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(54) **METHOD FOR CONTROLLED COOLING OF FORGED PARTS MADE OF MICROALLOYED STEEL**

(57) The invention relates to a method for controlled cooling of forged parts made of microalloyed steel, comprising the following sequence of actions: forming a part made of microalloyed steel by means of conventional forging; depositing the part, at a temperature comprised within the range of 1100-1300 °C, on a conveyor element (1); linearly moving the conveyor element (1) for first cooling, in open air, of the part; introducing the part into a closed chamber (2) for second cooling which is controlled and slowed down by means of air currents; removing the part from the closed chamber (2) for third cooling of the part, in open air; introducing the part inside a sudden cooling chamber (3) for sudden cooling of the entirety of the surface of the part by direct contact with a liquid coolant; and removing the part and transporting to a machining area.

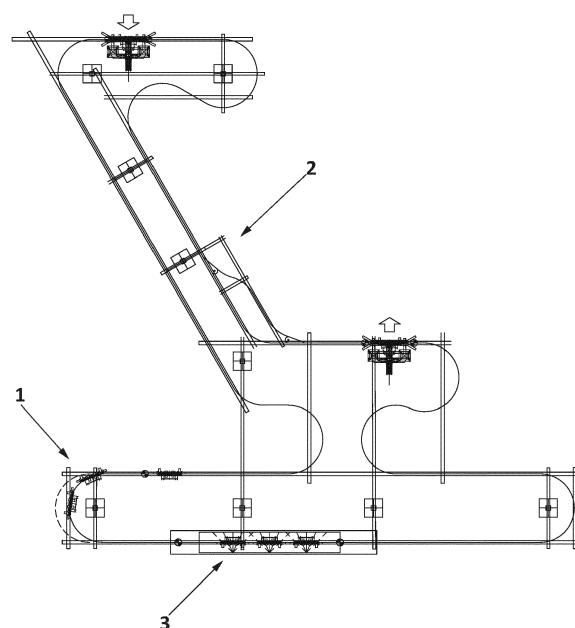


FIG. 1

Description

Object of the invention

[0001] The present invention falls within the technical field of methods and devices for spray tempering, as well as within the field of thermal treatments for crankshafts and differentiated thermal treatments for the outside and inside of a part, and it refers in particular to a method for controlled cooling of forged parts made of microalloyed steel.

Background of the invention

[0002] Microalloyed steel, or HSLA (High-strength low-alloy) steel, is a type of metal alloy with improved mechanical properties and greater resistance to corrosion than other types of steel, and which is also differentiated by the fact that it is not made to have a specific chemical composition, but rather to meet certain mechanical properties.

[0003] The qualities and compositions of microalloyed steels are set out in Standard UNE-EN 10267, relating to ferritic-pearlitic steels for precipitation hardening from hot-working temperatures. In general, microalloyed steels have a carbon content between 0.05 % and 0.50 % by weight in order to maintain suitable formability and weldability. Other elements of the alloy include up to 2.0 % manganese and small amounts of copper, nickel, niobium, nitrogen, vanadium, chromium, molybdenum, titanium, calcium, rare earth elements, or zirconium. Copper, titanium, vanadium and niobium are also added, in order to increase strength.

[0004] These elements are intended to alter the microstructure of the carbon steels, which is generally a mixture of ferrite-pearlite, in order to produce a very fine dispersion of carbide alloys in an almost pure ferrite matrix. This eliminates the effect of reducing the toughness caused by the volume fraction of pearlite, while maintaining and increasing the strength of the material by refining the grain size, which, in the case of ferrite, increases the creep stress by 50 % each time the average grain size is halved.

[0005] Due to their greater strength and toughness, microalloyed steels usually require between 25 % and 30 % more energy to be formed, compared to carbon steels. However, unlike these carbon steels, they prevent the need to be subjected to heat treatments after being forged, such as tempering, causing an improvement in productivity. These steels are usually used to make elements designed to withstand high stresses or which need a high stress-weight ratio, such as crankshafts.

[0006] In this specific case of automotive crankshafts, microalloyed steels used in forged crankshafts usually correspond to the qualities referenced in Standard UNE-EN 10267 as 38MnVS6 and 46MnVS6, and have carbon contents usually comprised between 0.34 and 0.49 % of carbon and 1.2 to 1.6 of manganese, the main feature

thereof being the use of alloy elements such as niobium, titanium and vanadium in lower amounts, which are able to maintain a very fine grain size after forging, which guarantees the good mechanical features required.

