According to FIG. 1, a flat rolled material 1 is to be cooled in a cooling zone 2. The flat rolled material 1 is composed of metal. Corresponding to the illustration in FIG. 1, the flat rolled material 1 may be a metal strip, for example, in particular a steel strip. Alternatively, the flat rolled material 1 may be a plate (typically of steel).

[0069] The cooling zone 2 is typically downstream of a processing line in which the rolled material 1 has been hot rolled. The processing line typically has a plurality of roll stands. For the sake of clarity, only the last roll stand 3 of the processing line is illustrated in FIG. 1. Nevertheless, it is possible that the processing line has only one single roll stand, being configured, for example, as a Steckel rolling mill or as a reversing rolling mill.

[0070] A temperature measurement spot 4 at which a temperature T of the rolled material 1 is detected is often disposed between the processing line and the cooling zone 2 (or ahead of the cooling zone 2, so as to correspond therewith). The temperature measurement spot 4, in order to be differentiated from a further temperature measurement spot that is to be introduced later, is referred to hereunder as the entry-side temperature measurement spot 4.

[0071] The cooling zone 2 has a plurality of transport rollers 5. The rolled material 1 is transported through the cooling zone 2 by means of the transport rollers 5. At least some of the transport rollers 5 are driven. The transport rollers 5 in their entirety form a transport installation by which the rolled material 1 is transported at a transportation speed v in a transportation direction through the cooling zone 2.

[0072] The cooling zone 2 furthermore has a multiplicity of cooling installations 6, 7. The cooling installations 6, 7 act on the rolled material 1 in a respective effective range 8, 9. The rolled material 1 (more specifically that portion of the rolled material 1 that at this time point is located in the effective range 8, 9 of the respective cooling installation 6, 7) is impinged by means of the cooling installations 6, 7 with a respective amount of coolant of a liquid coolant 10, the latter in most cases being water-based.

[0073] It is possible that upper cooling installations 6, that is to say cooling installations which act on an upper side of the rolled material 1, are exclusively present. Alternatively, in a corresponding manner to the illustration of FIG. 1 it is possible that lower cooling installations 7, that is to say cooling installations which act on a lower side of the rolled material 1, are present in addition to the upper cooling installations 6.

[0074] The cooling zone 2 furthermore has a control installation 11. The cooling zone 2 is operated under the control and supervision of the control installation 11.

[0075] As shown in FIG. 1B, the control installation 11 is typically programmed using a computer program 12. The computer program 12 may be supplied to the control installation 11 by way of a data carrier 13, for example, on which the computer program 12 is stored in machine-readable form

(preferably exclusively in machine-readable form, in particular in electronic form). The data carrier 13 may be designed in any arbitrary manner. The illustration in FIG. 1B in which the data carrier 13 is illustrated as a USB memory stick is only exemplary.

[0076] The computer program 12 comprises machine code 14 which is processable by the control installation 11. Processing of the machine code 14 by the control installation 11 causes the control installation 11 to operate the cooling zone 2 according to an operating method which is be discussed in more detail hereunder.

[0077] According to FIG. 2, the (real) rolled material 1 in terms of data is subdivided within the control installation 11 into a multiplicity of portions 15. One rolled material point P is assigned to each of the portions 15 of the rolled material 1. As opposed to the portions 15 of the real rolled material 1, the rolled material points P are present in the control installation 11 only in a virtual manner. The rolled material points P in their entirety represent an image of the real rolled material 1 in data terms. The rolled material points P in FIG. 2 have a numerical extension. If required, this index serves to enable the rolled material points P to be mutually differentiated in the context of the discussion of the invention. To the extent that it is immaterial which rolled material point P is being referred to in the text which follows, the reference sign P is used without a numerical extension.

[0078] This differentiation between portions 15 of the real rolled material 1 and virtual rolled material points P is consistently maintained in the course of the following description. Whenever reference is made to the portions 15, the portions 15 of the real rolled material 1 are referred to at all times and without exception. Whenever reference is made to the rolled material points P, the image of the portions 15 in terms of data is referred to at all times and without exception.

[0079] According to FIG. 3, the control installation 11 in a step S1 subdivides the cooling installations 6, 7 into released cooling installations 6, 7, and into non-released (=blocked) cooling installations 6, 7. The subdivision into released and non-released cooling installations 6, 7 is in any case disjointed and is typically also complementary. Each cooling installation 6, 7 is thus either released or blocked.

[0080] It is possible for all cooling installations 6, 7 to be released cooling installations. Alternatively, single units of the cooling installations 6, 7 may be blocked. Blocking of cooling installations 6, 7 may be performed on demand. For example, cooling installations 6, 7 may be blocked because they are defective and/or because they are too close to the starting point xA. However, in principle, arbitrary blocking of cooling installations 6, 7 is also possible and conceivable.

[0081] Thereafter, the control installation 11 in a step S2 determines final cooling outputs m_i for at least some of the rolled material points P (selected rolled material points P). The step S1 will be discussed in more detail hereunder in conjunction with FIGS. 4 and 6. In the case of the cooling outputs m_i , the index i refers to the numeral of the respective released cooling installation 6, 7 in the sequence in which the respective released cooling installation 6, 7 is reached by the respective portion 15 of the rolled material 1.

[0082] The control installation 11 in a step S3 determines actual cooling outputs m_i for a number of rolled material points P. For determining the actual cooling outputs m_i , the control installation 11 uses the final cooling outputs m_i which have been determined for the selected rolled material

points P. The control installation 11 assigns the actual cooling outputs m_i to the corresponding rolled material points P, while assigning the respective released cooling installation 6, 7. Potential design embodiments of the step S3 will be discussed in more detail hereunder in conjunction with FIGS. 7 and 8.

[0083] The rolled material 1 is then transported through the cooling zone 2. By virtue of the rolled material 1 being transported in its entirety through the cooling zone 2, the portions 15 of the rolled material 1 successively run through the effective ranges 8, 9 of the cooling installations 6, 7. So as to correspond to the illustration in FIG. 3, it is possible for the transport installation 5 to be controlled by the control installation 11 in a step S4. Alternatively, it is possible that the transport installation 5 is controlled by another control installation which is not illustrated in the figures.

