

Method and device for welding components, which can be
travelled upon, of a track by flash butt welding

The invention relates to a method and a device for welding
5 components, which can be travelled upon, of a track, in
particular rails, by means of flash butt welding.

In the flash butt welding of parts to be butt-jointed
together, such as rails, the joining parts are clamped in a
10 butt welding machine and brought into contact after switching
on the current, wherein in a first phase a straight flashing
takes place, which serves to level out irregularities in the
abutting surfaces of the connection. In a subsequent
preheating phase, the energized joining parts are moved
15 against each other with a certain contact force and pulled
apart again, and a high heating occurs at the contact points
due to the electrical resistance. This process is repeated
several times until sufficient heating has formed over the
entire cross-section and the abutting surfaces have become so
20 warm that the energy supplied is sufficient to initiate the
subsequent flash-off process. In the flashing phase, the
material is melted off at the abutting surfaces at intense
sparking and brought to welding temperature as uniformly as
possible, whereupon the actual welding process takes place in
25 an upsetting process, in which the abutting surfaces of the
two parts, brought to welding temperature, are pressed
together with the required welding force after switching off
the current. The molten material regions are pressed out of
the contact surface regions into a welding bead.

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After upsetting, the contact force between the joining parts
is maintained for some time or gradually or continuously
reduced.

The welding process causes microstructural changes in the welding joint and in the adjacent heat-affected zones, which adversely affect the component properties, in particular the hardness. The welding region, i.e. the welding joint and the adjacent heat-affected zones, is therefore subjected to heat treatment in some cases. This usually comprises normalization, consisting of austenitizing and subsequent accelerated cooling in air, thereby eliminating microstructural irregularities and achieving a fine-grained, uniform microstructure with reproducible strength and deformability properties.

Normalization is carried out in a heat treatment device separate from the butt welding machine. The heating is usually carried out by means of inductive heating using an inductor adapted to the rail cross-section or by means of a burner flame. Alternatively, the use of a resistance heater has also been proposed.

There is a need for improved heat treatment, which leads to an increase in hardness at the rail head and a fine-grained pearlitic structure with a very fine ferrite network.

The present invention therefore aims to further develop a flash butt welding method with respect to said properties.

In order to achieve this object, the invention provides, according to a first aspect, a method for welding components, which can be travelled upon, of a track, in particular rails, by flash butt welding in a welding device, comprising the steps of straight flashing, preheating, flashing and upsetting, wherein the upsetting process generates a welding

region, whereupon the welding region, from the welding heat, is subjected to a cooling step in which an austenitic structure of the welding region is converted into a pearlite structure, whereupon the welding region is subjected to a reheating step in which the welding region is heated to above the Ac1 conversion temperature, wherein the heating is performed by electrical resistance heating in the welding device using the power source that is used for the straight flashing, preheating and flashing, whereupon a region of the component coming into contact with a wheel, particularly a rail head is subjected to cooling in the welding region.

The invention is thus based, on the one hand, on a special design of the individual steps of a heat treatment and, on the other hand, on the idea of carrying out the heat treatment in interaction with the welding process in the welding device itself. Because the welded rails or track components for the heat treatment do not have to be removed from the welding device, the reheating step can be carried out immediately after the cooling step. Herein, cooling is carried out, which is just sufficient for an austenitic structure of the welding region to be converted into a pearlite structure. Further cooling, which would take place during a period of time required for the displacement of the rails into a position removed from the welding device, does not have to be accepted. This increases energy efficiency because the residual heat lost in this way does not have to be reintroduced in the subsequent reheating process.

Preferably, the cooling step immediately following the welding process is carried out in ambient air with natural convection.

According to a preferred embodiment, the cooling step is carried out to a temperature of the welding region of less than 500 °C. This ensures that the cooling curve in a time-temperature conversion (TTC) diagram leads into or through the pearlite region, particularly into the region where complete conversion of the austenite to pearlite is ensured. The cooling step is thus only aborted after the complete conversion of austenite into pearlite has taken place.

10 The duration of the cooling step is advantageously 120-240 seconds.

In order to minimize the above-mentioned energy loss due to excessive cooling of the welding region, it is preferably provided that the reheating step is started immediately after completion of the cooling step at a temperature of the welding region of >400° C, in particular at a temperature of the welding region of between 400° C and 500° C.