[0007] In the usual methods for forming parts made of microalloyed steel, after a forging and deburring process, and before being subjected to a shot blasting, the parts are cooled in a controlled manner. As a result of this controlled cooling, a ferritic-pearlitic microstructure is achieved. The mechanical strength of these steels is achieved due to the combination of factors such as grain refining with hardening due to interstitial solid solution, to the precipitation of carbides and nitrides, and to the hardening from phase transformation.

[0008] The main factor of these factors is the grain refining, a phenomenon based on the fact that at high temperatures precipitates of very small size are present which prevent the austenite grains from growing during the manufacturing process at high temperatures, thereby preventing the worsening of mechanical features such as toughness and ductility.

[0009] The cooling speed from the final forging temperature is the process factor which affects the final features of the forged parts with microalloyed steels the most, for which reason industrial systems are commonly used which enable microalloyed forging steels to cool freely in air, with help from coolers and combinations of both. This process, known as controlled cooling, guarantees that the microstructure and final mechanical features are the ones required.

[0010] High cooling speeds lead to a high hardness of the part and, therefore, to a high strength and elastic limit and a very low elongation and striction and low toughness, with the consequent high fragility. Moreover, low cooling speeds result in parts with a very low hardness and, therefore, low strength and elastic limit, high elongation and striction and, usually, high toughness.

[0011] The optimal cooling speed is mostly determined by the content of alloy and residual elements of the steel. By controlling the composition, it is possible to achieve the desired mechanical properties, in a wide range of sections and cooling conditions. By means of the cooling in air of the forged parts, the desired mechanical and tough properties can be obtained.

[0012] As the cooling speed increases, there is a slight tendency to refine the ferrite networks at the boundary of the austenitic grain; as the cooling speed increases, the ferrite fraction is reduced, and this may be the cause of the increase in the strength properties. For this reason, the final properties exhibited by a thermally and mechanically processed product are determined by the microstructure at the end of the processing.

[0013] Several patent documents relating to processes for the controlled cooling of forged parts are known in the current state of the art. For example, the European patent with publication number EP2103696 describes a method for obtaining forged parts with optimal fatigue performance, without needing to temper the entire part, since

that would make the subsequent machining of the part difficult.

[0014] The method is based on cooling a forged part in a controlled manner by means of surface spraying, on the newly-forged part, of a volume of liquid coolant. The objective is, within one same part, to obtain areas wherein the performance in response to the machining is optimal, and areas wherein the fatigue performance is optimal, thus differentiating, within one same part, between the axial portion and the sides, and therefore performing sprays specifically localized on certain points.

[0015] Moreover, the European patent with publication number EP3128038 discloses a hot-stamped steel, including a steel base metal with a tempered portion having a hardness corresponding to 85 % or less of the highest cooling hardness; and a coating layer of Zn that is formed in the tempered portion of the base metal. The Zn coating layer includes a solid solution layer including a solid solution phase containing Fe and Zn.

[0016] Finally, the US patent with publication number US2012241058 describes a cast iron cast part, in particular a cast crankshaft, having a first layer made of ausferrite, and a second layer, adjoining the interior, made of ausferrite and troostite.

[0017] It should therefore be noted that no documents are known in the current state of the art regarding methods for controlled cooling of forged parts wherein a microalloyed steel is started with, without needing subsequent heat treatment, in order to finally obtain a part with optimal fatigue strength.

Description of the invention

[0018] As indicated above, microalloyed steels are steels with a low amount of alloy and high strength resulting from the optimisation of the alloy and from a forming followed by a controlled cooling, the end result of which is a ferritic-pearlitic microstructure with mechanical features suitable for the required application. With this objective, the controlled cooling must always respect the cooling speeds corresponding to the transformations marked on the TTT curve (time-temperature-transformation) corresponding to the quality of steel in question, in order to guarantee the desired transformation.

[0019] The object of the invention consists of a method for controlled cooling of forged parts made of microalloyed steel wherein, with the aim of accelerating the decrease in temperature of a part to a forging temperature in a controlled manner, the part, previously cooled in open air and at an even higher temperature, is subjected to sudden surface cooling by direct contact with a liquid coolant.