[0084] During transportation of the portions 15 of the rolled material 1 through the cooling zone 2, the control installation 11 in a step S5 carries out tracking of the portions 15 of the rolled material 1. It is thus known to the control installation 11 at any time point which portion 15 of the rolled material 1 is located in the effective range 8, 9 of which cooling installation 6, 7. According to FIG. 3, the control installation 11 in a step S6 furthermore controls the cooling installations 6, 7. Controlling is performed in such a manner that by means of the released cooling installations 6, 7 that portion 15 of the rolled material 1 that is located in the effective range 8, 9 of the respective released cooling installation 6, 7 is impinged with the respective actual cooling output m_i that has been determined for the respective portion 15 for the respective released cooling installation 6, 7.

[0085] Often, the control installation 11 in a step S7 furthermore implements a so-called observer. In this case, the control installation 11 during transportation of the portions 15 of the rolled material 1 through the cooling zone 2 at least for these portions 15 conjointly calculates a state E currently in real time. The state E comprises at least one energy variable. The energy variable may be the enthalpy or the temperature, for example. In the simplest case, the energy variable may be a scalar. However, the energy variable will typically be a distribution of the energy variable at least in the direction z of the thickness of the rolled material 1. The state E may optionally also comprise further variables assigned to the rolled material points P. The control installation 11 in its determinations (self-evidently) considers the actuation of the cooling installations 6, 7. Conjoint calculating is performed using a model 16 (cf. FIG. 1). The model 16 is based on mathematical-physical equations. In particular, in the context of the model 16 at least one thermal conductivity equation is typically solved by the control installation 11. Optionally, a phase transformation equation may be additionally solved, the former in a stepwise manner being coupled to the thermal conductivity equation. In particular, the thermal conductivity equation may be the Fourier thermal conductivity equation as in DE 101 29 565 A1, for example. In particular, the phase transformation equation may be conceived as a so-called Stefan problem.

[0086] The steps S5 and S7 will furthermore be discussed in more detail hereunder in conjunction with FIG. 12.

[0087] The steps S2 to S7 in FIG. 3 are illustrated to be sequential to one another. In terms of the steps S4 to S6 (or S7, respectively), this is also factually the case. These steps (that is to say the steps S4 to S6, or S7, respectively) are

carried out in a cyclical manner at an operating cycle $\delta t'$. The operating cycle $\delta t'$ is typically between 100 ms and 500 ms, for example at 250 ms to 300 ms. The step S2 may also be carried out in a cyclical manner at the operating cycle $\delta t'$. Alternatively, processing is possible in a manner de-linked from the operating cycle $\delta t'$, so as to be parallel with the steps S4 to S6 (or S7, respectively). This will become evident from the following explanations.

[0088] The step S3 is coupled to the step S2. If the step S2 is carried out in a cyclical manner at the operating cycle $\delta t'$, this will also be the case in the step S3. If the step S2 is processed parallel with the steps S4 to S6 (or S7, respectively), this will also be the case in the step S3. This will also become evident from the following explanations.

[0089] The steps S2 to S7 will be discussed in more detail in conjunction with the further figures. The step S2 will first be discussed in more detail in conjunction with FIG. 4.

[0090] According to FIG. 4, one of the rolled material points P, for example the rolled material point which in FIG. 2 is referenced with P1, is selected in a step S11 by the control installation 11. To the extent that there is no explicit statement to the contrary, the following explanations pertaining to FIG. 4 refer exclusively to this one rolled material point P, that is to say to the selected rolled material point P.

[0091] A state E which that portion 15 of the rolled material 1 that corresponds to the selected rolled material point P has at a starting point xA of the cooling zone 2 is determined by the control installation 11 in a step S12. The determined state E in the step S12 is assigned to the selected rolled material point P.

[0092] The starting point xA, in a manner corresponding to the illustration in FIG. 1, may lie ahead of the cooling zone 2. In particular in this case, the starting point xA may lie at the location of the entry-side temperature measurement spot 4 such that the entry-side temperature measurement spot 4 is disposed at the starting point xA. As has already been mentioned in conjunction with FIG. 1, the current temperature T for the respective portion 15 that is running through the temperature measurement spot 4 is detected by means of the temperature measurement spot 4. In this case, the state E in the step S12 is preferably determined by means of the temperature T which has been determined for the respective portion 15.

[0093] In a step S13, a motion diagram 17 is furthermore made known to the control installation 11 (cf. FIG. 1). The motion diagram 17 indicates what speed vE is expected for the selected rolled material point P at which simulation time t (calculated from the starting point xA). It is possible that the motion diagram 17 is based on assumptions and expectations such that a speed vE which is expected by virtue of the motion diagram 17 typically is indeed substantially congruent with the later actual transportation speed v of the respective real portion 15 of the rolled material 1, this however not invariably having to be the case. Alternatively, it is possible that the motion diagram 17 is based on a prediction pertaining to the transportation speed v which will later also be adhered to with certainty or almost adhered to with certainty. Approaches to reliably predicting the transportation speed v are known to a person skilled in the art. Reference is made, in particular, to WO 2011/138 067 A2.

[0094] A total amount of coolant is determined by the control installation 11 by means of a defined total cooling function F1 in a step S14. The total cooling function F1

describes cooling which is required in order to cool the corresponding portion 15 in such a manner that an actual variable I of the respective portion 15 at a destination xZ (cf. FIG. 1) has a target variable EZ. The actual variable I may be the temperature of the respective portion 15, for example. However, this is in any case a variable which may be determined by means of the state Z of the respective portion 15.

[0095] In the simplest case, the total cooling function F1 is a trivial function, that is to say is independent of the state E of the selected rolled material point P at the starting point xA. For example, the total amount of coolant may be equal to that total amount of coolant which has been determined when the step S20 has been previously carried out (cf. there). Alternatively however, the total cooling function F1 is dependent on the state E of the selected rolled material point P at the starting point xA. In this case, the total amount of coolant with which the corresponding portion 15 of the rolled material 1 is to be totally impinged by means of the cooling installations 6, 7 is determined by inserting into the total cooling function F1 that state E (for example, a variable which has been determined by means of the state E, for example of a surface temperature of the rolled material 1, or of an average temperature of the rolled material 1) that has been determined in the step S12. The determined total amount of coolant in the step S14 is assigned to the selected rolled material point P as a residual amount of coolant M independent of the manner of determining.