20 According to the invention, the heat is supplied for the reheating step by electrical resistance heating using the welding power source used for straight flashing, preheating and flashing. In this case, a direct current is preferably passed through the welding region. However, alternating current may also be used. The current is preferably supplied in a plurality of successive current pulses, between which there are currentless periods. By suitably selecting the pulse shape and the duration of the individual current pulses in relation to the length of the currentless periods, the heat supply can be controlled, in particular with regard to a desired heating characteristic, such as a desired temperature curve over time. According to the invention, the reheating step is carried out in such a way that the welding region is

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heated to above the Ac1 conversion temperature. The Ac1 conversion temperature is understood to be the temperature of a steel at which the formation of austenite begins during heating.

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In this case, the welding region may be heated to a temperature of $>850^{\circ}\text{C}$, preferably to a temperature of $900-950^{\circ}\text{C}$, in the reheating step.

- 10 Preferably, the duration of the reheating step is a maximum of 30 seconds, in particular 25-30 seconds.

Preferably, it may also be provided that the reheating step is carried out at an average heating rate of $13-20^{\circ}\text{C}/\text{sec}$ in
15 order to promote the formation of a fine-grained austenite and to limit the heat input to the welding region as far as possible. These and higher heating rates are easily achieved by the power source.

- 20 The last step of the heat treatment is formed by cooling the region of the component that comes into contact with a wheel, in particular the rail head. Cooling may take place either in the welding device or in a position of the track component removed from the welding device. Cooling can be accelerated
25 or not accelerated depending on the type of steel. Accelerated cooling results in an increase in the hardness of the rail head and a fine-grained pearlitic structure with a very fine ferrite network.

- 30 In the case of accelerated cooling of the region of the component that comes into contact with a wheel, in particular of the rail head, it is preferably possible to proceed in such a way that a region without wheel contact, in particular

a rail foot, of the track component is subjected to a slower cooling in the welding region than the region of the component that comes into contact with a wheel, in particular the rail head. This results in a tougher structure on the rail foot. The rail foot may also be cooled in an accelerated manner, but at a lower cooling speed than the rail head, or the cooling of the rail foot may take place naturally, i.e. in still air without forced convection.

- 10 The accelerated cooling is preferably carried out in such a way that the pearlite region "P" in the time-temperature conversion diagram is traversed in such a way that at least 90 % of the fine pearlitic microstructure is present (preferably after approx. 80 sec). Thereafter, the
- 15 accelerated cooling may be continued until a temperature of less than 500 °C, preferably less than 400 °C, particularly preferably less than 350 °C, is reached. Preferably, the duration of the accelerated cooling is 80-150 seconds.
- 20 The accelerated cooling of the region of the component that comes into contact with a wheel, in particular the rail head, preferably takes place by forced convection of a cooling gas, preferably air.
- 25 The method according to the invention is particularly suitable for the flash butt welding of railway rails to one another and for the flash butt welding of railway rails to other parts of the track, such as, for example, intersections and the like, as well as for their production, since
- 30 particularly restrictedly accessible welding regions of intersections can only be uniformly heated with difficulty by inductors or gas burners.

The method according to the invention without accelerated cooling is particularly suitable for the flash butt welding of track components consisting of type R260 steel or similar naturally hard rail steels with a C content of $<0.75\%$.

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The method according to the invention with accelerated cooling is particularly suitable for the flash butt welding of track components consisting of R350HT steel or similar head-hardened rail steels with a C content of $>0.75\%$.

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According to a second aspect of the invention, a welding device for welding components, which can be travelled upon, of a track by flash butt welding is provided, comprising a welding power source, a feed device for pressing the track components against one another and a programmable control unit for controlling a time sequence of current pulses of the welding power source and a feed movement of the feed device, characterized in that the control unit is configured to control the feed device and the welding power source in a welding phase in order to carry out the steps of straight flashing, preheating, flashing and upsetting, a welding region being generated by the upsetting process, to control the welding power source in a subsequent reheating phase in order to carry out a reheating step, and to start the reheating step after a cooling step in which the welding region is cooled from the welding heat. The welding device according to the invention is particularly suitable for carrying out a method according to the first aspect of the invention.

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Preferred developments of the welding device are specified below and substantially correspond to features for carrying

out preferred embodiments of the method according to the invention described above.

