

(19)



(11)

EP 1 753 889 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
12.04.2017 Bulletin 2017/15

(51) Int Cl.:
C21D 9/40 (2006.01) **C21D 1/18** (2006.01)
C22C 38/10 (2006.01) **C22C 38/12** (2006.01)

(21) Application number: **04748593.3**

(86) International application number:
PCT/NL2004/000357

(22) Date of filing: **19.05.2004**

(87) International publication number:
WO 2005/111253 (24.11.2005 Gazette 2005/47)

(54) **PUSH BELT AND MANUFACTURING METHOD THEREFOR**

SCHUBRIEMEN UND HERSTELLUNGSVERFAHREN DAFÜR

COURROIE DE POUSSEE ET SON PROCEDE DE FABRICATION

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PL PT RO SE SI SK TR**

(43) Date of publication of application:
21.02.2007 Bulletin 2007/08

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EP-A- 1 055 738

- **PATENT ABSTRACTS OF JAPAN** vol. 013, no. 399 (C-632), 5 September 1989 (1989-09-05) & JP 01 142021 A (SUMITOMO METAL IND LTD), 2 June 1989 (1989-06-02)
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- **ASM INTERNATIONAL HANDBOOK COMMITTEE: "MARAGING STEELS" 1990, METALS HANDBOOK, ASM INTERNATIONAL, 10TH EDITION, USA 1, XP002319725 cited in the application page 797 - page 798**

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Description

[0001] The present invention relates to a manufacturing method for push belts. The push belt is mainly used as the means for power transmission between two adjustable pulleys of the well-known continuously variable transmission applied in motor vehicles.

[0002] Such push belts, which are generally composed of transverse metal elements that are slidably incorporated along one or more laminated set of radially nested metal rings or hoops, are generally known. The rings of such belts are produced from maraging steel, which kind of steel combines a/o the characteristic of great tensile strength and good resistance against bending and/or tensile stress fatigue with a relatively favourable possibility to process the material towards the desired shape and characteristics. These shape and characteristics should not vary along the circumference of the rings in the end product, i.e. should for example not show any weaker spot at a welding seam where the ends of a strip of base material are welded together to form the endless ring shape.

[0003] These characteristics comprise a fair hardness of the core material for realising the properties of good tensile, yield and bending strength combined with a high resistance against metal fatigue and a wear resistant outer surface layer, which is provided with a maximum thickness such that bending of the ring is not hampered by cracking and such that the core material of the ring retains sufficient strength and elasticity. Resistance against fatigue is a significant feature of the rings because of the numerous number of load and bending cycles the belt is subjected to during its service lifetime.

[0004] The manufacturing method for producing such belts, at least for such rings thereof, as applied by Applicant during several decades by now, is disclosed in general terms by the European patent application EP-A-1 055 738.

As a part of the known preparatory process, the metal rings are aged in a separate and well known precipitation hardening process by heat treatment in the presence of a controlled atmosphere predominantly composed of nitrogen (N₂), during which ageing process intermetallic precipitates are formed throughout the ring material, and, subsequently, in a separate and well known gas -soft-nitriding process, a narrow surface layer is additionally hardened in this so-called case hardening process by heat treatment in the presence of a controlled atmosphere predominantly composed of ammonia (NH₃) and nitrogen (N₂), during which nitriding process non-metallic particles, i.e. nitrides, are formed predominantly in a superficial or i.e. thin surface layer of the ring material.

[0005] It may be considered a general aim, and in the field of ring manufacture for push belts it has been a long standing desire, to combine the fore-mentioned separate preparatory hardening processes into one. Such combined ageing and nitriding is as such well known for the base material, i.e. maraging steel, of which the belt rings

are made as is e.g. illustrated by the Metals Handbook, Vol. 1, 1978 of the American Society for Metals (ASM). In this respect a particular example is given (chapter "Maraging Steels", page 448) in which it is provided that considerable surface hardening of up to 65 to 70 HRC can be achieved at depths of up to 0.15 mm after nitriding for 48 hours at 455 °C. Where such typical example is suitable for many applications requiring extensive surface hardening, the example also demonstrates a problem encountered within the field of continuously variable transmission, i.e. the manufacture of the rings of the metal belts therefor.

