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G3N

(54) **Method and device for monitoring or controlling the welding process when welding workpieces with the arc-welding method**

(57) In a method of monitoring arc-welding of two workpieces to be joined at a welding seam, radiation from the instantaneous welding zone or welding arc is spectroscopically analysed during welding to provide a monitoring signal indicative of whether each workpiece has adequately fused at the instantaneous position of formation of the welding seam. The method may be used in controlling welding using a welding torch adjustable during welding by having the monitoring signal further processed to provide a control signal to the welding torch to adjust its position if necessary during welding to ensure that each workpiece is adequately fused.

Apparatus for carrying out this method preferably comprises an emission spectrometer 5, an optical-fibre wave guide 7 for receiving radiation from the instantaneous welding zone or welding arc and capable of transmitting it to the spectrometer, and a microprocessor 13 comprising an evaluation system and control circuit capable of being programmed to analyse the presence and/or intensity of spectral lines to provide the control signal for the welding torch.

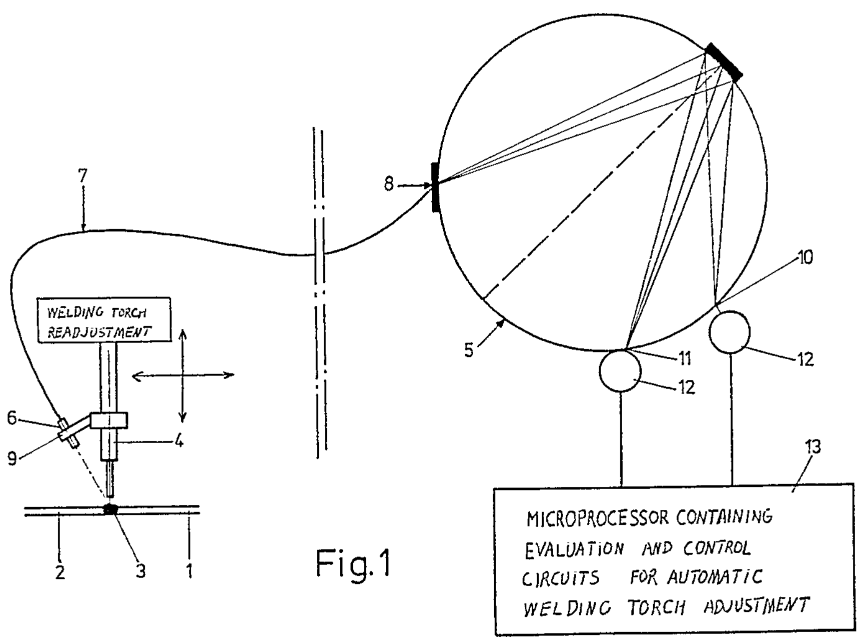

Fig.1

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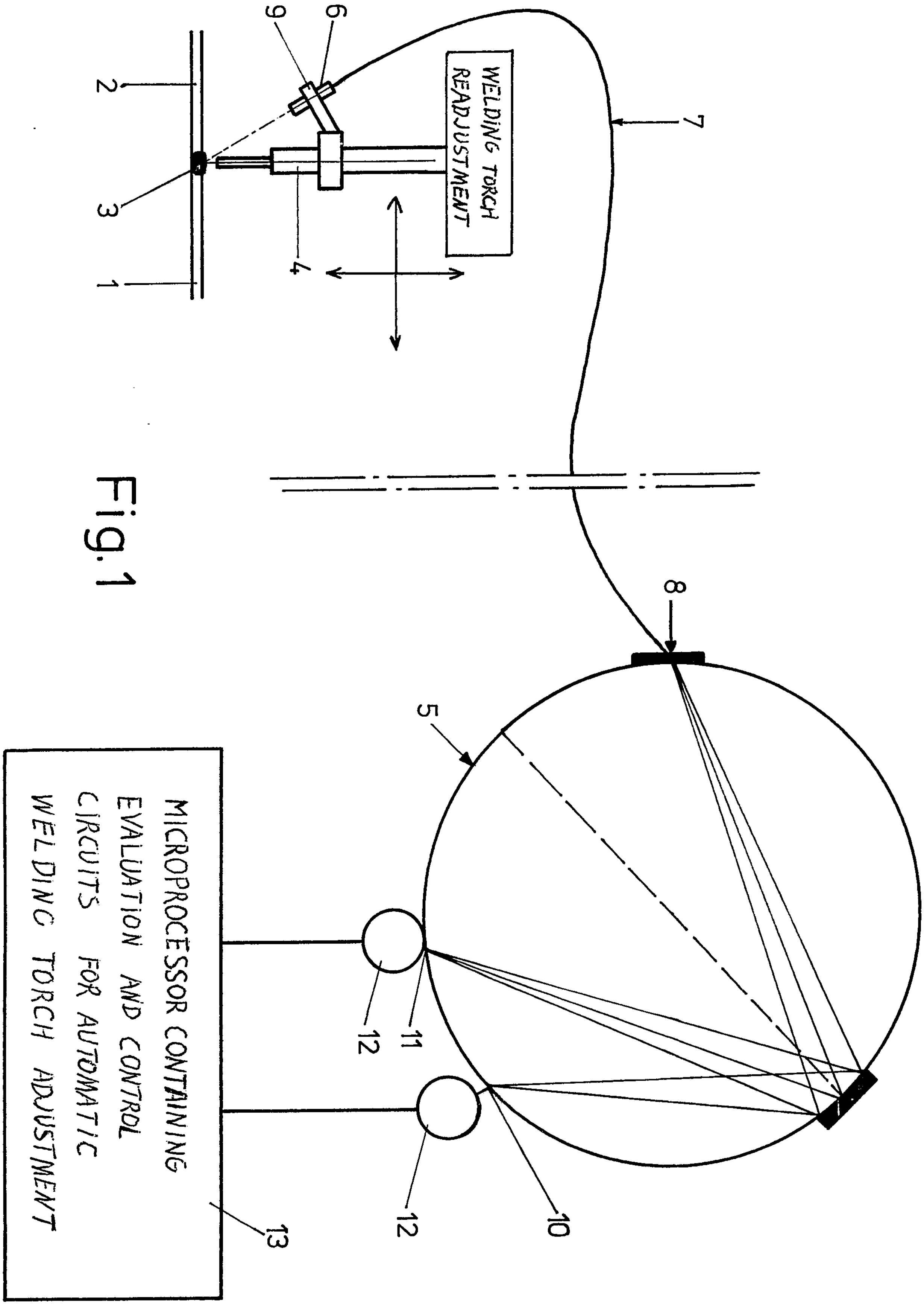

