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(54) Title: METHOD OF HEAT AND DEFORMATION TREATMENT OF A METAL SEMI-FINISHED PRODUCT

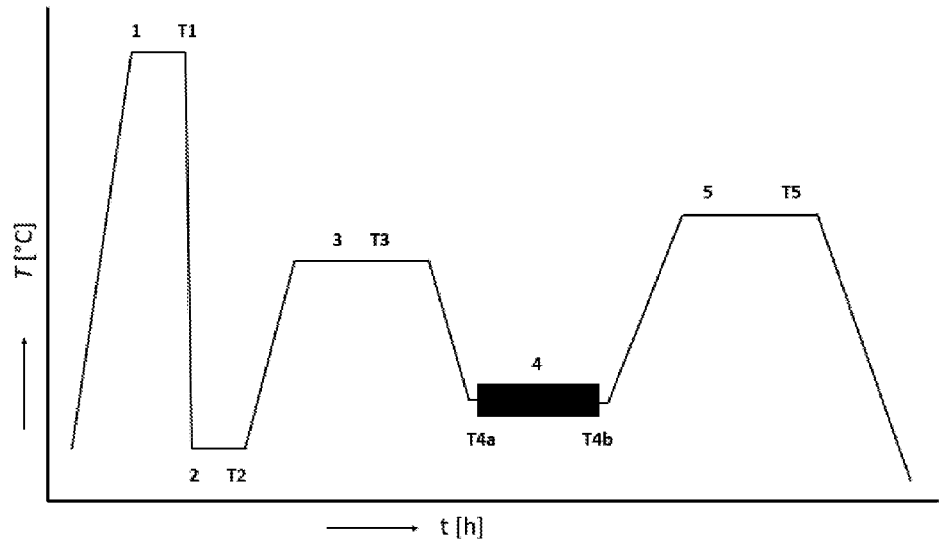

Fig. 1

(57) Abstract: The method includes a quenching (1) followed by a first tempering (3) either directly or after a dwell time. Furthermore, a sequence consisting of a plastic deformation (4) is conducted following the first tempering (3) to influence material properties of a semi-finished product and an additional tempering (5) following thereto. The plastic deformation (4) initial temperature (T4a) of the semi-finished product may be lower than, equal to, or higher than said plastic deformation (4) final temperature (T4b). The plastic deformation initial temperature (T4a) may be increased by deformation heat without external heat supply. The plastic deformation (4) initial temperature (T4a) of the semi-finished product being processed may be in general different from the first tempering (3) initial temperature (T2) of the semi-finished product. The first tempering (3) initial temperature (T2) of the semi-finished product being processed is lower than a martensitic transformation finish temperature (Mf) of said semi-finished product. The first tempering (3) temperature (T3) may differ from the additional tempering (5) temperature (T5).

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[Continued on next page]

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Method of heat and deformation treatment of a metal semi-finished product

Field of the invention

The present invention relates to the field of modification of physical structure of ferrous and non-ferrous metals or alloys by heat and deformation treatment.

Background art

A wide spectrum of procedures of heat and deformation treatment is used in order to modify the microstructure and physical and chemical properties of metal materials (ferrous and non-ferrous metals or alloys thereof). They are characterized in various combinations of steps (e.g., quenching, annealing, tempering, plastic deformation, and more), possibly separated by dwell times while holding at a temperature, and they may be further defined by various temperatures at which the steps are performed. A specific sequence of operations influences desirably the properties and microstructure of a metal material.

CN109594024 discloses a method for production of a high-carbon steel wire. Disclosed therein is the method of forming followed by heat treatment, and no deformation is incorporated in the course of heat treatment.

CN108380678 discloses a combination of alternate annealing cycles and cold forming. No quenching is incorporated into the process.

RU2709127 discloses a device that processes shafts by combination of heat modes and deformations. The deformation is incorporated in the sense of calibration, i.e., elimination of shape deviations from previous heat process. The deformation does not have any impact on mechanical properties of the material.

JPS5956521 discloses a process comprising quenching of material followed by a step that includes tempering and plastic deformation at the same time.

CN106282496 discloses a process comprising plastic deformation (forging) at the beginning of the process, wherein the forging is a high temperature forging. No further deformation occurs during subsequent heat treatment.