[0006] The thickness or depth dimension of the case hardened surface layer in the above handbook example largely corresponds to the entire thickness of the metal rings involved in the present type belts. It has been the experience of Applicant that the known combined hardening process is quite difficult if not virtually impossible to apply, at least with the Titanium (Ti) containing alloys of maraging steel that are used up to now for the belt rings. It has been found that in dependency on the duration of such combined hardening process either the nitriding process part thereof is too severe, resulting in the hardened surface layer of the rings becoming too thick so that the resulting rings are too brittle, or that the ageing process part thereof is too mild, resulting in the core hardness of the rings not reaching the required level, so that the resulting rings have insufficient yield and tensile strength.

[0007] This finding is also confirmed by the above mentioned EP-A-1 055 738 application, where the invention sought to improve the hardening process of the rings, by indicating that such combined ageing and nitriding process is problematic in that it would be "difficult to adjust the atmosphere in order to achieve an appropriate ageing hardness and a nitride layer of suitable depth".

[0008] Yet it is still an aim of the current invention to arrive at a single hardening process for rings for the push belt in which ageing and nitriding are performed simultaneously, thereby considerably reducing costs of and time required for the production of the rings. Therefore, the goal of the invention is to provide other means, i.e. outside said known solutions, enabling the production of maraging steel rings for push belts by said single and combined hardening process, while resulting in the desired, i.e. required material properties for the surface layer and core material of said rings.

[0009] According to the invention, such can be done by the feature provided in the characterising portion of claim 1. As a feature underlying the present invention it was conceived that, where for so long a time it was sought to treat maraging steel in a single heating chamber or oven both for ageing and nitriding and where it could not be found satisfactorily adapt the process settings such as temperature, duration and atmospheric composition, such that material properties could be retrieved for the ring that were suitable for push belt application in a continuously variable transmission, it might be an option to

turn around the direction wherein the solution to the above-described problem is sought, i.e. to adapt the material rather than or in addition to adapting the process settings.

JP01142021 discloses a seamless metallic belt excellent in workability, material strength, fatigue strength, and wear resistance by forming a metallic belt from a seamless steel pipe made of Ni-Co-Mo steel having a composition consisting of, by weight, <0.01% C, <0.05% Si, <0.05% Mn, <0.01% P, <0.01% S, 16-19% Ni, 8-15% Co, 3-6% Mo, <0.01% Ti, <0.15% Al, <0.003% N, <0.0015% O, and the balance Fe.

[0010] For successfully implementing the above idea, it was further conceived that the material should be of a type showing the feature of relatively rapid ageing, such that within the short time required for nitriding process part for forming the hardened surface layer of desired thickness (case hardening) also a sufficient precipitation or age hardening of the core material would be realised.

[0011] The above basic principle according to the invention will now be elucidated by way of example, along a drawing in which:

Figure 1 figuratively represents the basic prior art ring age and case hardening processes;

Figure 2 graphically represents the temperature T (Y-axis) and time t (X-axis) involved in the prior art processes according to figure 1;

Figure 3 represents another prior art solution, avoiding a cooling down of the ring material in-between the age and case hardening processes.

Figure 4 graphically represents the temperature T (Y-axis) and time t (X-axis) involved in the prior art processes according to figure 2;

Figure 5 represents the solution according to the invention, in which the process parts of the known overall hardening process are combined into one, whereby the process duration and effort are significantly reduced;

Figure 6 graphically represents the temperature T (Y-axis) and time t (X-axis) involved in the proposed combined hardening process according to figure 5; and in which;

Figure 7 represents the feature of the material core hardness Hv (Y-axis) of two ring material compositions M1 and M2 versus the duration of the ageing or precipitation hardening process.

[0012] Figure 1 illustrates the relevant part of the known process as practised since the early years of metal push belt production. It comprises a first oven 1 for ageing or precipitation hardening of a ring 10 for the belt, which process predominantly determines the hardness of the ring core material, and a second oven 2 for surface layer or case hardening of the ring 10, which process predominantly determines the hardness of the ring surface layer material. Ageing mainly adds to the tensile and yield strength of the ring 10, while a hardened surface layer is

required as a means of protection against wear of the rings 10, due to for instance mutual friction between the rings and friction with a contacting surface of transverse elements of the belt. In the so-called push belt such transverse elements are incorporated mounted on and freely slidably along one or two sets of mutually nested rings 10. The known rings 10 are made of Titanium (Ti) containing maraging steel, which steel is further mainly composed of Nickel (Ni), Molybdenum (Mo), Cobalt (Co) and balance Iron (Fe). This type of maraging steel has the unique combination of features of high tensile and yield strength, high resistance against metal fatigue and also has other properties, such as good weldability, that make it suited for the production process used in push belt production.

