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(54) Title: PROCESS OF ROLLING AND OF THERMAL TREATING OF ROLLED SECTIONS

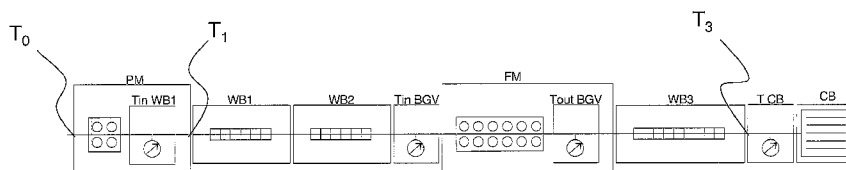


Fig. 2

(57) Abstract: A process of rolling and of thermal treating of rolled sections, in particular steel bars, in which the rolled section is passed through a pre-finishing stand PM, through two waterboxes WB1, WB2 and a finishing mill FM at the inlet temperature T_{in} chosen with a value such that the outlet temperature T_{out} of the rolled section does not exceed temperature $T_{out_max} = (Ac3 - d^{0.7})^{\circ}C$, where "Ac3" is the temperature at which in the steel, during heating, the transformation of ferrite into austenite ends, and "d" is the diameter of the bar to be treated.

PROCESS OF ROLLING AND OF THERMAL TREATING OF ROLLED SECTIONS

Description

Field of the invention

- 5 The present invention relates to a process of rolling and of thermal treating of rolled sections, in particular of bars for reinforced concrete.

State of the art

Bars for reinforced concrete are currently manufactured either by means of rolling processes including the introduction of micro-alloying elements, such as
10 manganese (Mn), or by means of processes which incorporate martensitic hardening and self-tempering of the surface. A process of this second type is described in Italian patent application IT1997UD00105.

Both the aforesaid methods have the common effect of increasing the mechanical features of steel with a carbon content varying in the range from 0,14 to 0,24 %.

- 15 The first method including the introduction of Mn, however, has high costs because of the micro-alloying elements used in the process, and thus tends to be increasingly avoided by rolled section manufacturers.

The second method, based on martensitic hardening, introduces a limitation in the plastic features achieved by the material, i.e. in the obtainable ratio of ultimate
20 tensile stress (UTS) and yield stress (YS). A disadvantage of this method is related to the hardness of martensite which is formed on the surface of the bar for a given depth, the size of which generally depends on the diameter of the bar itself. As the mechanical features which may be obtained in the rolled section, once the chemical composition of the steel has been determined, depend on the
25 depth of martensite created during the thermal process, it derives that the difference between yield stress and ultimate tensile stress is reduced when the martensite amount increases. A physical limit is however achieved, the consequence of which is that the chemical composition of steel needs to be changed by increasing Mn content and possibly micro-alloying element content in
30 order to increase the UTS/YS ratio.

Searching a high UTS/YS ratio value is justified by the need to ensure a better plastic reserve in the rolled section, a feature which is expressly required by the

laws of many countries where the geoseismic component is crucial. Figure 1 shows a typical diagram for steel which shows a curve in which the load (axis Y) depends on the shift (axis X) and from which the corresponding stresses YS and UTS are obtained. A material with a high plastic reserve shows a very marked difference between UTS and YS values typically with a UTS/YS ratio higher than 1,25.

Another method, conceived to obtain mechanical features which comply with the requirements of many countries, includes keeping a high UTS/YS ratio but without the aid of micro-alloying elements or chemical composition variations. It consists in avoiding the formation of the surface martensite structure during the thermal process and promoting the formation of highly fine structures, such as acicular ferritic-bainitic structures, uniformly distributed in a surface layer of the bar. The chemical composition of steel being equal, these structures allow to obtain a considerable increase of the UTS/YS ratio as compared to the two methods mentioned above.

It is known that in order to obtain acicular ferritic-bainitic structures, rolling must be carried out on the surface zone of the bar, named "skin", which is taken to a determined temperature in such manner to be defined as "undercooled".

The thermal gradients needed for such a process are obtained by a sequence cooling in pressurized water coolers, named "waterboxes", spaced by predetermined equalisation distances, which avoid the surface formation of a martensite layer which, if it were formed, would negatively influence the mechanical features of the product.