RU2287592 discloses treatment of corrosion resistant austenitic steels. The deformation between annealing modes after quenching occurs under cryogenic temperatures. Austenitic structure occurs from deformation martensite during the second annealing mode.
RU2422541 also discloses austenitic corrosion resistant steels. The deformation occurs under cryogenic temperatures. The disclosure is similar to RU2287592.
US3930907A discloses nitrogenated low-carbon steels and defines maximum heating temperature prior to quenching (hardening) as intercritical, the temperature must be in two-phase alpha + gamma – interval. A small-range, so-called calibration deformation, is applied.

Summary of the invention

The present invention relates to a method of heat and deformation treatment of a metal semi-finished product, purpose of which is improvement of mechanical properties of semi-finished product material, in particular yield strength while maintaining an acceptable material plasticity and toughness.
The method includes quenching followed by first tempering either directly or after a dwell time. When the dwell time is incorporated, the semi-finished product temperature may be constant during the dwell time, usually at ambient temperature. However, end of quenching at temperature other than ambient temperature may be contemplated. In this case, the semi-finished product temperature may change during the dwell time prior to the first tempering – to increase or decrease.
The first tempering initial temperature of the semi-finished product being processed is lower than the martensitic transformation finish temperature of said semi-finished product material. It depends on thermophysical value of finish martensitic transformation that may be in general higher or lower than the ambient temperature. Temperature progress management between the finish martensitic transformation and the first tempering may influence stability of some structure components, e.g., residual austenite. When the martensitic transformation finish temperature of a semi-finished product material is higher than the ambient temperature, finishing of the quenching at temperature lower than the ambient temperature is not necessary. Owing to this, liquid (water, oil) having the ambient temperature may be used for the quenching. This is advantageous with respect to energy and costs because cooling down the liquid under the ambient temperature is not necessary.

Further, following the first tempering, at least one sequence of plastic deformation is conducted to influence the material properties of the semi-finished product, followed by additional tempering. The sequence follows the first tempering either directly or after the dwell time. When the sequence repeats more than once, then the plastic deformation of the second sequence directly or after the dwell time follows said additional tempering of the first sequence.

Depending on the specific semi-finished product material and requirement for final properties, the process of the heat and deformation treatment may be controlled by various durations of each step and/or various semi-finished product temperatures when the step is initiated, in the course of and at the end thereof. Furthermore, the sequence steps may follow either directly or after a dwell time. The semi-finished product temperature may remain stable or may change during the dwell time. The essence is that the plastic deformation and tempering follow each other (do not occur at the same time).

The plastic deformation initial temperature of the semi-finished product may be lower than said plastic deformation final temperature. In a favourable embodiment, the temperature may rise by deformation heat without external heat supply. This may be achieved e.g., in a multi-axis forging device, a rolling mill, or some other forming machines where higher semi-finished product temperature is achieved by an intense plastic deformation. Under certain circumstances, the increase may contribute to relaxation processes in the deformed material.

However, the plastic deformation initial temperature of the semi-finished product may remain unchanged as the plastic deformation final temperature. This is achieved by a suitable plastic deformation intensity with respect to the semi-finished product temperature during the initial plastic deformation and natural or forced heat removal from the semi-finished product being deformed. The temperature increase is restricted during the plastic deformation in case that the relaxation and/or diffusion phenomena needs to be limited during the plastic deformation and immediately thereafter.

Alternatively, the plastic deformation initial temperature of the semi-finished product may be higher than said plastic deformation final temperature. It can be achieved e.g., at higher plastic deformation initial temperature of the semi-finished product and low-intensity plastic deformation where the deformation heat is unable to keep the plastic deformation initial temperature of the semi-finished product. Said method of treatment is favourable e.g., when the plastic deformation directly follows the previous tempering process without the temperature dropping to room temperature after the tempering. The grounds may be a logistic continuity of production line operations where time may be short to cool down the semi-

finished product, or an intention to deform at least partially at elevated temperature, e.g., to reduce the deformation resistance of the initial plastic deformation.

The plastic deformation initial temperature of the semi-finished product being processed may be equal to or different from the first tempering initial temperature of the semi-finished product.

A holding temperature at the first tempering may differ from the holding temperature at the additional tempering. When the sequence of plastic deformation and additional tempering following thereafter is repeated, the semi-finished product temperature during the plastic deformation and/or additional tempering may differ in the course of the second sequence from the plastic deformation semi-finished product temperature and/or during the additional tempering in the course of the first sequence. Again, the grounds may be logistic according to arrangement of the production line, or the temperature difference is desirable for achieving of the required material properties.

