

Method and apparatus for welding workpieces
made of superalloys

This invention relates to a method and apparatus for deposition welding or joint welding workpieces made of superalloys by means of arc welding using protective gas with an arc between a welding electrode and a workpiece which is preheated by an additional energy source.

A method of this type is known from DE-PS 28 31 702. In this known method, preheating is carried out using an additional energy source which is formed by a plasma arc of a non-fusible electrode. At least part of the preheating plasma arc of the non-fusible electrode streams obliquely into an arc of a fusible electrode.

The disadvantage of this method is that it cannot be applied to age-hardened superalloys, since the area of effect of the additional energy source, i.e. the plasma arc, is extremely limited and its temperature cannot be controlled accurately.

A method of welding, melting or heating a workpiece by means of light energy is known from DE 22 57 739. This method is used in a modified manner for preheating

superalloys using protective gas. In this modified method the light energy is not concentrated on the object to be heated as in DE 22 57 39, but parallel radiators heat the workpiece over a large area. In this method, welding is not carried out by means of light energy, but by arc welding using protective gas.

A disadvantage of this method is that parallel rays are limited with respect to size and heating capacity ratio, so that the whole workpiece is heated to the preheating temperature and considerable preheating times of more than 5 minutes are necessary. At the same time, the protective gas holder is disadvantageously also partly heated. Finally, the light source is a high cost factor on account of its high power density, as the life of the light radiators is severely restricted by the high output required. Furthermore, in this method not only is the welding region of the workpiece heated, but the protective gas is also heated by convection via the irradiated protective-gas container, which receives the workpiece, with the result that there is considerable thermal stress for co-workers in the application of this preheating and welding method. This method involves high energy consumption. Furthermore, cooling devices are necessary in particularly critical areas of the protective gas container.

A method of repairing turbine blades by means of deposition welding superalloys is known from US-PS 4,141,127. In this method, the welding stresses are subsequently reduced by a tempering process at 1200°C for 1 hour. A disadvantage of this method is that this repair process with subsequent tempering cannot be used for all precipitation-hardened superalloys. Furthermore there is the danger of crack formation when passing through the temperature range of what is known as the ductility hole with γ' constituents, and of workpiece distortion during welding and tempering.

The object of the invention is to provide a method of this type and apparatus wherein energy is saved, the preheating time shortened and the thermal stress on the protective-gas container and co-workers reduced, and wherein accurate control and regulation of the preheating temperature guarantees crack-free and distortion-free deposition welding or joint welding of superalloys without having a harmful effect on the basic material, even during subsequent heat treatments.

The invention provides a method of deposition welding or joint welding a workpiece made of superalloys as claimed in claim 1.

The advantage of this method is that as a result of heating by induction, the welding area is accurately preheated to a temperature which corresponds to a stress-free annealing temperature known for the material of the workpiece. As a result there is a continuous reduction in stress to a residual value of the resident internal welding stresses which is non-critical for crack formation.

Inductive heaters and inductive heating methods are known per se and are used in crystal growing, in the preparation of high-temperature melting baths or in soldering in a vacuum or a protective gas using high-temperature solder. Their advantages for arc welding using protective gas have not hitherto been obvious to the welding expert since the melting zone is always restricted to the interior of a coil in inductive heating. A welding zone would consequently have to be arranged in the interior of an inductor for effective preheating of the workpiece, which means negatively influencing the arc and insufficient working room for the welding expert for guiding the electrode.

If induction melting furnaces are used only for heating

components, the induction coil used therefor, and which is usually wound onto a ceramic or quartz glass tube, completely surrounds the workpiece to be heated, which does not permit simultaneous welding manipulations on the workpiece.

A positive effect of inductive preheating for the welding of superalloys is that the preheating temperature is reached within a few seconds, and consequently critical temperature ranges below the preheating temperature are quickly passed through. The continuous stress reduction in welding with inductive preheating furthermore prevents critical stress overlap as a result of structural transformations (fine γ' deposits) which cause volume shrinkage stresses with simultaneous brittleness (ductility hole) and consequently crack formation in age-hardening superalloys when passing through average temperatures below the preheating temperature.

The preheating temperature lies between 900 and 1100°C for γ' -depositing superalloys. The turns of the induction coil are water-cooled and are advantageously not subjected to wear.

The feature that the preheating temperature is held constant

by means of a regulator which is operatively connected to a pyrometer and a high-frequency generator has the advantage that the preheating temperature is reached within a few seconds by means of inductive heating and is kept constant during welding sustained over a relatively long period. For this purpose, the pyrometer measuring point on the side of the workpiece facing away from the welding area is adjusted and induction heating carried out at an induction frequency between 150KHz and 500KHz.

The invention further provides apparatus for carrying out the above method as claimed in claim 3.

The advantage of this apparatus is that the workpiece may be rotated within the high-frequency field of one or more induction coil turns in order to set the workpiece and its welding area in an optimum position in relation

to the induction coil, the pyrometer and the welding electrode with its welding burner and welding wire. A further advantage is that the workpiece may be processed under the simultaneous action of induction heating and arc welding. The apparatus furthermore guarantees reduced heating of the protective-gas container and the protective gas relative to lamp preheating.

In a preferred embodiment of the invention the pyrometer is directed, via an optical window in the protective-gas container, at a measuring point which is located on a side of the workpiece facing away from the welding area. This arrangement has the advantage that the welding temperature and preheating temperature do not become united via the workpiece and incorrect measurements of the preheating temperature during the welding process are avoided.