Summary of the invention

It is an object of the present invention is to provide a process of rolling and of thermal treating of rolled sections which overcomes the aforesaid drawbacks for producing steel rolled sections which have acicular ferritic-bainitic structures having elastic features sufficient to pass specific standards, and which keeps equivalent or reduces rolled section manufacturing costs.

This and other objects of the present invention are achieved by a process of rolling and of thermal treating of rolled sections, in particular of steel bars, wherein there is provided a rolling plant, defining a rolling line, comprising at least two first

waterboxes, a finishing block arranged downstream with respect to the at least two first waterboxes, at least a second waterbox arranged downstream of said finishing block, said process comprising the following steps in accordance with claim 1:

- 5 - conveying the rolled section at a first temperature T_0 through a pre-finishing stand,
 - extracting the rolled section from the pre-finishing stand to a second temperature T_1 ,
 - conveying the rolled section through the first and second of the at least two
 - 10 waterboxes,
 - conveying the rolled section through the finishing rolling mill at an inlet temperature T_{in} and an outlet temperature T_{out} ,
- wherein this inlet temperature T_{in} is chosen with a value such that the outlet temperature T_{out} of the rolled section does not exceed the temperature T_{out_max}
- 15 determined by the formula $T_{out_max} = (Ac3 - d^{0.7})^{\circ}C$, where
 - $Ac3$ is the temperature at which in the steel, during heating, the transformation of ferrite into austenite ends;
 - d is the diameter of the rolled section to be treated.

The dependent claims describe preferred embodiments of the invention.

20 Brief description of the drawings

Further features and advantages of the invention will be more apparent in the light of the detailed description of preferred, but not exclusive, embodiments of a process of rolling and of thermal treating of rolled sections illustrated by way of non-limitative example, with the aid of the accompanying drawings, in which:

- 25 Fig. 1 shows a characteristic steel stress-deformation curve,
- Fig. 2 shows a rolling line adapted to implement the process according to the present invention;
- Fig. 3 shows a reference curve of the process temperatures according to the invention;
- 30 Fig. 4 shows a final transformation curve of the rolled section subjected to the process of the invention.

Detailed description of preferred embodiments of the invention

An example of the process according to the present invention may be implemented by a rolling plant of the existing type, shown by way of example in figure 2, adapted to make long products, such as steel bars.

- 5 The structure of the rolling plant includes the arrangement of two waterboxes WB1, WB2 before the finishing block FM for carrying out the primary cooling, and of a further waterbox WB3 downstream of said finishing block for carrying out the secondary cooling of the rolled section. The positioning of the first two waterboxes WB1, WB2 must be such to allow the rolled section to enter the finishing block FM
- 10 at a predetermined surface temperature, which should be lower than a limit value, which is determined according to the thickness of the produced material. Three or more waterboxes (not shown) are provided in an advantageous variant to allow a more fractioned cooling.

- The process of rolling and thermal treating according to the invention is described
- 15 in detail below. Firstly, we will define the determinant values for the process of the invention:

Ac1 = temperature at which, during heating, the formation of austenite starts;

Ac3 = the temperature at which, during heating, the transformation of ferrite into austenite ends;

- 20 Ms = temperature at which, during cooling, the transformation of austenite into martensite starts;

d = diameter of the bar to be treated.

- The process of rolling and thermal treating comprises a first step in which the rolled section, coming from a production line at controlled temperature T_0 , crosses
- 25 a pre-finishing stand PM, from which the rolling product exits at a temperature T_1 . The rolled section then passes through the first waterbox WB1 and the second waterbox WB2, and is introduced into the finishing mill FM, also named fast rolling block (BGV). During this step of the process, the inlet temperature value of the bar in the finishing mill, named " $T_{in\ BGV}$ ", must be such that the outlet temperature
- 30 " $T_{out\ BGV}$ " does not exceed the temperature T_{out_max} determined by the formula:

$$T_{out_max} = (Ac3 - d^{0.7})^{\circ}C.$$

The surface temperature of the rolled section at the entrance of the finishing mill

FM is preferably comprised in the range from 580 to 680 °C.