[0096] It is possible for the total cooling function F1 to be fixedly pre-defined for the control installation 11, for example within the context of the computer program 12. Alternatively, it is possible that the total cooling function F1 is made known to the control installation 11 in another manner, for example by way of pre-definition or parameterization by an operator (not illustrated in the figures)

[0097] The control installation 11 in steps S15 and S16 mathematically simulates transportation of the rolled material point P through the cooling zone 2. For this purpose, the control installation 11 in the step S15 sets the current location x of the selected rolled material point P to be equal to the starting point xA, and sets the simulation time t to the value 0. The control installation 11 in the step S16 updates the current location x of the selected rolled material point P, using the motion diagram 17 and a temporal increment δt . The simulation time t is also updated, using the temporal increment δt . The temporal increment δt may be defined according to requirements. Said temporal increment δt may be in the range of a few milliseconds, for example. The temporal increment δt under certain circumstances may be variable. In particular, the temporal increment δt in the regions of the cooling zone 2 in which the rolled material point P is not located in the effective range 8, 9 of one of the cooling installations 6, 7 may be chosen to be larger than in regions of the cooling zone in which the rolled material point P is located in the effective range 8, 9 of one of the cooling installations 6, 7.

[0098] The control installation 11 in a step S17 by means of the model 16 conjointly calculates the temporal development of the state E of the observed rolled material point P. To the extent that the observed rolled material point P in the context of the respective processing of the step S17 is located in the effective range 8, 9 of one of the released cooling installations 6, 7, the control installation 11 in the context of the respective processing of the step S17 further-

more determines a final amount of coolant m_i for the respective cooling installation 6, 7. One potential design embodiment of the step S17 will be discussed in more detail later, in conjunction with FIG. 6.

[0099] The control installation 11 in a step S18 checks whether the destination x_Z has been reached in the context of the simulation. As long as this is not the case, the control installation 11 reverts to the step S16. Otherwise, the control installation 11 progresses to a step S19.

[0100] The control installation 11 in the step S19 determines the actual variable I . Determining is performed using the state E of the selected rolled material point P which now has been determined by means of repeated processing of the step S17. The control installation 11 in the step S19 furthermore compares the determined actual variable I with the pre-defined target variable E_Z . In particular, the control installation 11 typically determines the deviation ΔE between the actual variable I which has now been determined and the target variable E_Z . The control installation 11 in a step S20 by means of the comparison, typically by means of the deviation ΔE , adapts the total cooling function $F1$.

[0101] In the context of adapting the total cooling function $F1$ it is possible for a displacement of the total cooling function $F1$ to be performed about an (optionally vectorial) offset, so as to correspond to the illustration in FIG. 5 (cf. the chain-dotted line therein), the offset depending on the deviation ΔE . Alternatively, it is possible in the context of adapting the total cooling function $F1$ for scaling of the total cooling function $F1$ to be performed, the scaling factor depending on the deviation ΔE . This is indicated by a dashed line in FIG. 5.

[0102] In terms of the rolled material point P selected in the step S11, the approach as per FIG. 4 is completed. However, the approach as per FIG. 4 is carried out multiple times (cf. the loop in FIG. 3), in each case another rolled material point P being selected. In the context of the approach as per FIG. 4 being carried out next, the total cooling function $F1$ as adapted during the previous processing of the step S20 is referred to while processing the step S14.

[0103] A potential design embodiment of the step S17 of FIG. 4 will be discussed hereunder in conjunction with FIG. 6.

[0104] According to FIG. 6, the control installation 11 in a step S21 checks whether the current location x , up to which transportation of the selected rolled material point P has been simulated, corresponds to the effective range 8, 9 of one of the cooling installations 6, 7.

[0105] If this is the case, the control installation 11 progresses to a step S22. The control installation 11 in the step S22 checks whether the current location x , up to which transportation of the selected rolled material point P has been simulated, corresponds to the effective range 8 of one of the released upper cooling installations 6.

[0106] If this is the case, the control installation 11 progresses to a step S23. The control installation 11 in the step S23 by means of the then-current state E of the selected rolled material point P determines a temporary cooling output m_i for the respective released upper cooling installation 6. Determining is performed using a preferably smooth cooling curve $F2$ which is assigned to the respective upper cooling installation 6. The temporary cooling output m_i is always larger than 0. Said temporary cooling output m_i

is at least not smaller than 0. The value of 0 per se is thus still permissible. By contrast, the temporary cooling output m_i cannot assume any negative values which would correspond to heating the rolled material point P . The temporary cooling output m_i may optionally be upwardly limited.

[0107] It is possible for the cooling curve $F2$ to be individual to the respective upper cooling installation 6. However, the cooling curves $F2$ for the upper cooling installations 6 typically are mutually congruent. In this case, the cooling curve $F2$ for all upper cooling installations 6 has to be determined only once. For example, the cooling curve $F2$ describes an amount of coolant with which that portion 15 of the rolled material 1 that corresponds to the respective rolled material point P is to be impinged as a function of the current state E . Alternatively, a relative throughput amount (0% to 100%) or an opening position (from completely closed to completely opened) of a valve of the respective cooling installation 6 may be described, for example. In the case of the cooling installations 6 having (on/off) switch valves, it may be stated by means of an approximation, proceeding in each case from an activated released cooling installation 6, how many released cooling installations 6, 7 are to be skipped, for example.

[0108] The control installation 11 in a step S24 furthermore sets the final cooling output m_i for the respective released upper cooling installation 6 to the lower of the two values of temporary cooling output m_i and residual amount of coolant M . Furthermore, said control installation 11 in the step S24 reduces the residual amount of coolant M by the final cooling output m_i . Furthermore, the control installation 11 in a step S25 assigns the determined final cooling output m_i to the selected rolled material point P , while assigning the respective released upper cooling installation 6.

[0109] However, if the current location x up to which transportation of the selected rolled material point P has been simulated does not correspond to the effective range 8 of one of the released upper cooling installations 6, the control installation 11 progresses to a step S26. The control installation 11 in the step S26 checks whether the current location x up to which transportation of the selected rolled material point P has been simulated corresponds to the effective range 8 of one of the non-released upper cooling installations 6.

[0110] If this is the case, the control installation 11 progresses to a step S27. The control installation 11 in the step S27 sets the final cooling output m_i to a value which has been pre-defined for this upper cooling installation 6. However, assignment to the corresponding upper cooling installation 6 is not performed. The value which has been established in the context of the step S27 is only exploited in the context of a step S28.

[0111] The control installation 11 in the step S28 refreshes the state E by applying the model 16. The control installation 11, when applying the model 16 in the context of the step S28, considers the cooling output m_i which has been established in the context of the step S24 or of the step S27.