[0013] For ageing of the ring material, it is subjected to a heat treatment in a controlled atmosphere predominantly composed of nitrogen (N₂), which treatment is performed in the first oven 1. Subsequently, a ring 10 is heat treated for case hardening, which is performed in the second oven 2, in a controlled nitrogen (N₂) and -gaseous-ammonia (NH₃) environment, which treatment is known as the gas soft nitriding process. The latter heat treatment is performed to form a surface layer of typically 25-35 microns of extreme hardness, due to the formation of a nitrided surface layer in the ring material. This surface layer thickness compares to a total ring thickness in the range between 150 and 200 microns, typically about equal to 185 microns. In-between these two heat treatments the rings 10 are transported between the ovens 1, 2 and, as a consequence, cool down.

[0014] Figure 2 indicates that both the above-mentioned hardening processes are performed during a certain period of time t, whereby the processing time for the ageing process is indicated by 'H' and for the nitriding process by 'N'. A typical value for H may be 60 minutes at a processing temperature T between about 450 to 500 °C. The nitriding process may, typically, be performed for a somewhat shorter period and lasts between 45 to 60 minutes at a processing temperature T similar to that of the age hardening process. The resulting hardness of the ring core material typically is around 600 Hv (Vickers hardness), while the surface hardness of the rings 10 is typically around 900 Hv.

[0015] Figure 3 illustrates a recent prior art improvement disclosed by EP-A-1 055 738 of the above-mentioned separate hardening processes. In this improvement and immediately after the first heat treatment, the rings 10 are transferred from the first oven 1 to the second oven 2 through an intermediate space 3 by sequentially opening and closing intermediate doors 4 and 5 of such oven system 1-5 and by simultaneously moving the rings 10 between the subsequent (oven) spaces 1, 3 and 2. In-between cooling down and subsequent re-heating of rings 10 may in this way be omitted.

[0016] Figure 4 illustrates the singleness of the improved prior art process and shows a timesaving effect thereof in that at least a part of the cooling down and re-

heating time between the ageing and nitriding processes is saved. However, because of the ultimately small thickness of the rings 10 and the constant operation of the ovens 1, 2, such effect is minimal.

[0017] According to a well-known principle, indicated by the above-mentioned ASM Metals Handbook of 1978, a significant gain in required total process time of the hardening processes may be achieved by the simultaneous core and case hardening, i.e. within a single oven 6. This principle and effect are indicated by figures 5, 6 and 7.

[0018] The principle illustrated by figures 5 and 6 has long been striven for, however has never been reached in the field of ring manufacture for push belt. The focus for realising this principle has been on fine-tuning process time, temperature and atmosphere for realising the required mechanical material properties that can be obtained in the prior art separated hardening processes. However, this has never been realised with satisfying results: either the nitrided ring surface layer proved to be too thick and brittle, or the ring core hardness was insufficient.

[0019] In the solution according to the invention, surprisingly, a novel and entirely different approach has been taken in that not the settings of the hardening processes have been studied per se, but rather the ring material composition that is to be treated thereby. The idea underlying the invention is to provide a maraging steel composition that allows a considerable reduction of the processing time H for the ageing process, such that the required ring core hardness can be achieved within the processing time N required for the nitriding process, preferably at otherwise ordinary, i.e. known process settings. At doing so, it was conceived that rather than striving for the general aim of lowering the cost price of the maraging steel, a slight cost price increase could be accepted when the benefits of the combined hardening process would at the same time be realised.