In a further preferred embodiment of the apparatus, the rotary duct is designed as a rotary lifting duct, with the result that a relatively large manipulation region is advantageously formed and the apparatus may be used for the most varied of workpiece sizes. Furthermore, there is preferably at least one manipulator arranged outside the protective-gas container for guiding the welding electrode inside the container during arc welding, as a result of which welding is possible in a

container which is closed on all sides. For this purpose, the protective-gas container has optical windows for use in monitoring, regulating and controlling preheating and welding.

An embodiment of the invention will now be described with reference to the accompanying drawing which shows schematically in partial section preferred apparatus for carrying out the method according to the invention.

In the drawing apparatus for deposition welding or joint welding a workpiece comprises a protective-gas container 1 for receiving a workpiece 7. The container 1 is provided with pipe ducts 14 and 15 for supplying and drawing off protective gas in arrow directions D and H, respectively, and with at least one rotary lifting duct 2 for manipulating the workpiece 7 in directions of movement B and C. In the region of the welding area 16 inside the container 1, the workpiece 7 is surrounded by a cooled induction coil 8 with two turns, for example, which are operatively connected to a high-frequency generator 12 via high-frequency ducts 17 and 18 in the container 1. A micromanipulator 19 for guiding the welding electrode inside the container 1 during arc welding is arranged outside the container 1 and can tilt the welding electrode 20 with welding burner and welding wire 31 in the directions of arrows E and F and also

about an axis in the direction G. The movement is transmitted via an electrically insulated ball-and-socket joint 38, for example, which is incorporated into a displaceable glass plate made of quartz as a viewing and monitoring window 22.

Furthermore, the container 1 is provided with an additional optical window 23 for monitoring and regulating preheating by means of a pyrometer 11. The pyrometer 11 measures the preheating temperature of the workpiece 7 at a point thereon facing away from the arc in order to exclude incorrect measurements of the preheating temperature.

The pyrometer is operatively connected, via the electric lines 24, to a regulator 30 and the high-frequency generator 12 which supplies the water-cooled induction coil 8 (e.g. having two turns) with energy via the high-frequency adapter 9. The water-cooled induction coil 8 in this example comprises a copper pipe cast in an insulating material. The insulating material is temperature and oxidation resistant and should prevent electric arcs and short circuits between the induction coil 8 and the welding electrode 20 or a TIG welding burner. In order to increase safety, the high-frequency generator 12 and welding current source 29 are arranged so as to be electronically screened from each other.

After the high-frequency field has been switched on, the workpiece 7 reaches a preheating temperature between 900 and 1100°C in the region of the welding area 16 within less than 12 seconds. In the region of the crack 10, which has previously been ground out to form a welding joint, welding can now be carried out with the aid of the electrode 20 which is guided by the manipulator 19 and which simultaneously guides the welding wire 31 in its centre. In order to weld the complete crack 10, either the workpiece 7 can be optimally positioned and subsequently guided via the rotary lifting duct 2, or the welding electrode 20 can be optimally positioned and subsequently guided via the ball-and-socket joint 38 with the sliding seat 25.

For this purpose, the workpiece 7 is secured to a workpiece support 6 which may be raised or lowered in arrow direction B and rotated in arrow direction C via a pipe 13 and may be supplied with protective gas in the direction of arrow A. If the workpiece 7 is a hollow component or, as in this example, an engine blade provided with cooling channels 26, the hollow spaces or cooling channels 26 may be filled with protective gas in the direction of arrows K via the workpiece support 6.

A network of conduits at the base of the container 1 is supplied with protective gas via the gas feedpipe 5 in

the direction of arrow D. This network of conduits is surrounded, for example, by steel wool 3 in order to achieve uniform distribution of the protective gas at the base of the container 1. The protective gas subsequently flows through the perforated base plate 4 into the working space 28 of the container 1 and during the entire process uniformly flows round the outer surfaces of the workpiece 7.

Claims:

1. A method of deposition welding or joint welding a workpiece made of superalloys by means of arc welding using protective gas with an arc between a welding electrode and a workpiece preheated by an additional energy source, wherein the workpiece is arranged in a protective-gas container to which protective gas is supplied and is first heated to a preheating temperature adjacent a welding area by means of an inductive heating device having a cooled induction coil surrounding the workpiece, and material of the same type is then applied to the surface of the workpiece or placed in the welding joint by means of arc welding the preheating temperature being held constant by means of a regulator operatively connected to a pyrometer and a high-frequency generator controlling the cooled induction coil.

2. A method of deposition welding or joint welding a workpiece made of superalloys substantially as herein described with reference to the accompanying drawing.

3. Apparatus for carrying out the method according to claim 1 or 2, comprising a protective-gas container for receiving a workpiece, a welding electrode in the container for providing an arc between the welding electrode and the workpiece, a pipe duct for conveying



protective gas to the container and at least one rotary duct for manipulating the workpiece, wherein a cooled induction coil is provided inside the container for surrounding, in use, the welding area of the workpiece, the cooled induction coil being operatively connected to a high-frequency generator via high-frequency ducts in the container, and to a regulator and a pyrometer arranged outside the container for monitoring the preheating temperature.

4. Apparatus according to claim 3, wherein the pyrometer is directed, via an optical window in the container, at a measuring point located on a side of the workpiece facing, in use, away from the welding area.

5. Apparatus according to claim 3 or 4, wherein the rotary duct is a rotary lifting duct and there is at least one manipulator arranged outside the protective-gas container for guiding the welding electrode inside the container during arc welding, and the container has optical windows for monitoring, regulating and controlling preheating and welding.

6. Apparatus for carrying out the method as claimed in claim 1 or 2 and substantially as herein described and shown in the accompanying drawing.