[0112] In an analogous manner, the control installation 11 in a step S29 checks whether the current location x up to which transportation of the selected rolled material point P has been simulated corresponds to the effective range 9 of one of the released lower cooling installations 7.

[0113] If this is the case, the control installation 11 progresses to a step S30. The control installation 11 in the step S30 by means of the then-current state E of the selected

rolled material point P determines a temporary cooling output m_i for the respective released lower cooling installation 7. To the extent that the step S28 has already been previously carried out, it is the state E which has already been modified in the step S28 that is proceeded from in the context of the step S30.

[0114] In an analogous manner to the step S23, determining is performed using a preferably smooth cooling curve F3 which is assigned to the respective lower cooling installation 7. The temporary cooling output m_i is at all times larger than 0 or assumes at a minimum the value of 0. Said temporary cooling output m_i may thus not assume any negative values. It is possible for the cooling curve F3 to be individual to the respective lower cooling installation 7. However, the cooling curves F3 for the lower cooling installations 7 are typically mutually congruent. In this case, the cooling curve F3 for all lower cooling installations 7 has to be determined only once.

[0115] Furthermore, the control installation 11 in a step S31 sets the final cooling output m_i for the respective released lower cooling installation 7 to the lower of the two values of temporary cooling output m_i and residual amount of coolant M. Furthermore, said control installation 11 in the step S31 reduces the residual amount of coolant M by the final cooling output m_i . To the extent that the step S24 has already been carried out, it is the residual amount of coolant M that has already been reduced in the step S24 that is proceeded from in the context of the step S31. Furthermore, the control installation 11 in a step S32 assigns the determined final cooling output m_i to the selected rolled material point P, while assigning the corresponding released lower cooling installation 7.

[0116] However, if the current location x up to which transportation of the selected rolled material point P has been simulated does not correspond to the effective range 9 of one of the released lower cooling installations 7, the control installation 11 progresses to a step S33. The control installation 11 in the step S33 checks whether the current location x up to which transportation of the selected rolled material point P has been simulated corresponds to the effective range 9 of one of the non-released lower cooling installations 7.

[0117] If this is the case, the control installation 11 progresses to a step S34. The control installation 11 in the step S34 sets the final cooling output m_i to a value which has been pre-defined for this lower cooling installation 7. Assignment to the respective lower cooling installations 7 is not performed. The value which has been established in the context of the step S34 is only exploited in the context of a step S35.

[0118] The control installation 11 in the step S35 refreshes the state E by applying the model 16. The control installation 11, when applying the model 16 in the context of the step S35, considers the cooling output m_i which has been established in the context of the step S31 or of the step S34. To the extent that the step S28 has already been previously carried out, it is the state E which has already been modified in the step S28 that is proceeded from in the context of the step S35.

[0119] In the "no" branch of the step S21, the state E of the selected rolled material point P is refreshed in a step S36, while applying the model 16. However, in the context of the step S36 an interaction with the environment which is not caused by active cooling by the cooling installations 6, 7 is

exclusively modelled (air cooling and/or contact cooling by way of the transport rollers 5).

[0120] By virtue of the approach according to FIG. 6 and to the extent that cooling installations 6, 7 which have not been released by the rolled material point P are being passed, the cooling outputs m_i which have been applied by these cooling installations 6, 7 are thus indeed considered in the context of the development of the state E of the rolled material point P. However, the cooling outputs m_i of these cooling installations 6, 7 are not determined in the context of the approach according to the invention but are accepted as given. Only the cooling outputs m_i for the released cooling installations 6, 7 are determined by the approach according to FIG. 6.

[0121] It is significant in the context of the approach of FIG. 6 that in the case of the effective range 8 of an upper cooling installation 6 as well as the effective range 9 of a lower cooling installation 7 lying in one and the same location x, the cooling outputs m_i for the respective upper and the respective lower cooling installation 6, 7 are also successively determined, wherein the change in the state E and in the residual amount of coolant M by the cooling output m_i which has been first determined is already considered when determining the cooling output m_i for the later determined cooling output m_i . By contrast, it is of minor significance whether, so as to correspond to the illustration in FIG. 6, the cooling output m_i for the upper cooling installation 6 is determined first, or whether the cooling output m_i for the lower cooling installation 7 is determined first.

[0122] According to the approach of FIG. 6, the cooling curve F2 for the upper cooling installations 6, and the cooling curve F3 for the lower cooling installations 7, are furthermore pre-defined in a mutually independent manner. In particular, the two cooling curves F2, F3 may thus be dissimilar from one another (cf. also FIG. 1). Alternatively, it is possible that the cooling curves F2 and F3 are mutually congruent. The statements made in relation to the pre-requirement of the total cooling function F1 correspondingly apply to the pre-requirement of the cooling curves F2, F3.

[0123] As has already been mentioned, the approach of FIGS. 4 and 6 may be carried out using the operating cycle $\delta t'$ which has also been used when carrying out the steps S4 to S6 (or S7, respectively) of FIG. 3. It is possible in particular in this case for each rolled material point P to be successively selected. The step S3 of FIG. 3 in this case degenerates to a trivial solution. This is because the determined final cooling outputs m_i need only to be acquired at a ratio of 1:1 as actual cooling outputs m_i for this one rolled material point P.

[0124] As has likewise been already mentioned, it is alternatively possible for the step S2 of FIG. 3 to be carried out in a manner decoupled from the operating cycle $\delta t'$ and in parallel with the steps S4 to S6 (or S7, respectively) of FIG. 3.

[0125] In this case too, in each case one rolled material point P is indeed iteratively selected. However, not all rolled material points P are selected. In this case and at least in the typical case, at least one further rolled material point P which is not selected therefore lies between two immediately successive selected rolled material points P. To the extent that this relates to the selected rolled material point P which has been selected in each case, the determined final cooling outputs m_i may furthermore also in this case be

acquired at a ratio of 1:1 in the step S3 as actual cooling outputs m_i for this rolled material point P, that is to say for the selected rolled material point P.

[0126] In both cases, the actual cooling outputs m_i for the selected rolled material points P are identical to the final cooling outputs m_i . Since the actual cooling outputs m_i are required in the context of the step S6, and the final cooling outputs m_i for the selected rolled material point P are required for determining the actual cooling outputs m_i , it is immediately and readily evident that the approach of FIGS. 4 and 6 has to be completed before that portion 15 of the real rolled material 1 that corresponds to the selected rolled material point P, proceeding from the starting point xA, reaches the next released effective range 8.