[0020] Said direct contact with a liquid coolant, which preferably consists of spraying a volume of water from a plane above the part, achieves sudden cooling of the surface, which induces residual stresses in the vicinity of the outermost surface of the part which contribute to the strengthening thereof, while the inner core is hardly

affected, wherein the temperature thereof hardly decreases and the properties thereof are hardly affected.

[0021] From this combination of a surface with high surface compression stresses and an unaltered core, a part emerges with the aforementioned optimal fatigue strength.

[0022] Since the parts thus cooled have to be subsequently subjected to additional mechanical treatments, preferably shot blasting, it is necessary to note at this point that the surface thickness of the part affected by the sudden cooling, and the consequential structural change, must be greater than the excesses from machining, so that it is not altered or lost during said machining.

[0023] Thus, a newly-forged part, at a high temperature, is deposited in transportation means, generally hung from a hook fastened to a carousel which moves linearly. Thus, the part advances in an open space, in direct contact with the surrounding air, such that a first phase of rapid cooling occurs.

[0024] Subsequently, it continues advancing in order to enter a closed chamber with a controlled atmosphere, wherein more controlled cooling of the air is produced, in this case slower, thanks to which the formation of different structures of the ferrite-pearlite is prevented, which, as already indicated, is the optimal structure in the case of microalloyed steels.

[0025] After this cooling by means of air in a controlled atmosphere, the part runs once again through a space with open air during a brief interval of time, then being subsequently introduced into a closed area, known as a sudden cooling chamber, wherein it is subjected to the sudden cooling of the most superficial area thereof, by means of direct contact with the liquid coolant. After said sudden cooling, the part is removed for the subsequent mechanical treatment thereof.

[0026] The residual stress generated in the part depends on a plurality of factors, among which it is worth noting the quality and composition of the microalloyed steel used, as well as the cooling gradient applied. As for the first factor, the higher the elastic limit of the material, the greater the range of residual stresses that will be able to be achieved, always taking into account that the elastic limit must not be exceeded in order to prevent unwanted deformations.

[0027] As for the gradient or cooling speed, it should be noted that the more sudden the cooling from the temperature that it is at before being sprayed with liquid coolant, the greater the residual stress that will be generated, always with the limitation of the material and the mechanical features thereof. This cooling gradient will depend in turn, first, on the range of temperatures to be reached, which will determine the microstructure generated in the steel.

[0028] Another fundamental factor is the sudden cooling means used, and the form of applying them to the part. Thus, in a preferred embodiment of the method, water is applied by means of nebulisation, although the use of other liquid coolants and other means of applica-

tion, such as for example submersion, are also envisaged.

[0029] Likewise, the features of the newly-obtained part made of alloyed steel part by means of forging are also a relevant factor for determining the cooling gradient. Thus, for example, the volume thereof, the surface exposed to the cooling means, or the geometry of the part, by which certain areas of the surface thereof may be more exposed.

[0030] There are other determining factors of the cooling gradient, such as the distance at which it is located from the spray nozzle, in the case of liquid spraying, or the distance between two consecutive parts arranged in the transportation means, since they can interfere both with the volume of liquid which impacts the part and with the mutual transmission of heat.

[0031] Although in the current state of the art the controlled cooling of parts by projecting a coolant is known, none of the documents seems to anticipate the method described above, wherein the forged parts made of microalloyed steel are, in a first phase, left to cool to room temperature and, in a second phase, nebulised with a liquid coolant, in order to thereby make parts with optimal fatigue strength without needing additional thermal treatments.

Description of the drawings

[0032] As a complement to the description provided herein, and for the purpose of helping to make the features of the invention more readily understandable, in accordance with a preferred practical exemplary embodiment thereof, said description is accompanied by a set of drawings which, by way of illustration and not limitation, represent the following:

Figure 1 shows a schematic view of an installation for performing the method for controlled cooling of forged parts made of microalloyed steel.

Preferred embodiment of the invention

[0033] A detailed explanation of a preferred exemplary embodiment of the object of the present invention is provided below with the help of the figures referred to above.