Fig.1

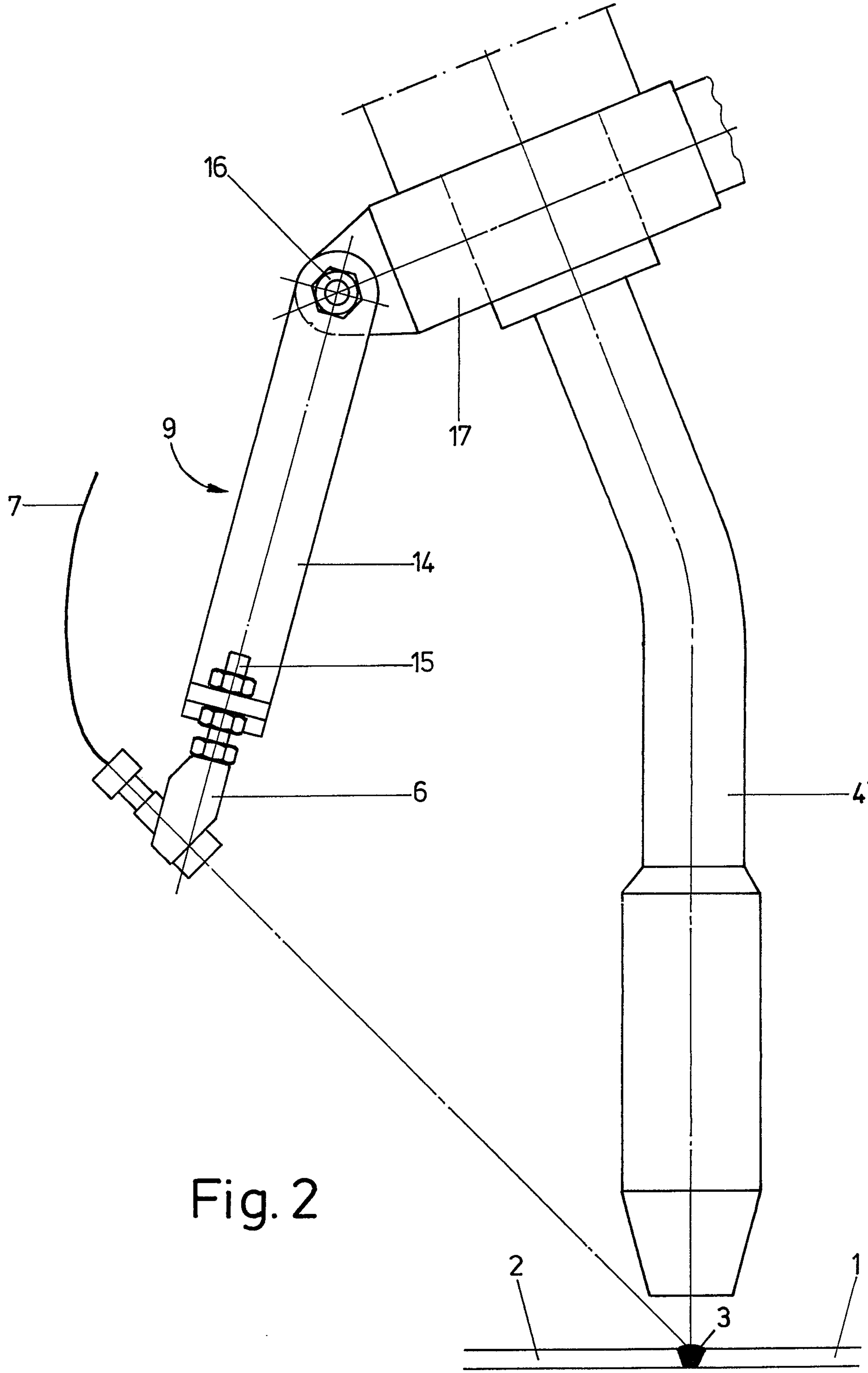

Fig. 2

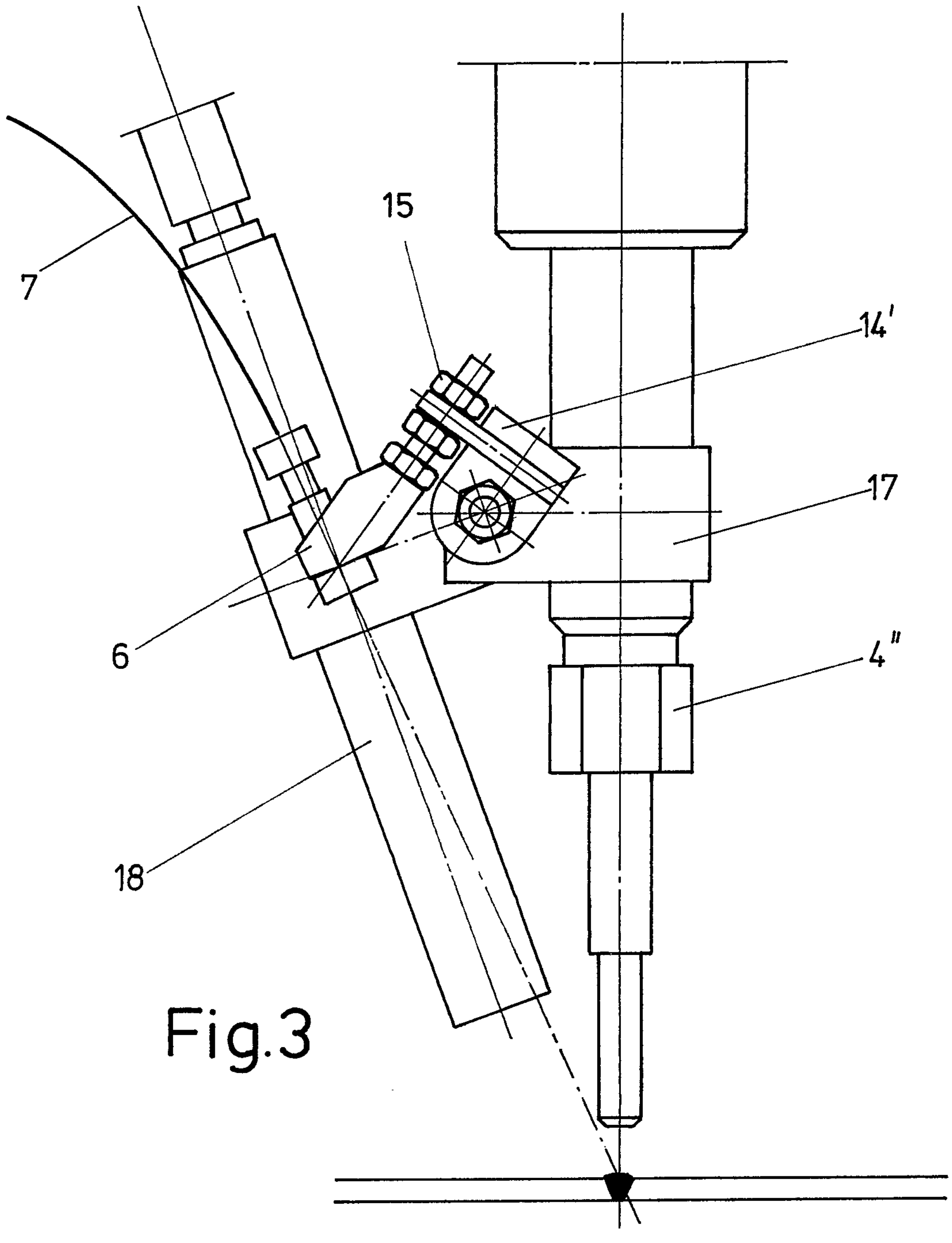

Fig.3

SPECIFICATION

Method and device for monitoring or controlling the welding process when welding workpieces with the arc-welding method

The invention relates to a method and a device for monitoring or controlling the welding process when welding workpieces, particularly those in which at least one material component is different, in automatic arc welding.

It is known that the most dangerous faults of a welding seam include incomplete fusion of the materials to be joined since this greatly reduces the strength of the welding joint. In many cases, the cause of the incomplete fusion can be found in inaccurate guidance of the welding torch or electrode in its position relative to the joint, leading to the one material being caused to melt only to an inadequate extent, that is to say with insufficient penetration in depth, at the welding location.

The aforementioned reasons make it necessary in many cases to subject the welding joint, after completion of the welding process, to a test which is carried out by means of a radiographic examination by means of X-rays or ultrasonics, among others.

Naturally, the test of the quality of a welding joint after completion of the welding seam basically is only an expedient since its only result can be that workpieces with defective welding joints are detected as rejects, but not that the actual cause of the defective welding joint is eliminated.