[0127] If not all rolled material points P are selected in the context of the step S1, the actual cooling outputs m_i must also be determined for the other non-selected rolled material points P in the context of the step S2. Various approaches are possible in this case. Potential approaches will be discussed hereunder in conjunction with FIGS. 7 and 8. In the context of FIGS. 7 and 8 it is assumed that the rolled material points P1 and P5 (cf. FIG. 2) are selected such that a total of three other non-selected rolled material points P, specifically the rolled material points P2, P3, and P4 lie between the two directly successive selected rolled material points P1 and P5.

[0128] However, analogous approaches are likewise possible if other rolled material points P are selected and/or if more or fewer than three other non-selected rolled material points P lie between the two selected rolled material points P.

[0129] In this way, according to the illustration of FIG. 7, it is possible in particular for the cooling outputs m_i which have been determined for one selected rolled material point P, for example for the rolled material point P1, to be acquired at a ratio of 1:1 for the subsequent rolled material points P. In this case, the acquisition is performed until a new determination for a further selected rolled material point P, for example for the rolled material point P5, is performed. Specifically, so as to correspond to the illustration in FIG. 7, in this example the cooling outputs m_i which have been determined for the rolled material point P1 would be acquired for the rolled material points P2, P3, and P4.

[0130] The approach according to FIG. 7 is capable of being carried out at all times. However, in the case of a sufficiently large computing capacity being available, this to be specified in more detail hereunder, it is alternatively possible according to FIG. 8 that the actual cooling outputs m_i for the non-selected rolled material points P (for the rolled material points P2, P3, and P4, according to the example) are determined by interpolating those cooling outputs m_i that have been determined for the two selected rolled material points P (the rolled material points P1 and P5, according to the example).

[0131] In the approach according to FIG. 8, the calculation according to FIGS. 4 and 6 for the later selected rolled material point P (for the rolled material point P5, according to the example) must be completed in order to be able to determine the actual cooling outputs m_i for the non-selected rolled material point P (the rolled material point P2, according to the example) which follows the first selected rolled material point P (the rolled material point P1, according to the example). The determination of the actual cooling outputs m_i for the later selected rolled material point P (the rolled material point P5, according to the example) must

thus be completed before the rolled material point P (the rolled material point P2, according to the example) which follows the first selected rolled material point P1, proceeding from the starting point xA, reaches the effective range 8, 9 of the next released cooling installation 6 and/or 7. This approach is thus possible only under this pre-condition.

[0132] FIG. 9 shows a modification of the approach of FIG. 4, the former being possible if an adequately large computing capacity is available. In the context of the approach of FIG. 9, the steps S11 to S20 of FIG. 4 are grouped together. Therefore, the individual approaches are not discussed in more detail, as this has already been performed in conjunction with FIG. 4.

[0133] According to FIG. 9, a step S41 is initially carried out. The step S41 in terms of content corresponds to the steps S11 to S13 of FIG. 4. Thereafter, a step S42 is carried out. The step S42 in terms of content corresponds to the steps S14 to S20 of FIG. 4. The entire approach of FIG. 4 has thus been processed once for now. However, a further step S43 which in terms of content likewise corresponds to the steps S14 to S20 of FIG. 4 follows the step S42. As a result, by way of the approach according to FIG. 9, the steps S14 to S20 which follow selecting of the rolled material point P will be carried out again once the total cooling function F1 for the same rolled material point P has been adapted. The steps S12 and S13 may likewise be repeated. However, this is not required as mandatory, since the values located therein have not been changed. When the step S14 is carried out the second time in the context of the step S43, the total cooling function F1 which has been adapted in the step S20 to step S42 is used as the basis during evaluation of the step S14.

[0134] As has already been mentioned, the starting point xA, so as to correspond to the illustration in FIG. 1, may lie ahead of the cooling zone 2. In particular in this case, and as has likewise already been mentioned, a temperature measurement spot 4 may be disposed at the starting point xA. Alternatively, it is possible for the starting point xA to lie in the cooling zone 2, so as to correspond to the illustration of FIG. 10. In this case, no temperature measurement spot is typically disposed at the starting point xA. The state E in this case has to be determined in another manner. For example, the state E may be known by virtue of the observer mentioned in conjunction with the step S7.

[0135] By virtue of the mutual spacing of the rolled material points P it is possible that no rolled material point P is passing the starting point xA at that time point at which one of the rolled material points P is to be selected. In this case, the state E of a fictional rolled material point P may be determined and subsequently used, for example, by means of the states E of the two rolled material points P directly ahead and directly behind the starting point xA, in particular by weighted or non-weighted interpolation of the two respective states E.

[0136] In an analogous manner, it is possible that the destination xZ lies behind the cooling zone 2, so as to correspond to the illustration in FIG. 1. Alternatively however, so as to correspond to the illustration in FIG. 10, it is likewise possible that the destination xZ lies in the cooling zone 2. However, independently of the location of the starting point xA and of the destination xZ, the destination xZ must self-evidently lie behind the starting point xA, when viewed in the transportation direction of the rolled material 1.

[0137] So as to correspond with the illustration in FIGS. 11 and 12, it is even possible that the operating method which has been discussed above in conjunction with FIGS. 1 to 10, in terms of the extent of the cooling zone 2, is applied multiple times in respective regions 18, 19 of the cooling zone 2. It is possible for the regions 18, 19 to be mutually successive, so as to correspond to the illustration in FIG. 11. In this case, an intermediate portion 20 in which the rolled material 1 is not actively cooled typically lies between the two regions 18, 19. Cooling in the intermediate portion 20 thus is performed only by natural convection, by contact with the transport rollers 5, and by radiation of heat, but not by the coolant 10. This approach may be of advantage in particular when cooling a dual-phase type steel. Alternatively, it is possible that the regions 18, 19 are mutually overlapping. In particular, so as to correspond to the illustration in FIG. 12, the destination xZ may be identical for both regions 18, 19, while the starting points xA are mutually dissimilar.

[0138] A potential implementation of tracking in the step S5 of FIG. 3, and a potential implementation of an observer according to the step S7 of FIG. 3 will be discussed in more detail hereunder in conjunction with FIG. 13. Here, only the approach for a single portion 15 is discussed in conjunction with FIG. 13. However, the approach of FIG. 13 is carried out in parallel for many portions 15. The approach of FIG. 13 is carried out at least for those portions 15 that at a particular time point are located between the starting point xA and the destination xZ. However, said approach may likewise be carried out for further portions 15 which are located outside this region. By virtue of the situation that FIG. 13 shows implementation of the steps S5 and S7 of FIG. 3, it is self-evident that the approach of FIG. 13 is carried out at the operating cycle $\delta t'$.