[0034] The method for controlled cooling of forged parts made of microalloyed steel described is preferably designed for automotive crankshafts forged in microalloyed steel, although it is equally applicable to other types of parts forged in microalloyed steel and intended to be subjected during the useful life thereof to prolonged and high mechanical fatigue.

[0035] Figure 1 schematically illustrates an installation for performing the method. Thus, said method begins after the outlet of a part made of microalloyed steel formed by means of a conventional forging process, at an approximate temperature comprised within the range of 1100-1300 °C.

[0036] The part, at that high temperature, is deposited on a conveyor element (1), which in this preferred embodiment consists of a conveyor belt provided with a plurality of hooks from which the parts are suspended.

[0037] The conveyor element (1) moves linearly, putting the part in direct contact with the surrounding open air, such that a first quick cooling to room temperature occurs. Subsequently, the conveyor element (1) moves the part, at a temperature that has already been significantly reduced, to the inside of a closed chamber (2), wherein an atmosphere controlled by means of air currents which are generated and controlled externally is maintained.

[0038] In the closed chamber (2) a second cooling of the part is performed, in this case slowed down, with which the formation in the microalloyed steel of different structures of the ferrite-pearlite is prevented, which is considered as optimal.

[0039] The set of the coolings in air of the part, both in open air and in a controlled atmosphere inside the closed chamber (2), lasts for a total of 17 minutes, decreasing the surface temperature of the part from the forging temperature to a temperature comprised in the range of 350-650 °C.

[0040] The conveyor element (1) removes the part from the inside of the closed chamber (2) to an open area again in open air, wherein it remains for a period of approximately 4 minutes for a third cooling.

[0041] Subsequently, the conveyor element (1) introduces the part inside a sudden cooling chamber (3) in order to be subjected to sudden surface cooling by direct contact with a liquid coolant. In the preferred embodiment described herein, said contact is produced by means of spraying a volume of water on the steel part from a plane above it.

[0042] The parts remain inside the sudden cooling chamber (3) for a period of time comprised in the range of 120-180 seconds, during which time the surface temperature thereof descends suddenly from 500-600 °C to 60-70 °C. It has been determined that, after one or two seconds of being subjected to contact with the liquid coolant, the surface temperature of the part decreases to a value comprised in the range of 80-120 °C.

[0043] Homogeneous cooling of the surface of the part prevents subsequent sudden surface reheating due to the residual heat coming from the core of the part, which has not been cooled. The surface of the part is understood as the outermost 3-5 mm thereof.

[0044] The part thus cooled is removed from the sudden cooling chamber (3) by the conveyor element (1) in order to be transported until it is unloaded in a machining area, wherein it is finally subjected to mechanical transformations, preferably shot blasting.

[0045] Thus, a forged part made of microalloyed steel is obtained, the surface of which has high compression stresses which give it optimal fatigue strength during the useful life thereof.

Claims

60-70 °C.

1. A method for controlled cooling of forged parts made of microalloyed steel, **characterised in that** it comprises the following sequence of actions: 5
 - forming a part made of microalloyed steel by means of conventional forging,
 - depositing the part, at a temperature comprised within the range of 1100-1300 °C, on a conveyor element (1), 10
 - linearly moving the conveyor element (1) for first cooling, in open air, of the part,
 - introducing the part into a closed chamber (2) for second cooling which is controlled and slowed down by means of air currents, 15
 - removing the part from the closed chamber (2) for third cooling of the part, in open air,
 - introducing the part inside a sudden cooling chamber (3) for sudden cooling of the entirety of the surface of the part by direct contact with a liquid coolant, and 20
 - removing the part and transporting to a machining area. 25
2. The method according to claim 1, **characterised in that** the direct contact between the part and the liquid coolant is performed by means of spraying a volume of the liquid coolant on the part. 30
3. The method according to claim 2, **characterised in that** the spraying is performed from above the part.
4. The method according to any of the preceding claims, **characterised in that** the liquid coolant is water. 35
5. The method according to any of the preceding claims, **characterised in that** the part is an automotive crankshaft. 40
6. The method according to claim 1, **characterised in that:**
 - the first cooling and the second cooling last for a total of 17 minutes, and 45
 - the surface temperature of the part after the first cooling and the second cooling is comprised within the range of 350-650 °C. 50
7. The method according to claim 1, **characterised in that:**
 - the sudden cooling of the part inside the sudden cooling chamber (3) lasts for a period of time comprised in the range of 120-180 seconds, and 55
 - the surface temperature of the part after the sudden cooling is comprised within the range of