In the past, considerable efforts were directed towards improving the quality of the welding seams, in automatic welding processes with and without welding robots, by more accurate weld guidance and by these measures to eliminate the production of rejects. However, these efforts have hitherto not met with any decisive success. This particularly applies to the field of thin-plate welding where it has hitherto not been possible to use sensors with satisfactory success for improving weld guidance during the welding operation.

The invention has the object of creating a method which is suitable also for the field of thin-plate welding and with which it is reliably possible considerably to improve welding seam guidance during the welding operation, that is to say to achieve a faultless welding of the materials to be joined. The method according to the invention is particularly intended for automatic electric arc welding with or without use of robots. In addition, the invention involves a suitable device for carrying out the method.

The aforementioned object is achieved with the method according to the invention when, during the welding process, the radiation emitted from the welding zone is spectroscopically determined by means of an emission spectrometer and is evaluated for supplying a monitoring signal and/or a signal which corrects the welding process.

According to a first aspect of the invention there is provided a method for monitoring or controlling the welding process when welding workpieces, particularly those in which at least one material component is different, preferably in automatic arc welding, characterised in that, during the welding process, the radiation emitted from the welding zone is spectroscopically determined by means of an emission spectrometer and is evaluated for supplying a monitoring signal and/or a signal which corrects the welding process.

The radiation may be transmitted to the emission spectrometer by means of an optical wave guide, particularly a fiber or a bundle of fibers, such as, preferably, a quartz fiber.

The position of the welding location with respect to the position of the torch or of the welding head may be readjusted in the direction of a correction of the fusion or of the welding in dependence on the respective measurement results of the emission spectrometer.

In the case of workpieces of which the one contains a material component (for example as alloy component) which is not contained in the material of the other workpiece, the presence of this material component is spectrometrically determined during the welding process and is utilised for monitoring the welding process and/or as a controlled variable for correcting the welding process.

During the welding process, the intensity of one or several spectral lines may be measured as a measure of certain material concentrations and may be utilised for monitoring and/or regulating the welding process.

According to a second aspect of the invention a method of welding at least a first workpiece and a second workpiece, preferably in automatic arc welding, comprises the steps of :

positioning said first workpiece and said second workpiece in a welding position;

applying welding energy through a welding head to said first workpiece and said second workpiece in said welding position thereby welding said workpieces;

spectroscopically monitoring the radiation produced by said welding with a spectrometer and producing a signal based upon the spectroscopic characteristics of said radiation; and

using said signal in controlling said welding.

Where the chemical composition of said first workpiece differs qualitatively from the chemical composition of said second workpiece because the first workpiece contains a material component which is not contained in said second workpiece, the presence of said material component can be spectrometrically determined during the welding process and said signal will vary in accordance with such presence.

Alternatively, or in the cases where the chemical compositions of the first and second workpieces differ only quantitatively the spectrometer monitors the intensity of at least one spectral line as a measure of selected material concentration and said intensity is used as the basis for producing said signal.

Said signal may be produced based upon a comparison of the spectroscopic characteristics of said radiation to a preset standard.

According to yet another aspect of the invention there is provided a welding apparatus comprising:

a welding head;

means positioning the workpiece to be welded in a welding position;

means positioning an optical sensor near said welding head such that said optical sensor senses radiation from the area of said welding position;

means producing a signal dependent on the characteristics of the radiation reaching said sensor.

Said sensor may be connected to a spectrometer by a fiber optics cable, and said sensor positioning means may be adjustable.

Suitably the signal producing means comprises a spectrometer producing at least one spectrometer signal dependent on the characteristics of the radiation sensed by said sensor and signal processing means producing a control signal dependent on said spectrometer signals.

The apparatus may include means adjusting the relative position of said welding position and said welding head in response to said control signal.

In one embodiment said spectrometer is provided with at least one spectroscopic sensor monitoring the intensity of a preselected frequency of radiation.The spectroscopic sensors may be adjustable in the frequency which they monitor.