Preferably, the control unit has stored a metallurgical
5 specification of the track components to be welded and is configured to heat the welding region to above the Ac1 conversion temperature in the reheating step.

It is preferably provided that the control unit is configured
10 to start the reheating step after an austenitic structure of the welding region has been converted into a pearlite structure in the cooling step, wherein a residual heat present in the welding region from the welding phase is preferably usable.

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Preferably, it is provided that the control unit is configured to carry out the cooling step to a temperature of the welding region of less than 500 °C.

20 Preferably, it is provided that the control unit is configured to carry out the reheating step for a duration of 120-240 seconds.

It is preferably provided that the control unit is configured
25 to start the reheating step immediately after completion of the cooling step and preferably at a fixed temporal distance from the welding step at a temperature of the welding region of between 400 °C and 500 °C.

30 Preferably, it is provided that the control unit is configured to carry out the reheating step for a duration of a maximum of 30 seconds.

Preferably, the control unit is configured to carry out the reheating step at an average heating rate of 13-20 °C/sec.

Preferably, it is provided that the control unit is
5 configured to heat the welding region to a temperature of >850 °C, preferably to a temperature of 900-950 °C, in the reheating step.

The welding device preferably also comprises a cooling device
10 for accelerated cooling of the welding region, wherein the control unit cooperates with the cooling device in such a way that a region of the component, in particular the rail head, that comes into contact with a wheel is subjected to accelerated cooling in the welding region after the reheating
15 step.

It is preferably provided that the cooling device for blowing a gas or gas mixture is formed on at least one section of the welding region in order to accelerate its cooling.

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It is preferably provided that at least one flow rate of the gas or gas mixture or its pressure is controllable by the cooling device.

25 It is preferably provided that the control unit is configured to carry out the accelerated cooling to a temperature of less than 500 °C, preferably less than 400 °C, particularly preferably less than 350 °C, wherein the duration of the accelerated cooling is preferably 80-150 seconds.

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The execution of a welding with subsequent heat treatment of the welding region in the same welding machine allows the control of the welding machine to comply with a certain time

sequence of welding and heat treatment. Thus, current pulses of the power source for a known combination of components can cause both the desired welding and the required temperature control for the heat treatment of the welding region

5 according to a sequence that is fixed in time. As part of the creation of a program for controlling the welding machine, the desired temporal temperature profile of the welding region is determined once for a specific combination of two components by a time sequence of current pulses and their
10 pulse shapes. The heat treatment at a fixed temporal distance from the weld ensures a constant initial condition for the heat treatment in the sense of an existing welding heat or temperature distribution in the welding region. Due to the adherence to a programmed time sequence of welding and heat
15 treatment ensured by the welding machine control system and the time-defined sequence of current pulses for the heat treatment, there is no need to measure or regulate the temperature of the welding region.

20 Optionally, in a further embodiment of the welding machine, at least one controllable cooling device is provided for accelerating a cooling of the welding region, wherein said cooling device can be controlled by the control of the welding machine. When creating a program for controlling the
25 welding machine, the desired temporal temperature profile of the welding region is determined once for a specific combination of two components, in addition to a time sequence of current pulses and their pulse shapes, by the time sequence of operating states of the cooling device.

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As a result, welding with heat treatment with high robustness and repeatability is made possible with a welding machine according to the invention, wherein a measurement or

regulation of a temperature of the welding region is no longer required, especially for the heat treatment.

A welding machine with the following features is also disclosed:

10 A welding machine for welding two components of a track for rail vehicles by means of flash butt welding, comprising a welding power source and a programmable controller having a program for welding a certain combination of two components of a track, wherein the program for welding specifies a time sequence of current pulses of the welding power source, wherein a program for heat treatment of the welding region of the two components, preferably for execution on the
15 programmable controller of the welding machine, is provided for controlling the welding power source in temporal relation to a program for welding or is comprised by a program for welding.

20 The welding machine is preferably further developed in such a way that sequences of current pulses of the welding power source can be programmed in a program for a heat treatment in such a way that uninfluenced cooling, delayed cooling, maintaining a temperature and heating can be achieved for a
25 welding region, wherein residual heat present in the welding region from a previous flash butt welding can be used for heating the welding region, for preferably at least partial austenitization of the microstructure of the welding region.