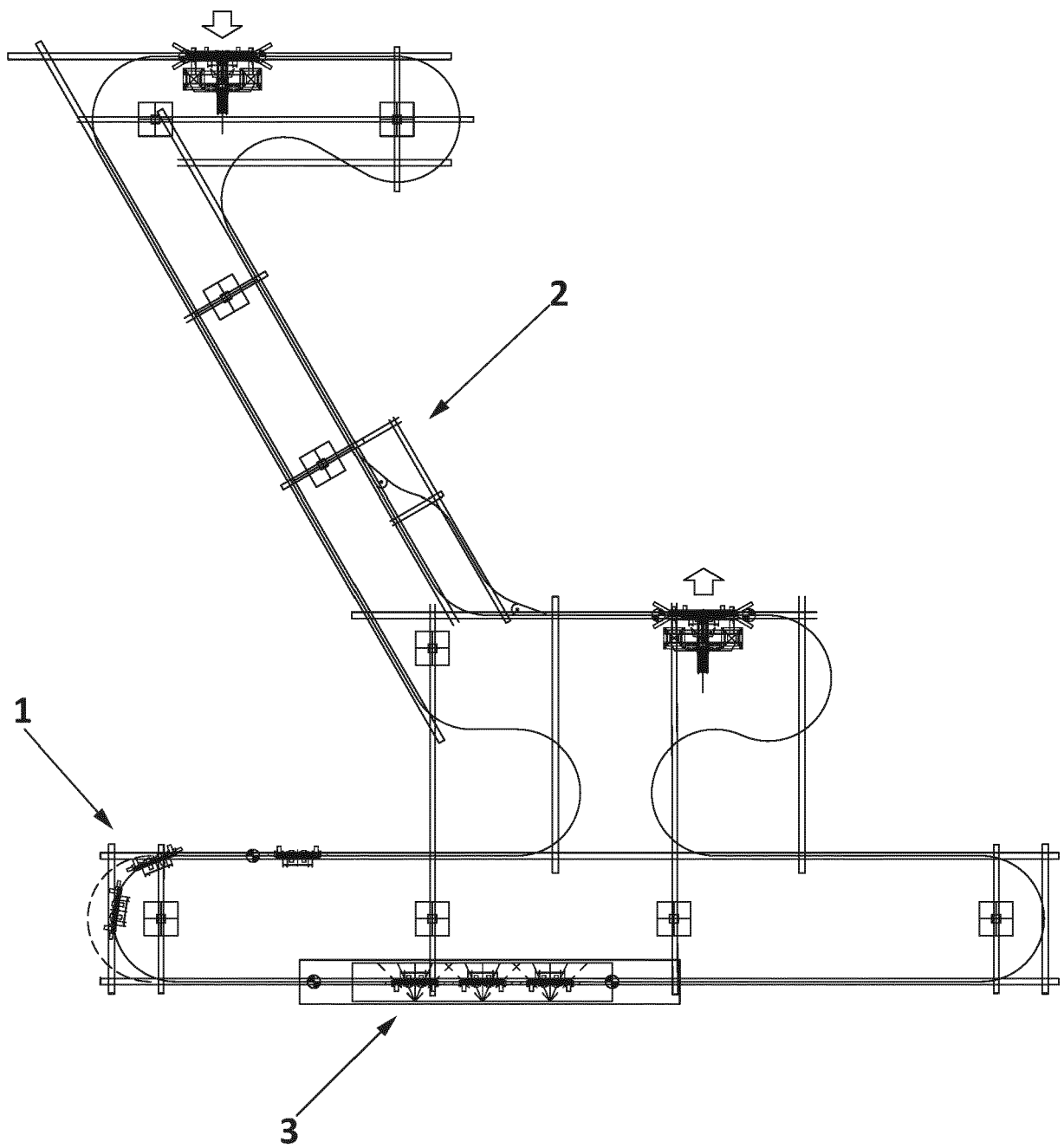


FIG. 1



EUROPEAN SEARCH REPORT

 Application Number
EP 20 38 2044

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 24 June 2020	Examiner Abrasonis, Gintautas
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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