Said procedure is in particular suitable for the semi-finished products of steel having ferritic-carbidic structure at room temperature. The procedure specified herein may be used to get a material being stronger by several hundreds of megapascals than after traditional treatment, i.e., quenching and one tempering. Hence, steels being stronger by 20 – 35% can be provided, which is significant benefit from the technical point of view. At the same time, toughness of such steel is retained or even improved in some cases. The plastic properties such as ductility and contraction are usually slightly, but not too much, decreased.

Description of drawings

The exemplary embodiment of the present invention is described with reference to the drawings, in which

Fig. 1 shows a scheme of steps of heat and deformation treatment with one sequence of plastic deformation and additional tempering, where temperature differences over time are illustrated;

Fig. 2 shows a scheme of steps of heat and deformation treatment with two sequences of plastic deformation and additional tempering, where temperature differences over time are illustrated.

Exemplary embodiment of the invention

The exemplary embodiment of a metal semi-finished product heat and deformation treatment comprises a quenching 1 from quenching temperature T1 and a first tempering 3. An interface 2 between the quenching 1 and the first tempering 3 has a form of a dwell time at ambient temperature. Following the first tempering 3, a sequence consisting of a plastic deformation 4 to influence the material properties of a semi-finished product followed by additional tempering 5 is conducted at least once. This sequence follows the first tempering 3.

The plastic deformation 4 initial temperature T4a of the semi-finished product being processed equals in this case to the plastic deformation 4 final temperature T4b. At the same time, the plastic deformation 4 initial temperature T4a is higher than the first tempering 3 initial temperature T2 of the semi-finished product at the interface 2 between the quenching 1 and the first tempering 3. The first tempering 3 initial temperature T2 of the semi-finished product is lower than a martensitic transformation Mf finish temperature of said semi-finished product. The first tempering 3 temperature T3 is lower than an additional tempering 5 temperature T5.

The semi-finished product being processed comprises 54SiCr6 spring steel. In this way, the material yield strength was increased by several tens of percent. The method also influences other mechanical properties of the material, such as strength, ductility, contraction and toughness. The method is favourably applicable to a large group of steels intended for refinement and a wide range of aluminium alloys intended for precipitation quenching. The exemplary embodiment is shown in Fig. 1.

List of reference symbols

1 – quenching

2 – interface between quenching and first tempering

3 – first tempering

4 – plastic deformation

5 – additional tempering

T1 – quenching temperature

T2 – first tempering initial temperature

T3 – first tempering temperature

T4a – plastic deformation initial temperature

T4b – plastic deformation final temperature

T5 – additional tempering temperature

Mf – martensitic transformation finish temperature

Claims

1. A method of heat and deformation treatment of a metal semi-finished product comprising a quenching (1) with cooling down to temperature lower than a martensitic transformation finish temperature (Mf) of said semi-finished product material, the quenching (1) is followed by a first tempering (3) either directly or after a dwell time,
wherein furthermore, a sequence consisting of a plastic deformation (4) is conducted following the first tempering (3) to influence material properties of the semi-finished product and an additional tempering (5) following thereto, characterized in that
the first tempering (3) initial temperature (T2) of the semi-finished product being processed is lower than a martensitic transformation finish temperature (Mf) of said semi-finished product material.

2. The method according to claim 1 characterized in that the plastic deformation (4) initial temperature (T4a) of the semi-finished product being processed is lower than said plastic deformation (4) final temperature (T4b).

3. The method according to claim 2 characterized in that the plastic deformation (4) initial temperature (T4a) of the semi-finished product is increased to said plastic deformation (4) final temperature (T4b) by deformation heat without external heat supply.

4. The method according to claim 1 characterized in that the plastic deformation (4) initial temperature (T4a) of the semi-finished product being processed is equal to said plastic deformation (4) final temperature (T4b).

5. The method according to claim 1 characterized in that the plastic deformation (4) initial temperature (T4a) of the semi-finished product being processed is higher than said plastic deformation (4) final temperature (T4b).

6. The method according to any one of claims 1 to 5 characterized in that the plastic deformation (4) initial temperature (T4a) of the semi-finished product being processed differs from the first tempering (3) initial temperature (T2).

7. The method according to any one of claims 1 to 6 characterized in that the first tempering (3) holding temperature (T3) differs from the additional tempering (5) holding temperature (T5).

8. The method according to any one of claims 1 to 7 characterized in that the material of said semi-finished product is a steel having ferritic-carbidic structure at room temperature.