[0139] According to FIG. 13, the control installation 11 in a step S51, at that moment at which a specific portion 15 passes the starting point xA (in contrast to the approach of FIG. 4), sets the now real location x of the respective portion 15 to the starting point xA. The control installation 11 in a step S52 detects the current actual transportation speed v. The control installation 11 in a step S53 by means of the current actual transportation speed v and of the operating cycle $\delta t'$ refreshes the location x of the traced portion 15. The steps S51 to S53 substantially correspond to the tracking of the portion 15 per se, that is to say to the step S5 of FIG. 3.

[0140] The control installation 11 in a step S54 checks whether the respective portion 15 is located in the effective range 8, 9 of a cooling installation 6, 7. If this is the case, the control installation 11 in a step S55 actuates the respective cooling installation 6, 7. If the respective portion 15 is located in the effective range 8, 9 of a released cooling installation 6, 7, actuation is performed so as to correspond to the actual cooling output m_i which has been assigned to the corresponding rolled material point P for the respective cooling installation 6, 7 in the context of the step S3 of FIG. 3. If the respective portion 15 is located in the effective range 8, 9 of a non-released cooling installation 6, 7, actuation is performed so as to correspond to the cooling output m_i which has been assigned to the corresponding rolled material point P in another manner, that is to say not as per the approach according to the invention. Otherwise, the step S55 is skipped. The steps S54 and S55 substantially correspond to the step S5 of FIG. 3.

[0141] The control installation 11 in a step S56 refreshes the state E of the corresponding portion 15. In particular, the control installation 11 in the context of the step S56 solves the thermal conductivity equation in a manner corresponding to the model 16. The control installation 11 in the context of the step S56, as far as necessary, considers the respective actuation of the respective cooling installation 6, 7. The step S56 substantially corresponds to the step S7 of FIG. 3.

[0142] As has already been mentioned, the approach according to FIG. 13 is carried out at least for all portions 15 of the rolled material 1 that are located between the starting point xA and the destination xZ. The control installation 11, during transportation of the portions 15 of the rolled material 1 through the cooling zone 2 at the operating cycle $\delta t'$, thus conjointly calculates the states E of the portions 15 of the rolled material 1 that are transported through the cooling zone 2. Since the step S56 is furthermore carried out at the operating cycle $\delta t'$, the control installation 11 determines the states E of the portions 15 in real time.

[0143] Corresponding to the illustration in FIG. 13, further steps S57 to S60 are often present in addition to the steps S51 to S56. If the steps S57 to S60 are present, the control installation 11 in the step S57 checks whether the respective portion 15 is passing a temperature measurement spot 21. As opposed to the entry-side temperature measurement spot 4, the temperature measurement spot 21 is disposed behind the starting point xA. Depending on the individual case, the temperature measurement spot 21 may be disposed ahead of the destination xZ, at the destination xZ, or behind the latter. The temperature measurement spot 21 (exit-side temperature measurement spot) is most often disposed behind the cooling zone 2, for example between the cooling zone 2 and a reel 22.

[0144] When the observed portion 15 passes the exit-side temperature measurement spot 21, the control installation 11 in the step S58 detects an actual temperature T of the corresponding portion 15 of the rolled material 1. The control installation 11 in the step S59 compares the detected temperature T with a temperature which is determined by means of the state E which has been determined in the context of repeated processing of the step S56. In particular, the control installation 11 typically determines the deviation ΔT between the detected temperature T and the temperature which has been determined by means of the state E. The control installation 11 in the step S60 by means of the comparison, typically by means of the deviation ΔT , then updates at least one parameter k of the model 16. The heat transfer from the rolled material 1 to the coolant 10 may be adapted by means of the parameter k, for example.

[0145] A further substantial advantage of the present invention is derived from the discussion points above. This is in particular because the present invention may also be applied when the transportation speed v does not have the same direction throughout, but when the rolled material 1 is transported back and forth in the cooling zone 2.

[0146] In order for the steps S54 and S55 to be implemented, one preferably proceeds as will be discussed hereunder in conjunction with FIG. 14.

[0147] According to FIG. 14, the control installation 11 in a step S61 initially selects one of the cooling installations 6, 7. The control installation 11 in a step S62 determines those portions 15 of the rolled material 1 that at the observed operating cycle $\delta t'$ are located in the effective range 8, 9 of the cooling installation 6, 7 selected in the step S61. The

control installation 11, by means of the portions 15 which have been determined in the step S62, in a step S63 determines the corresponding rolled material points P and the actual cooling outputs m_i which are assigned to these rolled material points P for the corresponding cooling installation 6, 7. The control installation 11, by means of the actual cooling outputs m_i which have been determined in the step S63, in a step S64 determines an effective actuation of the corresponding cooling installation 6, 7. The control installation 11 in a step S65 checks whether the approach of the steps S61 to S64 has already been carried out for all cooling installations 6, 7. If this is not the case, the control installation 11 reverts to the step S61 by now selecting another cooling installation 6, 7 which has not yet been selected. Otherwise, the control installation 11 progresses to a step S66. The control installation 11 in the step S66 issues the effective actuations which have now been determined to the cooling installations 6, 7.

[0148] According to FIG. 15, the cooling installations 6, 7 often have significant time lags t_1 , t_2 . The time lags t_1 , t_2 are those times which elapse upon changing of the actuating variable S of the respective cooling installation 6, 7 until the reaction R thereto takes place. The time lags t_1 , t_2 may be in the range of a plurality of seconds. The time lags t_1 , t_2 may be identical or mutually dissimilar. Said time lags t_1 , t_2 may also differ from one cooling installation 6, 7 to another cooling installation 6, 7. The control installation 11, when actuating the cooling installations 6, 7, preferably considers the time lags t_1 , t_2 . For example, if the time lag t_1 of the cooling installation 6, 7 upon activation is uniformly 2 seconds, and the current transportation speed v is 10 m/s, the cooling installations 6, 7 are each activated at a time point at which the respective portion 15 is located 20 m ahead of the respective effective range 8, 9. In order for the time lags t_1 , t_2 to be considered in an orderly manner, the step S62 of FIG. 14 in this case is modified in such a manner that the control installation 11, using the motion diagram 17, determines those portions 15 of the rolled material 1 that at the observed operating cycle $\delta t'$ plus the time lags t_1 , t_2 to be considered are located in the effective range 8, 9 of the cooling installation 6, 7 which has been selected in the step S61. The other steps of FIG. 14 may remain unchanged.