30 The welding machine is preferably further developed in such a way that at least one controllable device, preferably via its programmable controller, is provided for accelerated cooling of the welding region.

The welding machine is preferably further developed in such a way that the heat treatment program further comprises the control of the device for accelerated cooling.

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The welding machine is preferably further developed in such a way that a controllable cooling device is designed to blow a gas or gas mixture on at least one section of the welding region for the accelerated cooling thereof.

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The welding machine is preferably further developed in such a way that at least one flow rate of a gas or gas mixture or its pressure is controllable by the device for accelerated cooling.

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The welding machine is preferably further developed in such a way that, following a flash butt welding, the microstructure of the welding region, preferably the fineness of a pearlitic structure, can be influenced via an attached or integrated program for a heat treatment.

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The invention is explained in more detail below with reference to an exemplary embodiment schematically illustrated in the drawing. FIG. 1 shows the course of the force, the current, the path and the temperature of the joining partners moved towards one another during a flash butt welding method according to the invention, FIG. 2 shows a temperature-time conversion diagram in which the cooling curve is shown during the cooling step, FIG. 3 shows a temperature-time austenitization diagram in which the heating curve is shown during the reheating step, and FIG. 4 shows a temperature-time conversion diagram in which cooling curves are shown during a final accelerated cooling.

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FIG. 1 shows the various phases of a flash butt welding method comprising straight flashing 1, preheating 2, flashing 3 and upsetting 4. After upsetting, a cooling step 5, which in the present example lasts about 180 seconds, follows while maintaining the force with which the two rails are pressed against one another. After cooling step 5, a reheating step 6 is carried out to above the "Ac1" conversion temperature line, in which the welding region is heated resistively by passing a plurality of successive current pulses through, the current intensity being selected to be decreasing and a compressive force acting on the welding region.

The welding region is understood here to mean that longitudinal section of welded components of a track, e.g. rails, which comprises or consists of the welding joint and the heat-affected zones arranged on both sides of the welding joint.

At the end of the heat treatment, for example, the welding region on a rail head is subjected to accelerated cooling 7.

FIG. 2 shows the temperature curve for the cooling step 5, wherein a possible cooling curve 8 is drawn with the line starting at approximately 910 °C. The cooling curve 8 represents a cooling over a duration of about 2-3 minutes. In any case, the cooling curve reaches or traverses the pearlite region denoted by "P", so that the austenite is converted into pearlite. In the present example, the cooling step is terminated at a temperature of less than 500 °C.

FIG. 3 shows the temperature curve 9 coming from 600 °C during the reheating step 6 and it can be seen that the

heating takes place within a period of about 30 seconds to more than the A_{c1} conversion temperature 10, wherein in this example an approximately 90 percent austenitization is achieved.

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FIG. 4 shows various cooling curves of the accelerated cooling 7 following the reheating 6. Here, curve 11 shows a profile of accelerated cooling of the rail head at a faster cooling speed, and curve 12 shows a profile of accelerated
10 cooling of the associated rail foot at a slower cooling speed.

Claims:

1. A method for welding components, which can be travelled upon, of a track by flash butt welding in a welding device,
5 comprising the steps of straight flashing, preheating, flashing and upsetting, wherein the upsetting process generates a welding region, whereupon the welding region, from the welding heat, is subjected to a cooling step (5) in which an austenitic structure of the welding region is
10 converted into a pearlite structure, whereupon the welding region is subjected to a reheating step (6) in which the welding region is heated to above the Ac1 conversion temperature, wherein the heating is performed by electrical resistance heating in the welding device using the welding
15 power source that is used for the straight flashing, preheating and flashing, whereupon a region of the component coming into contact with a wheel, particularly a rail head is subjected to cooling (7) in the welding region.
- 20 2. The method according to claim 1, characterized in that the region of the component that comes into contact with a wheel is subjected to accelerated cooling (7).
3. The method according to claim 1 or 2, characterized in
25 that the cooling step (5) is carried out to a temperature of the welding region of less than 500 °C.
4. The method according to claim 1, 2 or 3, characterized in that the duration of the cooling step (5) is 120-240
30 seconds.
5. The method according to any one of claims 1 to 4, characterized in that the reheating step (6) is started

immediately after completion of the cooling step (5) and preferably at a fixed temporal distance from the welding step at a temperature of the welding region of between 400 °C and 500 °C.