[0020] According to the invention the solution is found in selected a new ring material, i.e. a maraging steel composition that is characterised by the Titanium element being largely, if not almost entirely omitted from the steel, i.e. a Titanium content that amounts to less than 0.1 mass-%, while at the same time the Cobalt content of the maraging steel is increased to 16.5 mass-%, preferably to within a range of 85% to 100% of the Nickel content. With such a new type of maraging steel, it was realised in accordance with the aim underlying the invention that the rings 10 could be aged and nitrided simultaneously in a single one oven 6 in a combined hardening process with while obtaining the required mechanical and other material properties as discussed in the above. A preferred material in this respect further satisfies the requirement that the product of mass-% Cobalt and mass-% Molybdenum is equal to or larger than 50, but preferably smaller than 200.

[0021] The maraging steel M2 used here as an example, is according to the invention consisting of less than

0.1 mass-% Ti, 18 mass-% Ni, 5 mass-% Mo, 16.5 mass-% Co and balance Fe, which compares to the conventional maraging steel M1 that is provided with about 0.45 mass-% Ti, 18 mass-% Ni, 5 mass-% Mo, 9 mass-% Co and balance Fe. With such a new ring material M2, the strengthening effect of Cobalt in association with Molybdenum is used in an advantageous manner. It is considered that Cobalt will lower the solubility of Molybdenum in the martensite matrix of the steel, enhancing precipitation of Mo-rich intermetallic phases during ageing, and enhancing, i.e. shortening, the required age hardening processing time H of the maraging steel M2. With this specific example of the composition of the maraging steel M2, a case hardened (nitrided) surface layer of the rings 10 of 28 microns was realised in the combined hardening, i.e. ageing and nitriding processes, at a total ring thickness of 185 microns. Moreover the additional advantage of an increased (i.e. with respect to the conventional maraging steel M1) ring core hardness of about 640 Hv was surprisingly realised with this maraging steel composition M2, while otherwise completely satisfying the required mechanical material properties.

[0022] Of course, the maraging steel composition may be fine-tuned within the ranges and requirements defined by the invention to reach the desired nitrided surface layer thickness in relation to the total ring thickness.

[0023] The feature enabling the combined hardening process for belt rings 10 is illustrated along the graph of figure 7. In figure 7, the development over time t of the material hardness Hv due to ageing (precipitation hardening) has been indicated for both the conventional maraging steel M1 for belt rings 10 and the new maraging steel M2 at certain processing temperatures T.

[0024] The graph, in first place, shows that even at 480 °C the maximum (core) hardness level Hv of rings 10 of conventional maraging steel M1, i.e. as a result of age or precipitation hardening is reached only after a significantly long processing time t of up to 120 min. or 2 hours, whereas the newly selected maraging steel M2 reaches the same hardness level Hv must faster even at the lower processing temperature of 440°C. Moreover, the maximum hardness level Hv of the newly selected maraging steel M2 is considerably higher than that of M1, which is considered an advantageous feature for the belt rings 10.

[0025] The processing time t range between 45 and 65 minutes and temperature T range between 440°C and 480°C that, according to the graph of figure 7, are at least allowable for realising the preferred material core hardness Hv of about 640 Hv, where indeed found to also allow the known nitriding process to be simultaneously performed in a combined hardening process, while obtaining the desired ring surface layer of required thickness and hardness. Such would clearly not be the case for the conventional maraging steel M1 that, according to the graph of figure 7, requires the ageing process to be performed for 2 hours at 480 °C (or for an even longer period at a lowered temperature, or at an even higher temperature for a shortened period), which latter process

settings do not conform to those required by the desired nitriding process.

[0026] The invention will not be defined further along a set of claims and, apart from the preceding description, also relates to all details therein, and to all details and aspects in the discussed drawing which are directly and unambiguously derivable there from, at least by a man skilled in the art.

Claims

1. Method of manufacturing an endless ring of a push belt for continuously variable transmissions, in which the material of the ring is a maraging steel and in which said ring is subjected to a first heat treatment for realising a core hardening of the ring material through ageing and to a second heat treatment under the presence of ammonia gas (NH₃) for realising a case hardening of the ring material through nitriding, **characterised in that** the first and second heat treatments are performed in a combined hardening process, simultaneously and in a single heating chamber for 45 to 65 minutes at 440°C to 480 °C and **in that** the maraging steel used has a composition consisting of less than 0.1 mass-% Titanium, 18 mass-% Nickel, 5 mass-% Molybdenum, 16.5 mass-% Cobalt and balance Iron.