[0149] A consideration of the time lags t_1 , t_2 is not required in the context of the prognosis of FIGS. 4 and 6. Rather, it may be assumed in the context of the prognosis of FIGS. 4 and 6 that the cooling installations 6, 7 react without any temporal delay.

[0150] As has already been mentioned, the approach of FIGS. 4 and 6 must be completed before the respective portion 15 corresponding to the selected rolled material point P, proceeding from the starting point xA, reaches the effective range 8, 9 of the next released cooling installation 6, 7. The time point at which this approach is completed hereunder is referred to as the completion time point. The corresponding portion 15 reaches the effective range 8, 9 of the next released cooling installation 6, 7 at a time point which hereunder will be referred to as the cooling start time point. In order to guarantee a timely actuation of the cooling installation 6, 7 using the corresponding actual cooling output m_i , the actuation of the cooling installation 6, 7 must lie before the cooling start time point so as to include the respective time lag t_1 , t_2 . That is to say that determining the respective actual cooling output m_i should be completed before this time point. Therefore, in order to achieve orderly

actuation of the cooling installations 6, 7, a temporal difference between the completion time point and the cooling start time point should be at least the size of the time lags t_1 , t_2 , optionally larger than the time lags t_1 , t_2 , of the next released cooling installation 6, 7. Under certain circumstances, however, it may be acceptable for this condition to be violated.

[0151] The present invention has many advantages. So-called valve clatter is almost completely avoided in this way, for example. Instead, actuating the cooling installations 6, 7 is performed in a very quiet manner. Furthermore, the method according to the invention also operates very reliably at very low temperatures (for example below approx. 350° C.). Even a ten-fold increase in the heat transfer in the case of low temperatures may be readily managed. The operating method according to the invention is thus particularly also suitable in the case when so-called dual-phase type steel is to be cooled. This applies even in the case when an acceleration cannot be avoided in the manufacture of the dual-phase type steel, because other target variables such as, for example, a final rolling temperature, a rolled material thickness, and the like would otherwise be excluded from a permissible tolerance range. The approach according to the invention furthermore offers high flexibility. For example, a high cooling rate may even be employed up to a surface temperature of approx. 400° C. The latter may then be reduced to a very minor value once approx. 350° C. has been undershot. On account thereof, cooling may also be reduced at the critical point at which the so-called Leidenfrost temperature is reached, without said critical point having to be known up front. The method according to the invention also offers the possibility of being employed multiple times within one and the same cooling zone 2. It has only to be considered that the starting point xA of each subsequent carrying-out must lie behind the starting point xA of the respective preceding carrying-out, optionally under consideration of the current transportation direction. The possibilities of a cooling zone 2 having continuously controllable cooling installations 6, 7 may in particular be fully utilized in order to achieve an optimal cooling result.

[0152] In summary, the present invention relates to the following actual situation:

[0153] A flat rolled material 1 is transported through a cooling zone 2 such that portions 15 of the rolled material 1 successively pass through effective ranges 8, 9 of cooling installations 6, 7. Virtual rolled material points P are assigned to the portions 15. During transportation of the portions 15 through the cooling zone 2, tracking of the portions 15 is carried out by way of an operating cycle $\delta t'$. The cooling installations 6, 7 are controlled so as to correspond to the respective rolled material points P for actual cooling outputs m_i which are assigned to the cooling installations 6, 7. On account thereof, that portion 15 that is in each case located in the effective range 8, 9 of the respective cooling installation 6, 7 is impinged with a respective amount of coolant. The cooling installations 6, 7 are subdivided into released and non-released cooling installations. A rolled material point P is in each case iteratively selected. Before the corresponding portion 15, proceeding from a starting point xA, reaches the effective range 8, 9 of the next released cooling installation 6, 7, a state E which the respective rolled material point P has at the starting point xA is determined. A total amount of coolant is determined by means of a total cooling function F1 and assigned to the

rolled material point P as a residual amount of coolant M. Transportation of the rolled material point P through the cooling zone 2 is mathematically simulated using a motion diagram 17. The temporal development of the state E here is conjointly calculated by means of a model 16. When the rolled material point P reaches a released effective range 8, 9, a respective temporary cooling output m_i is determined by means of the then-current state E. The minimum of temporary cooling output m_i and of residual amount of coolant M is assigned as the final cooling output m_i to the rolled material point P for the respective released cooling installation 6, 7. The residual amount of coolant M is correspondingly reduced. At a destination xZ, an actual variable I which has been determined by means of the state E therein is compared with a target variable EZ. The total cooling function F1 is adapted by means of the comparison. Using the determined final cooling outputs m_i , the actual cooling outputs m_i are determined for a number of rolled material points P and assigned to the rolled material points P, while assigning the respective released cooling installation 6, 7.

[0154] While the invention has been illustrated and described in greater detail by the preferred exemplary embodiment, the invention is not limited by the disclosed examples, and other variations thereof may be derived therefrom by a person skilled in the art, without departing from the scope of protection of the invention.

1. An operating method for a cooling zone for cooling a flat rolled material;

wherein the cooling zone has a multiplicity of cooling installations;

the method comprising:

transporting the rolled material through the cooling zone such that portions of the rolled material successively pass through effective ranges of the cooling installations;

assigning one virtual rolled material point to each of the portions of the rolled material;

tracking the portions of the rolled material during transportation of the portions of the rolled material through the cooling zone at an operating cycle ($\delta t'$); and

controlling the cooling installations according to actual cooling outputs (m_i) of the cooling installations assigned to the respective rolled material points (P) for the respective cooling installations so that portion of the rolled material that is in each case located in an effective range of the respective cooling installation is impinged with a respective amount of coolant;

subdividing the cooling installations into released cooling installations which release coolant during the operating method and non-released cooling installations, which prevent release of coolant during the operating method, wherein those cooling outputs which have been applied by non-released cooling installations during the operating method are also considered in development of the state of the rolled material point, and the cooling outputs of these cooling installations are accepted as given;

iteratively selecting a virtual rolled material point (P) in respective ones of the portions of the rolled material and, in relation to the respective virtual rolled material point (P);

prior to the respective portion of the real rolled material, proceeding from a pre-defined starting point (xA), reaching an effective range of the next released cooling installation;