In one embodiment of the invention there is provided a method of monitoring arc-welding of two workpieces to be joined at a welding seam wherein radiation from the instantaneous welding zone or welding arc is spectroscopically analysed during welding to provide a monitoring signal indicative of whether each workpiece has adequately fused at the instantaneous position of formation of the welding seam.

If the two workpieces differ from each other in at least one component, the suitably selected spectral lines associated with this difference are analysed to provide the monitoring signal. This is particularly appropriate for workpieces selected so that each has a component not present in the other, when spectral lines associated with these components are analysed.

Alternatively the workpieces are selected so that the volume percentage of one component in the two workpieces is different, and spectral lines relating to this are analysed. If however the workpieces are of the same material, radiation from the instantaneous welding seam edge of each workpiece is separately analysed to provide said monitoring signal.

The method of monitoring may be combined with a method of controlling welding wherein welding is carried out by a welding torch adjustable during welding and the monitoring signal is further processed to provide a control signal to the welding torch to adjust its position if necessary during welding to ensure that each workpiece is adequately fused.

According to a further aspect of the invention there is provided apparatus for monitoring arc-welding of two workpieces comprising an emission spectrometer, an optical system for receiving radiation from the instantaneous welding zone or welding arc and capable of transmitting it to the spectrometer, and an evaluation system capable of being programmed to analyse the presence and/or intensity of spectral lines to provide a signal indicative of whether each workpiece has adequately jused at the instantaneous position of the welding seam.

The optical system may comprise an optical fibre or bundle of fibres, preferably of quartz. Further it preferably comprises a head-end for the optical fibre, which head end can be adjusted in its angular position relative to the welding zone. The head-end may be held by a holder adapted to be mounted on the welding torch used.

The evaluation system conveniently comprises a microprocessor.

The apparatus may comprise an alarm device for activation by the monitoring signal on detection of inadequate fusion.

Alternatively it may be combined with apparatus for controlling arc-welding comprising a control circuit for receiving the monitoring signal and producing a control signal, for controlling an adjustable welding torch, used to adjust the position of the latter if necessary during welding to ensure that both work-pieces are adequately fused at the welding seam.

A microprocessor provides both the evaluation system and the control circuit.

The suggested method also allows the carrying out of a spectrometric comparison of two workpieces by successively using each in a monitored welding process, and comparing the monitoring signals being produced.

In embodiments of the invention, therefore, a spectrometer, which is known in itself and such as is used for the spectroscopic determination of the composition of metal alloys and the like, is used as sensor for scanning the welding location.

The spectrometer is used, in its function as a sensor which monitors the progress of the process, for the continuous monitoring of the light emanating from the welding location or from the arc. If workpieces, which are to be welded together, differ from each other at least in one material component, it is possible reliably to detect, by spectroscopic evaluation of the arc, whether the base material of both workpieces to be joined is fused. This provides the possibility of obtaining continuous information on whether a fa tless material joint is achieved during weld guidance. Differences in at least one material component of the workpieces to be welded together is given in many cases of welding work in the field of thin-plate welding and similar, or can be selected to be such in production or design.

Embodiments of the invention can be carried out most simply if the two materials alternately contain in each case at least one alloy component which is not present in the other material. On the other hand, the difference in material components can also exist in their respective volume fractions within the alloy. Since, spectrometrically, not only qualitative information but, via the intensity of the spectral lines and the photo-electrically obtained measurement values, also quantitative information can be obtained on the volume fractions of certain components, the method can also be used in cases where the materials of the workpieces to be welded together differ either in their material composition and/or in their quantitative compositions.

The method can be used even when the workpieces to be welded together are identical. In this case, the seam edges of the two workpieces to be joined, the fusing of which is to be checked, are in each case separately spectrometrically monitored.