AMENDED CLAIMS
received by the International Bureau on 03 June 2022 (03.06.2022)

Claims

1. A method of heat and deformation treatment of a metal semi-finished product from material being steel having ferritic-carbidic structure at room temperature, the method comprising a quenching (1) with cooling down to temperature lower than a martensitic transformation finish temperature (Mf) of said semi-finished product material, the quenching (1) followed by a first tempering (3) either directly or after a dwell time,
wherein the temperature (T2) of the semi-finished product being processed is at the beginning of the first tempering (3) lower than a martensitic transformation finish temperature (Mf) of said semi-finished product material characterized in that following the first tempering (3), a sequence consisting of a plastic deformation (4) to influence material properties of the semi-finished product and an additional tempering (5) following thereto is conducted.

2. The method according to claim 1 characterized in that the temperature (T4a) of the semi-finished product being processed is at the beginning of the plastic deformation (4) lower than said plastic deformation (4) final temperature (T4b).

3. The method according to claim 2 characterized in that the temperature (T4a) of the semi-finished product being processed at the beginning of plastic deformation (4) is increased to said plastic deformation (4) final temperature (T4b) by deformation heat without external heat supply.

4. The method according to claim 1 characterized in that the temperature (T4a) of the semi-finished product being processed is at the beginning of plastic deformation (4) equal to said plastic deformation (4) final temperature (T4b).

5. The method according to claim 1 characterized in that the temperature (T4a) of the semi-finished product being processed is at the beginning of the plastic deformation (4) higher than said plastic deformation (4) final temperature (T4b).

6. The method according to any one of claims 1 to 5 characterized in that the temperature (T4a) of the semi-finished product being processed at the beginning of plastic deformation (4) differs from the temperature (T2) at the beginning of the first tempering (3).

7. The method according to any one of claims 1 to 6 characterized in that the first tempering (3) holding temperature (T3) differs from the additional tempering (5) holding temperature (T5).

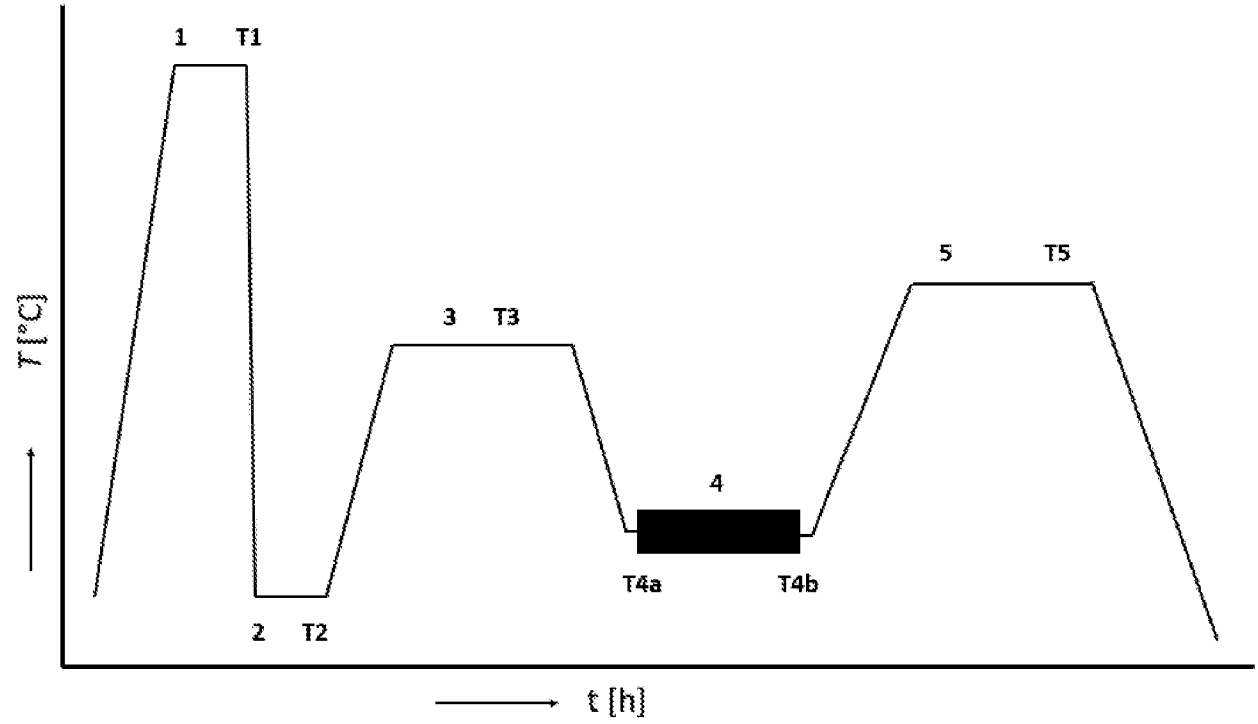
1 T1
T [°C]
3 T3
5 T5
4
T4a
T4b
2 T2
t [h]