determining a state (E) which comprises at least one energy variable and which the respective portion of the rolled material at the starting point (xA) of the cooling zone;

determining a total amount of coolant for the rolled material point (P) by a defined total cooling function (F1) and assigned as a residual amount of coolant (M) to the rolled material point (P);

mathematically simulating by using a motion diagram of transporting the rolled material point (P) through the cooling zone up to a pre-defined destination (xZ), wherein the diagram states a transportation speed v_E for the selected rolled material point (P) at a simulation time (t) and calculated from the starting point (xA);

conjointly calculating temporal development of the state (E) of the rolled material point (P) during the simulation by means of a model;

each time when the rolled material point (P) reaches the effective range of one of the released cooling installations, determining a respective temporary cooling output (m_i) by the then-current state (E) of the rolled material point (P) while using a cooling curve (F2, F3) which is assigned to the respective released cooling installation,

assigning the rolled material point (P) for the respective released cooling installation the lower of the two values of temporary cooling output (m_i) and residual amount of coolant (M) as the final cooling output (m_i), and reducing the residual amount of coolant (M) by the final cooling output (m_i);

determining an actual variable (I) of the temperature by means of the state (E) of the rolled material point (P) at the destination (xZ) and comparing the actual variable with a pre-defined target variable (EZ), of temperature and adapting the total cooling function (F1) by means of the comparison;

defining the actual cooling outputs (m_i) for a number of the rolled material points (P) while using the final cooling outputs (m_i) which have been determined for the selected rolled material point (P), and assigning to the respective rolled material points (P), the respective released cooling installation being assigned thereby.

2. The operating method as claimed in claim 1, further comprising:

at least one further virtual, non-selected rolled material point (P2 to P4) lies between two directly successive selected virtual rolled material points (P1, P5);

the selecting of the later selected virtual rolled material point (P5) and the carrying out of the calculations in relation to the virtual rolled material point (P5) are completed before those portions of the rolled material that correspond to the non-selected rolled material points (P2 to P4), and proceeding from the starting point (xA), reach the effective range of the next released cooling installation; and

determining the actual cooling outputs (m_i) for the non-selected rolled material points (P2 to P4) are determined by interpolation of the final cooling outputs (m_i) which have been determined for the two adjacent selected rolled material points (P1, P5).

3. The operating method as claimed in claim 1, further comprising at least one part of the cooling installations acting on the upper side of the rolled material, such that cooling curves (F2) for the one part of the cooling installations which act on the upper side of the rolled material are mutually congruent.

4. The operating method as claimed in claim 3, further comprising a further part of the cooling installations acting on the lower side of the rolled material, such that cooling curves (F3) for further part of the cooling installations which act on the lower side of the rolled material are mutually congruent.

5. The operating method as claimed in claim 4, wherein the cooling curves (F2) for the one part of the cooling installations that act on the upper side of the rolled material, on the one hand, and the cooling curves (F3) for the further part of the cooling installations that act on the lower side of the rolled material, on the other hand, are mutually congruent or mutually dissimilar.

6. The operating method as claimed in claim 1, wherein the starting point (xA) lies ahead of the cooling zone or in the cooling zone.

7. The operating method as claimed in claim 6, further comprising by means of a temperature measurement spot, detecting a temperature (T) of each respective portion of the rolled material and;

disposing the temperature measurement point at the starting point (xA), and determining the state (E) of the rolled material point (P) at the starting point (xA) by means of the detected temperature (T).

8. The operating method as claimed in claim 6, wherein no temperature measurement spot is disposed at the starting point (xA).

9. The operating method as claimed in claim 1, wherein the predetermined destination (xZ) lies in the cooling zone or behind the cooling zone.

10. The operating method as claimed in claim 1, further comprising again performing those steps that follow selecting the rolled material point (P) after adapting the total cooling function (F1) for the same rolled material point (P).

11. The operating method as claimed in claim 1, further comprising considering time lags (t1, t2) of the cooling installations when actuating the cooling installations.

12. The operating method as claimed in claim 11, further comprising the cooling installations have time lags (t1, t2), in that those steps that follow selecting the respective rolled material point (P) are completed at a completion time point, in that the respective portion of the real rolled material, proceeding from the starting point (xA), reaches the effective range of the next released cooling installation at a cooling start time point, and in that a temporal difference between the completion time point and the cooling start time point is at least the duration of the time lag (t1, t2) of the next released cooling installation.

13. The operating method as claimed in claim 1, further comprising:

conjointly calculating the states (E) of those portions of the rolled material that are transported through the

cooling zone in real time during transportation of the portions of the rolled material through the cooling zone at the operating cycle ($\delta t'$), while considering actuation of the cooling installations;

at a temperature measurement spot, detecting an actual temperature (T) of that respective portion of the rolled material that passes the temperature measurement spot; and

comparing the respective detected temperature (T) with an expected temperature for that respective portion that has been determined by means of the conjointly calculated state (E), and updating at least one parameter (k) of the model by means of the comparison.

14. The operating method as claimed in claim 1, further comprising over the extent of the cooling zone, applying the operating method multiple times in respective regions of the cooling zone.

15. The operating method as claimed in claim 14, further comprising not actively cooling an intermediate portion in which the rolled material lies between those regions of the cooling zone in which the operating method is applied.

16. The operating method as claimed in claim 15, wherein those regions of the cooling zone in which the operating method is in each case applied are mutually overlapping.

17. The operating method as claimed in claim 1, wherein the total cooling function (F1) is dependent or independent of the state (E) of the selected rolled material point (P) at the starting point (xA).

18. A computer program product comprising a non-transitory medium for storing a computer program, a computer program stored on the medium, the computer program comprising machine code which is processable by a control installation for a cooling zone, for a flat rolled material, wherein processing of the machine code by the control installation causes the control installation to operate the cooling zone according to an operating method as claimed in claim 1.

19. A control installation for a cooling zone, for a flat rolled material, wherein the control installation is programmed using a computer program product as claimed in claim 18.

20. A cooling zone for cooling a flat rolled material, comprising:

the cooling zone has a multiplicity of cooling installations, each located in a respective effective range, and by each of the cooling installations impinging a portion of the rolled material that is with a respective amount of coolant;

a transport installation configured for transporting the rolled material through the cooling zone such that the portions of the rolled material successively run through the effective ranges of the cooling installations; and

wherein the cooling zone has a control installation which operates the cooling zone according to an operating method as claimed in claim 1.

* * * * *