The following step consists in passing the rolled section through the waterbox WB3, which takes the surface temperature of the rolled section to the value T_3 before continuing through the final cooling device or bed CB. The surface temperature T_3 of the bar at the exit from the waterbox WB3 must neither be over Ac1 nor under temperature Ms. The temperature T_3 also corresponds to the surface temperature of the rolled section at the entrance of the cooling device CB. In fact, all cooling steps must be defined by values such that the surface temperature of the bar never drops below the critical martensite forming temperature Ms, which is a value depending on the specific chemical composition of steel, unless the time between the moment in which the first step of cooling in the waterbox WB1 occurs and the subsequent rolling produces a partial hardening at a temperature higher than Ac1. The purpose of the final step of cooling in the cooling bed CB is to reduce the ramp-up temperature during rolling in the finishing mill FM to prevent the production of self-tempering in the surface layer structure of the rolled section.

The curve in figure 3 shows the reference curve of the process, in which the temperatures in various points of the rolled section are separately shown. The curve indicated by numeral 1 is the temperature of the rolled section core, curve 2 is the average temperature of the rolled section, and curve 3 is the temperature on the rolled section surface in which three characteristic temperature points are highlighted.

The zone of the temperature curves indicated by letter A indicates the surface temperature drop of the rolled section in the first cooling section or waterbox WB1, this drop being comprised in a range from about 150°C to about 500°C.

Zone B indicates the temperature increase of the rolled section due to rolling deformation, which may normally take values comprised in the range from about 20°C to about 100°C.

Zone C indicates the temperature drop of the rolled section at the final cooling section CB, which may take values from about 400°C to 750°C.

Figure 4 shows a final transformation curve on which significant points of the process are indicated. In this graph, the curve indicated by numeral 6 is the

temperature of the rolled section core; the curve 4 is the average temperature in the rolled section and the curve 5 is the temperature of the rolled section surface.

The curve 8 represents the beginning of the ferritic transformation in the presence of a cooling gradient; the upper and lower curves 9 represent the beginning and the end of the pearlitic transformation, respectively, in the presence of a cooling gradient; the curve 10 represents the beginning of the bainitic transformation in the presence of cooling gradient; and the upper and lower curves 11 are the limits for the occurrence of the martensitic transformation. The upper and lower curves 7 represent temperature A_{c3} and A_{c1} , respectively, i.e. the beginning of the ferritic and pearlitic transformation under nearly static cooling conditions.

Point T_{out} BGV indicates the surface temperature of the rolled section exiting the finishing mill FM, corresponding to the value of $782,2^{\circ}\text{C}$ in this example, and point T_3 indicates the surface temperature of the rolled section at the entrance of the cooling device CB, equal to $714,1^{\circ}\text{C}$.

Since an important element of the invention consists in rolling bars by means of the finishing mill FM with a supercooled surface in the passage through the waterboxes WB1 and WB2, a temperature control of the rolled section must be provided for ensuring that the thickness of the supercooled surface has a dimension from 2 to 10 mm in depth. The exact thickness is defined according to the diameter of the bar and according to the final physical properties required for the bar.

As a consequence of these process rolling steps, partial austenitic transformations are produced, which cause a mixed ferritic-bainitic acicular micro-structure.

The rolling and thermal treating process of the invention may be advantageously applied to ribbed round bars for reinforced concrete, commonly named "rebars", or to bars and profiles or construction steel in general which are used in a crude rolling state i.e. without following surface finishing or treatments. This steel is of the type with a low or very low carbon content, with or preferably without micro-alloying elements.

The main advantage of the process of the invention is that it may be applied either to existing systems or new systems.

Further important advantages of the process of the invention are:

- the possibility of reducing the manganese content needed in steel to minimum levels, lower than about 0,4%, because the value of the UTS/YS ratio is increased by the micro-structural modification, and this ratio may reach a value higher than 1,35;
- 5 - the suppression of micro-alloying elements, because the strength increase is also obtained by said micro-structural modification;
- an improvement of the fatigue strength features and an increase of the low-temperature toughness due to a greater fineness of the micro-structure of the rolled section surface;
- 10 - according to the above aspects, a consequent reduction of manufacturing costs of the rolled section itself is obtained.