In the method of automatic evaluation by means of an emission spectrometer, upper and lower tolerance values can also be taken into consideration so that it is also possible to monitor the welding process with respect to the upper and/or lower tolerance values of certain alloy components. Embodiments of the invention can be used not only for monitoring the welding process but also, in a preferred embodiment, can be used simultaneously for process control or regulation. Since, as has been mentioned, the intensity of the light emitted also provides information on the quantity of fused material, information can be obtained, via decreasing and increasing intensity, on the position of the welding seam on the base material of the two workpieces. The evaluation of the measurement results of the emission spectrometer can be carried out with the aid of electronic equipment, for example in such a manner that the position of the welding seam is automatically corrected with the aid of the increasing and decreasing intensities of the spectral lines.

The radiation is suitably transmitted to the emission spectrometer, which can be installed to be stationary, with the aid of an optical wave guide, particularly a fibre-optical system. Quartz fibres are particularly suitable. As a result of this measure, the detection and control units, which are endangered by possible weld spatter, are located outside the danger zone.

A preferred device for carrying out the method according to the invention is particularly characterised by the fact that a holder for a fibre-optical system directed towards the welding zone is arranged at the welding head or welding torch. Preferably, however, the angular position of the fibre-optical system with respect to the welding zone is arranged to be adjustable so that it can be aligned directly with the welding location or with the arc. Preferably, the holder consists of a rotating member which can be moved at the welding head or torch, for example a rotating arm or similar which carries the fibre-optical system and can be adjusted to the desired distance to the welding location or to the arc. The emission spectrometer is advantageously connected to a microprocessor which includes evaluation circuits and which is simultaneously provided with control circuits for readjustment.

In the text which follows, the invention is explained in greater detail in connection with the illustrative embodiments shown in the drawing, in which :

Figure 1 shows a diagrammatic representation of a device according to the invention for carrying out the method according to the invention;

Figure 2 shows a side view of a device according to the invention, comprising a fibre-optical system arranged at the welding or torch head;

Figure 3 shows, in the style of Figure 2, a modified embodiment of the invention.

In the drawing, 1 and 2 designate two metallic workpieces, which, for example, consist of thin plates and which are joined by means of a welding joint 3. In Figure 1, 4 designates a welding torch or welding head of an automatic welding device or of a welding robot. The workpieces 1 and 2 are preferably joined using the automatic arc-welding method.

In order to achieve, during the welding process, a faultless joint or a sufficiently deep penetration, respectively, at the abutting edges of the workpieces 1 and 2, the welding location or the arc is scanned during the welding process. For this, an emission spectrometer 5 is used as a sensor which includes a fibre-optical system 7, the part 6 of which is formed by a head end in which the end of an optical wave guide in the shape of a fibre 7 or of a fibre bundle, preferably of quartz, is held. The other end of the optical wave guide is attached at the source slit 8 of the emission spectrometer 5 which can be arranged to be stationary.

At the welding head or welding torch 4, the head end 6 of the fibre-optical system is mounted in a holder 9 in such a manner that it is aligned exactly onto the welding location or the arc and the emitted light is fed via the fibre guide 7 to the emission spectrometer.

The emission spectrometer 5 is of familiar design; it consists of a spectroscopic instrument in which the radiation of the arc or of the welding location is dispersed into the individual spectral lines, the intensity of a selected spectral line being photo-electrically measured in each case. In this arrangement, the ratio of the intensities of certain spectral lines which represent certain alloy components of the workpieces 1 and 2 can also be photoelectrically measured, the ratio measured being a measure of the quantity of these components contained in the weld pool. The exit slits 10 and 11 of the emission spectrometer 5 are adjusted for the selected spectral lines. Behind these slits, photo electric receivers 12 are arranged, the electric signals of which are fed to a microprocessor 13 which is provided with evaluation circuits and with control circuits for the automatic readjustment of the welding head or welding torch. During the readjustment, the welding head or welding torch 4 is adjusted into the nominal position in which the desired faultless fusion of the material of the two workpieces 1 and 2 is given. In Figure 1, the directions of the adjusting movements are specified by the four arrows.