Fig. 1

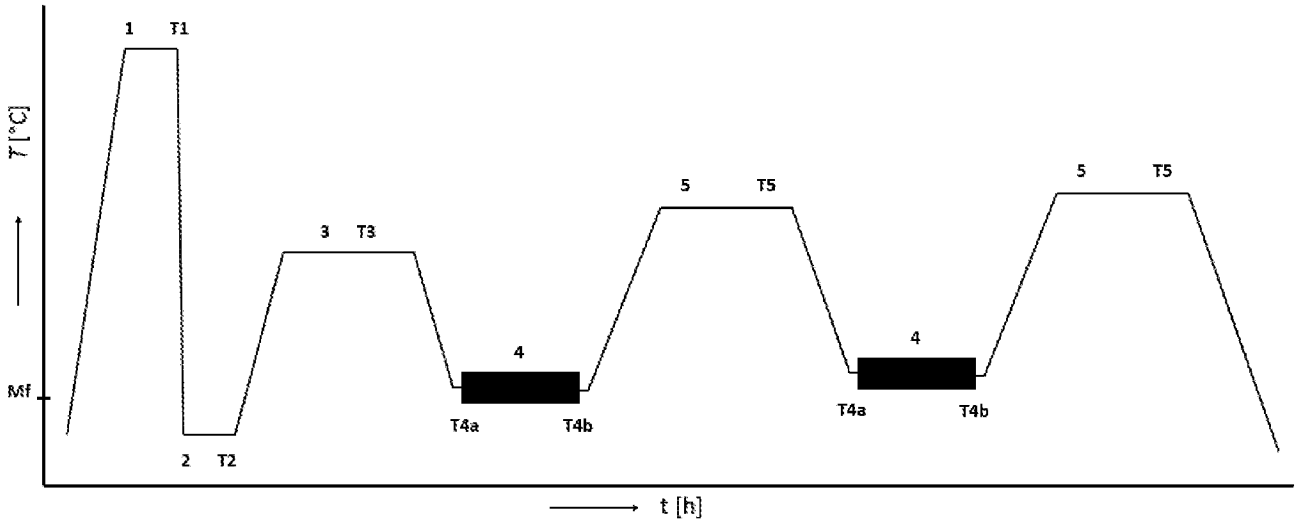
1 T1
T [°C]
3 T3
5 T5
5 T5
4
4
Mf
T4a
T4b
T4a
T4b
2 T2
t [h]

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/CZ2021/050149

A. CLASSIFICATION OF SUBJECT MATTER
INV. C21D7/13 B21D22/00 C21D9/48 C21D1/18 C21D1/26
C21D1/25 C21D7/10 C21D6/04
ADD. C21D9/02 C21D9/52
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 B21D

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 practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 109 594 024 A (ZHONGNENG TIANJIN INTELLIGENT TRANS EQUIPMENT CO LTD) 9 April 2019 (2019-04-09) 0063-0069; 0072-0086; 0117-0136	1-8
A	RU 2 287 592 C1 (G OBRAZOVATEL NOE UCHREZHDENIE [RU]) 20 November 2006 (2006-11-20) example, claim	1,2,6,8

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[x] Further documents are listed in the continuation of Box C.
[x] 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
"E" earlier application or patent but published on or after the international filing date
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 March 2022	04/04/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kreutzer, Ingo

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/CZ2021/050149

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	STOROJEVA L ET AL: "ON THE INFLUENCE OF HEAVY WARM REDUCTION ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF A MEDIUM-CARBON FERRITIC-PEARLITIC STEEL", ZEITSCHRIFT FUR METALLKUNDE, CARL HANSER, MUNICH, DE, vol. 95, no. 12, 1 December 2004 (2004-12-01), pages 1108-1114, XP001221255, ISSN: 0044-3093 p. 1109, left column; fig. 1, (d) -----	1-8

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/CZ2021/050149

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 109594024 A	09-04-2019	NONE	
RU 2287592 C1	20-11-2006	NONE	