CLAIMS

1. Process of rolling and of thermal treating of rolled sections, in particular steel bars, wherein there is provided a rolling plant which defines a rolling line comprising at least two first waterboxes (WB1, WB2), a finishing block (FM) placed downstream of the at least two first waterboxes, at least a second waterbox (WB3) placed downstream of said finishing block (FM), wherein the following process steps are provided:
 - conveying the rolled section at a first temperature (T_0) through a pre-finishing stand (PM),
 - 10 - extracting the rolled section from the pre-finishing stand (PM) at a second temperature (T_1),
 - conveying the rolled section through a first (WB1) and a second (WB2) of the at least two waterboxes,
 - conveying the rolled section through the finishing rolling mill (FM) at an inlet temperature (T_{in}) and an outlet temperature (T_{out}),
 - 15 wherein said inlet temperature (T_{in}) is chosen with such a value that the outlet temperature (T_{out}) of the rolled section does not exceed the temperature T_{out_max} determined by the formula

$$T_{out_max} = (Ac3 - d^{0.7})^{\circ}C, \text{ wherein}$$
 - 20 - Ac3 is the temperature at which in steel, during the heating, the transformation of ferrite into austenite ends,
 - d is the diameter of the rolled section to be treated.
2. Process according to claim 1, wherein the inlet temperature (T_{in}) of the rolled section at the entrance of the finishing rolling mill (FM) is comprised in the range
 - 25 between 580 and 680°C.
3. Process according to claim 1, wherein the rolled section is made of steel with a manganese content lower than 0,4% and free from micro-alloying elements.
4. Process according to claim 1, wherein a surface temperature (T_3) of the rolled section at the exit from the at least one second waterbox (WB3) must not exceed
 - 30 the temperature at which, during the heating, the transformation of austenite into martensite (M_s) starts.