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6. The method according to any one of claims 1 to 5, characterized in that the duration of the reheating step (6) is a maximum of 30 seconds.

10 7. The method according to any one of claims 1 to 6, characterized in that the reheating step (6) is carried out at an average heating rate of 13-20 °C/sec.

8. The method according to any one of claims 1 to 7,
15 characterized in that the welding region is heated to a temperature of >850 °C, preferably to a temperature of 900-950 °C, in the reheating step (6).

9. The method according to any of claims 2 to 8,
20 characterized in that the accelerated cooling (7) is carried out to a temperature of less than 500 °C, preferably less than 400 °C, particularly preferably less than 350 °C, the duration of the accelerated cooling (7) preferably being 80-150 seconds.

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10. The method according to any one of claims 2 to 9, characterized in that the accelerated cooling (7) is effected by forced convection, in particular by blowing, of a cooling gas, preferably air.

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11. The method according to any one of claims 2 to 10, characterized in that a rail foot of the track component is subjected to a slower cooling in the welding region than the

region of the component that comes into contact with a wheel, in particular the rail head.

12. The method according to any one of claims 2 to 11,
5 characterized in that the rails consist of a hardenable rail steel having a carbon content of $> 0.75\%$.

13. A welding device for welding components, which can be travelled upon, of a track by flash butt welding, comprising
10 a welding power source, a feed device for pressing the track components against one another and a programmable control unit for controlling a time sequence of current pulses of the welding power source and a feed movement of the feed device, characterized in that the control unit is configured to
15 control the feed device and the welding power source in a welding phase in order to carry out the steps of straight flashing, preheating, flashing and upsetting, a welding region being generated by the upsetting process, to control the welding power source in a subsequent reheating phase in
20 order to carry out a reheating step (6), and to start the reheating step (6) after a cooling step (5) in which the welding region is cooled from the welding heat.

14. The welding device according to claim 13, characterized
25 in that the control unit has stored a metallurgical specification of the track components to be welded and is configured to heat the welding region to above the Ac_1 conversion temperature in the reheating step (6).

30 15. The welding device according to claim 13 or 14, characterized in that the control unit is configured to start the reheating step (6) after an austenitic structure of the welding region has been converted into a pearlite structure

in the cooling step (5), wherein a residual heat present in the welding region from the welding phase is preferably usable.

- 5 16. The welding device according to claim 13, 14 or 15, characterized in that the control unit is configured to carry out the cooling step (5) to a temperature of the welding region of less than 500 °C.
- 10 17. The welding device according to any one of claims 13 to 16, characterized in that the control unit is configured to carry out the reheating step (6) for a duration of 120-240 seconds.
- 15 18. The welding device according to any one of claims 13 to 17, characterized in that the control unit is configured to start the reheating step (6) immediately after completion of the cooling step (5) at a temperature of the welding region of between 400 °C and 500 °C.
- 20 19. The welding device according to any one of claims 13 to 18, characterized in that the control unit is configured to carry out the reheating step (6) for a maximum duration of 30 seconds.
- 25 20. The welding device according to any one of claims 13 to 19, characterized in that the control unit is configured to carry out the reheating step (6) at an average heating rate of 13-20 °C/sec.
- 30 21. The welding device according to any one of claims 13 to 20, characterized in that the control unit is configured to heat the welding region to a temperature of >850 °C,

preferably to a temperature of 900-950 °C, in the reheating step (6).

22. The welding device according to any one of claims 13 to
5 21, further comprising a cooling device for accelerated
cooling of the welding region, wherein the control unit
cooperates with the cooling device in such a way that a
region of the component, in particular a rail head, that
comes into contact with a wheel is subjected to accelerated
10 cooling (7) in the welding region after the reheating step.

23. The welding device according to claim 22, characterized
in that the cooling device is designed to blow a gas or gas
mixture on at least one section of the welding region for the
15 accelerated cooling (7) thereof.

24. The welding device according to claim 23, characterized
in that at least one flow rate of the gas or gas mixture or
its pressure is controllable by the cooling device.

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25. The welding device according to any one of claims 22 to
24, characterized in that the control unit is configured to
carry out the accelerated cooling (7) to a temperature of
less than 500 °C, preferably less than 400 °C, particularly
25 preferably less than 350 °C, wherein the duration of the
accelerated cooling (7) is preferably 80-150 seconds.