Patentansprüche

1. Verfahren zur Herstellung eines Endlosrings eines Schubriemens für stufenlose Getriebe, wobei das Material des Rings ein martensitaushärtender Stahl ist und wobei der Ring einer ersten Wärmebehandlung zur Ausführung eines Kernhärtens des Ringmaterials durch Alterung und einer zweiten Wärmebehandlung in Gegenwart von Ammoniakgas (NH₃) zur Ausführung einer Einsatzhärtung des Ringmaterials durch Nitrieren unterzogen wird, **dadurch gekennzeichnet, dass** die erste und die zweite Wärmebehandlung in einem kombinierten Aushärtungsverfahren gleichzeitig und in einer einzigen Heizkammer für 45 bis 65 Minuten bei 440 °C bis 480 °C durchgeführt werden, und dadurch, dass der verwendete martensitaushärtende Stahl eine Zusammensetzung aufweist, die aus weniger als 0,1 Massen-% Titan, 18 Massen-% Nickel, 5 Massen-% Molybdän, 16,5 Massen-% Kobalt und Resteisen besteht.

Revendications

1. Procédé de fabrication d'un anneau sans fin d'une courroie de poussée pour des transmissions à variation continue, dans lequel le matériau de l'anneau

est un acier maraging et dans lequel ledit anneau est soumis à un premier traitement par la chaleur afin de réaliser une trempe à cœur du matériau de l'anneau par vieillissement et à un second traitement par la chaleur en présence d'ammoniac (NH₃) afin de réaliser une trempe superficielle du matériau de l'anneau par nitruration, **caractérisé en ce que** les premier et second traitements par la chaleur sont effectués dans un procédé de durcissement combiné, de manière simultanée et dans une chambre de chauffe unique pendant 45 à 65 minutes à 440°C à 480°C et **en ce que** l'acier maraging utilisé présente une composition constituée de moins de 0,1 % en masse de titane, 18 % en masse de nickel, 5 % en masse de molybdène, 16,5 % en masse de cobalt et de fer pour le reste.