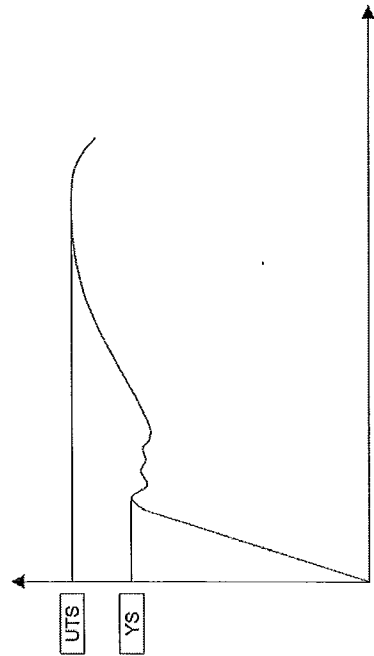


Fig. 1

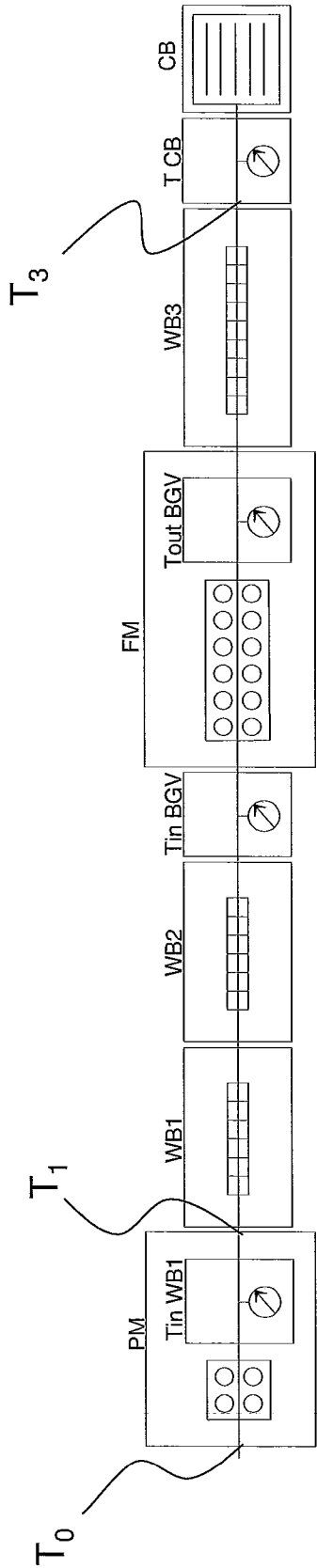


Fig. 2

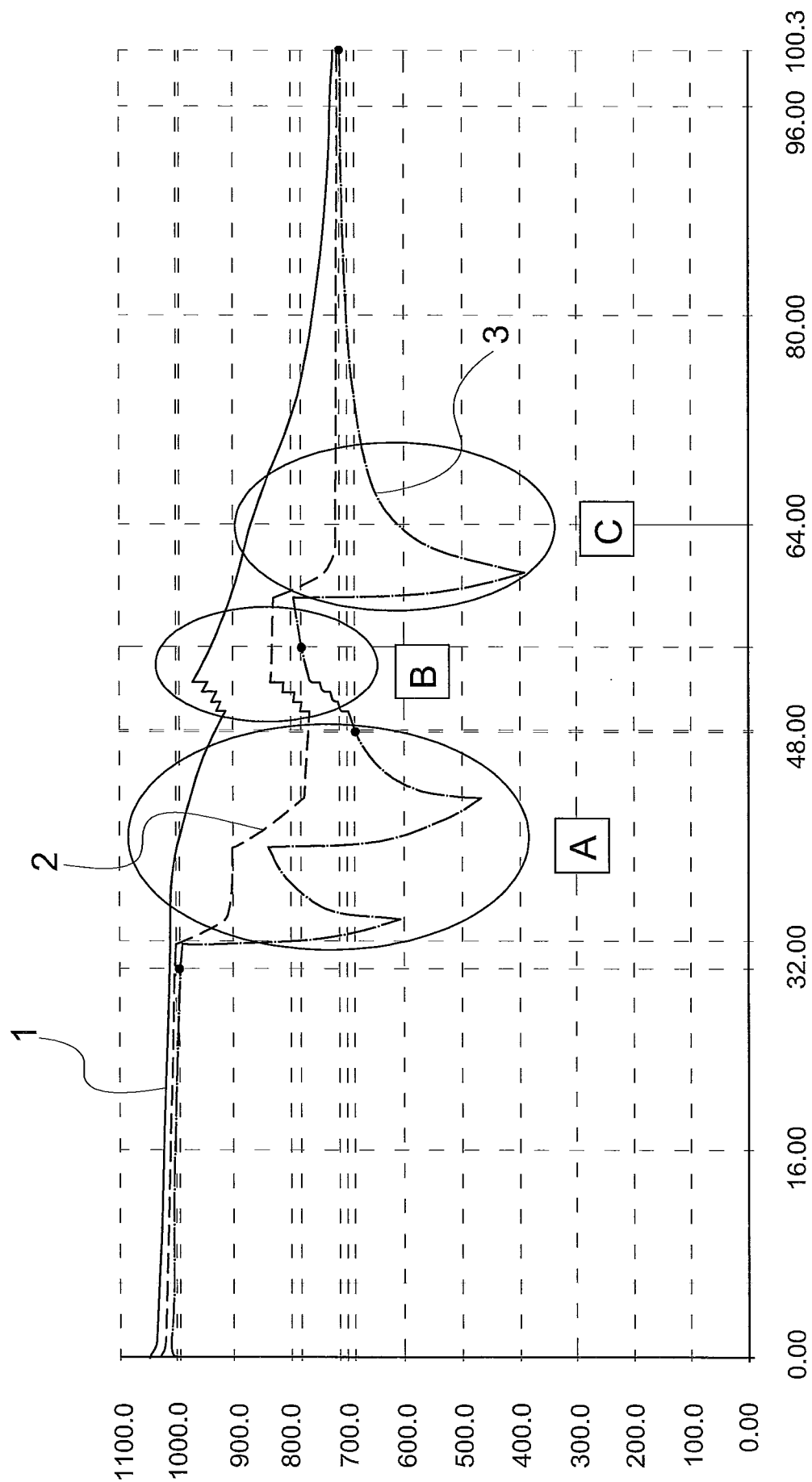


Fig. 3

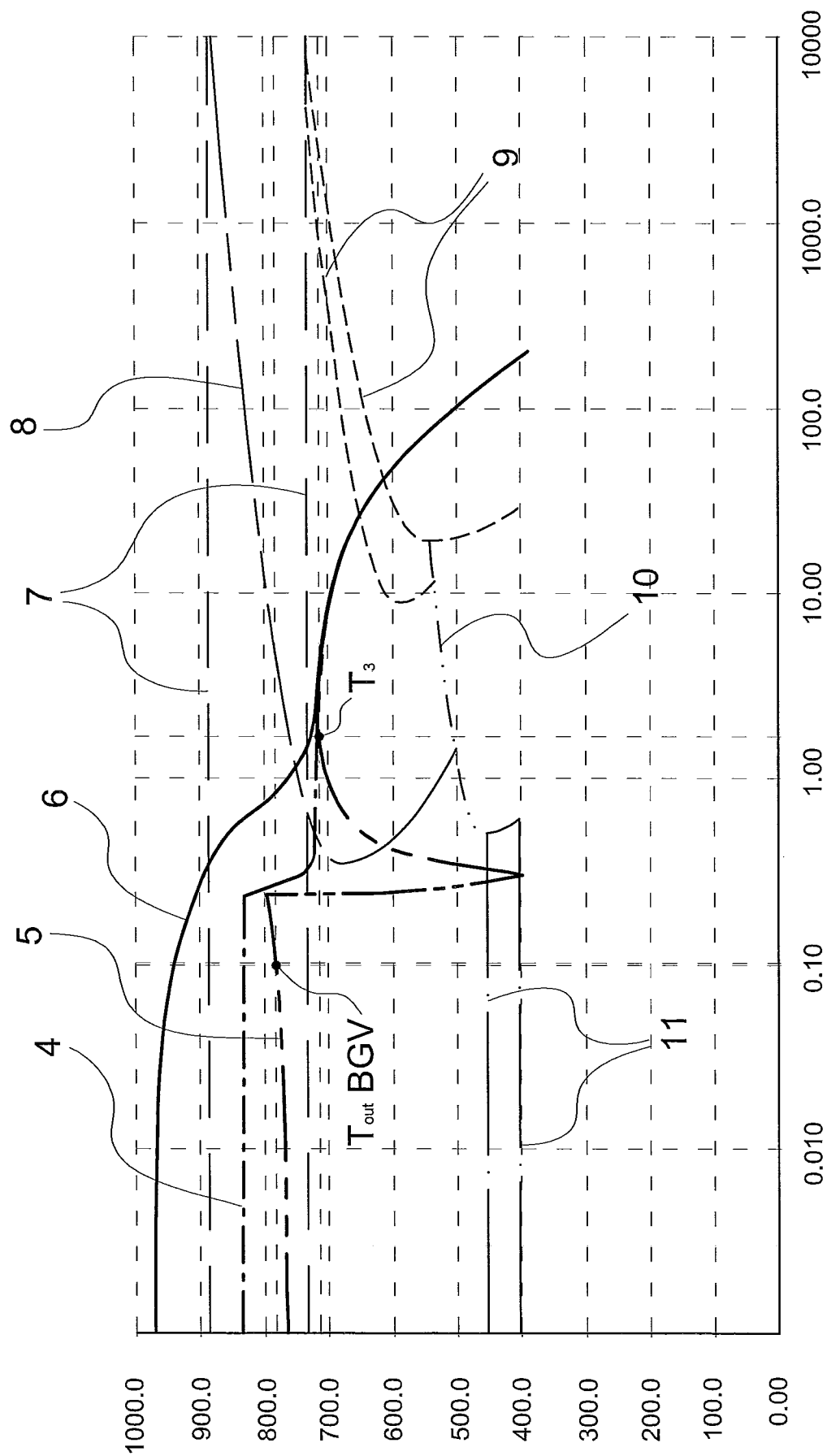


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/065003

A. CLASSIFICATION OF SUBJECT MATTER

INV. C21D8/08 C21D9/52 B21B45/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C21D B21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

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X	WO 2006/043156 A (DANIELI OFF MECC [IT]; TOSCHI FRANCESCO [IT]; PAOLONE ROLANDO [IT]) 27 April 2006 (2006-04-27) page 7, line 33 - page 9, line 17; claims 1-19; figures 5,6	1-4
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X	JP 61 183412 A (NIPPON STEEL CORP) 16 August 1986 (1986-08-16) abstract; figure 1	1-4
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No

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Information on patent family members

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