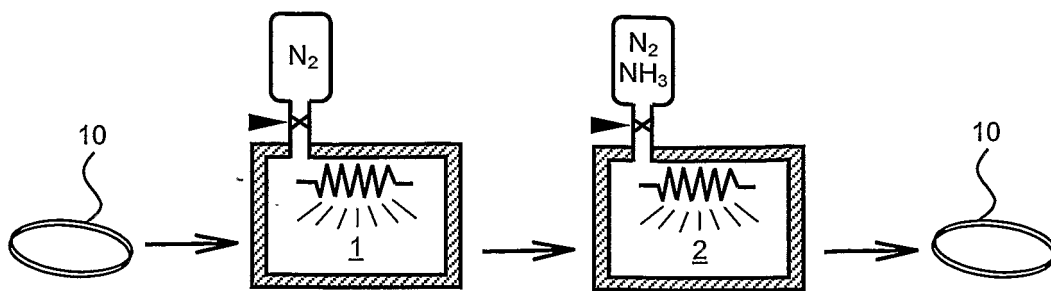


FIG. 1

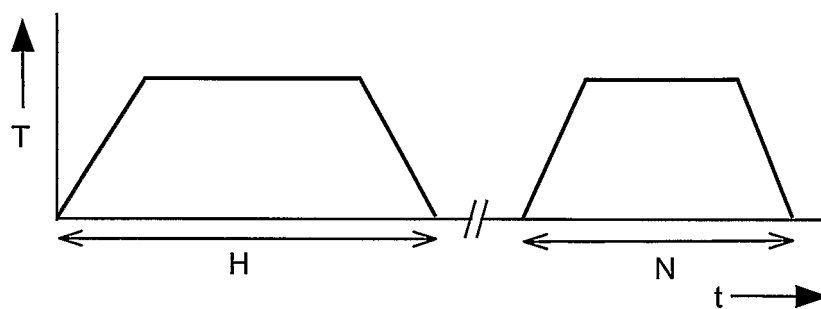


FIG. 2

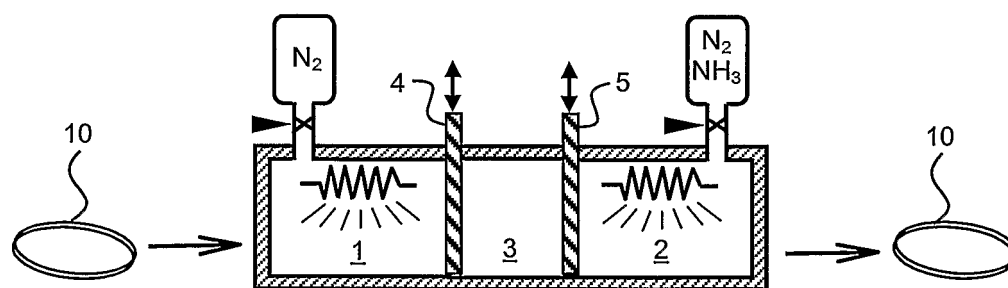


FIG. 3

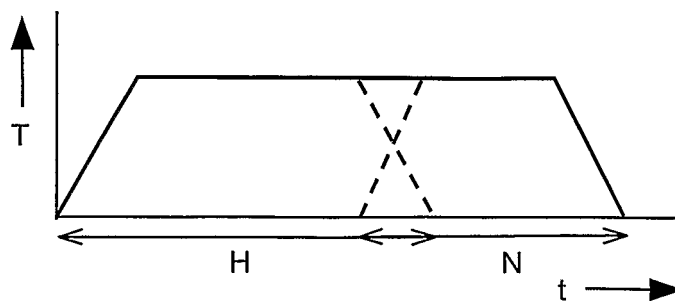


FIG. 4

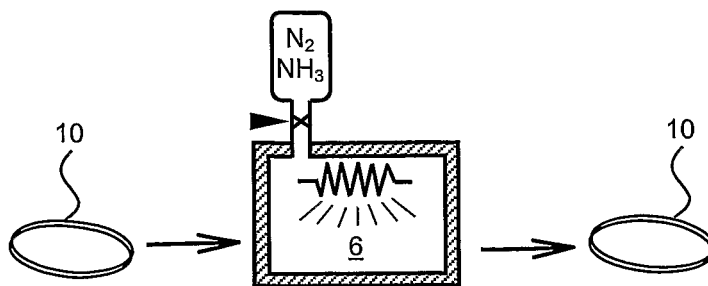


FIG. 5

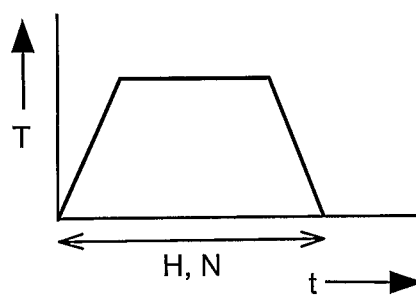


FIG. 6

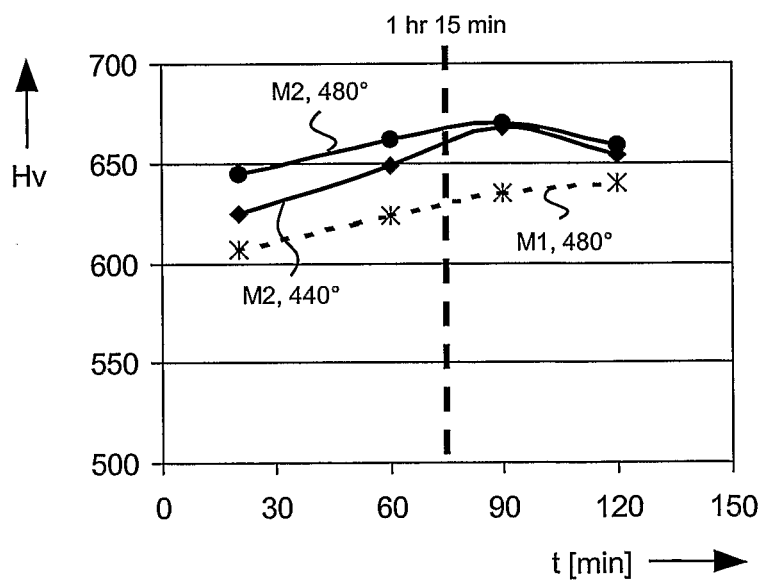


FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 01142021 A [0009]

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- Maraging Steels. 448 [0005]
- ASM Metals Handbook. 1978 [0017]