Figure 2 shows a bent mechanically-operated torch including holder 9 for the head end 6 of the fibre-optical system. The head end 6 is supported at the free end of a rotatable arm 14 to be adjustable in the direction of the longitudinal axis of the rotatable arm by means of a screwing device 15. The other end of the rotatable arm 14 is supported at 16 to be rotatably movable around a transverse axis and can be fixed in the various positions of rotation by means of its fixing screw or similar. The pivot 16 is located at a clamping ring 17 or similar of the torch or welding head 4'. With the assistance of the aforementioned adjusting possibilities, the head end 6 of the fibre-optical system can be brought to the intended distance from the welding location and aligned onto the latter or onto the arc.

In the embodiment of Figure 3, the fibre-optical system 6, 7 and its holder is adjustably supported at a straight mechanically-operated torch 4''. The latter is provided at a sleeve 17 or similar with a short rotatable member 14' at which the head end 6 of the fibre-optical system is arranged to be supported so as to be adjustable by means of the threaded adjusting device 15. 18 designates a gas tube for supplying protective gas.

During welding operation, the radiation emitted at the welding zone or by the arc and fed via the fibre-optical system 6, 7 to the emission spectrometer 5 is determined by the latter in the manner discussed and is evaluated for supplying a monitoring and/or a control or regulating signal which corrects the welding process. The measurement results are evaluated by the evaluation circuits of the microprocessor 13. If optimum welding conditions are not given, an optical and/or acoustical warning signal can be triggered. However, the arrangement is preferably made in such a manner that an automatic readjustment is carried out with the assistance of the control circuits of the microprocessor 13, in which readjustment process the position of the welding torch or welding head is readjusted with respect to the position of the welding location in the direction of achieving the desired fusion or the desired penetration at the location of abuttment of the workpieces 1 and 2. This makes it possible to provide monitoring and accurate controlling of the melting of the material of the parts 1 and 2 to be joined and, accordingly, to achieve control of the position of the welding seam 3 with respect to the predetermined joining location of the two parts in 1 and 2 in the direction of achieving proper joining by welding and fusion.

The method according to the invention and the device according to the invention can be used with particular advantage for monitoring and/or for controlling welding machines with or also without welding robots. A welding seam position predetermined in the program can be continuously checked during welding operations with the assistance of the method according to the invention and, if necessary, also corrected in order to achieve optimum welding results.

CLAIMS

1. A method for monitoring or controlling the welding process when welding workpieces, particularly those in which at least one material component is different, preferably in automatic arc welding, characterised in that, during the welding process, the radiation emitted from the welding zone is spectroscopically determined by means of an emission spectrometer and is evaluated for supplying a monitoring signal and/or a signal which corrects the welding process.

2. Method according to claim 1, characterised in that the radiation is transmitted to the emission spectrometer by means of an optical wave guide, particularly a fiber or a bundle of fibers, such as, preferably, a quartz fiber.

3. Method according to claim 1 or 2, characterised in that the position of the welding location with respect to the position of the torch or of the welding head is readjusted in the direction of a correction of the fusion or of the welding in dependence on the respective measurement results of the emission spectrometer.

4. Method according to one of claims 1 to 3, characterised in that in the case of workpieces of which the one contains a material component (for example as alloy component) which is not contained in the material of the other workpiece, the presence of this material component is spectrometrically determined during the welding process and is utilised for monitoring the welding process and/or as a controlled variable for correcting the welding process.

5. Method according to one of claims 1 to 4, characterised in that, during the welding process, the intensity of one or several spectral lines is measured as a measure of certain material concentrations and is utilised for monitoring and/or regulating the welding process.

6. A method of welding at least a first workpiece and a second workpiece, preferably in automatic arc welding, comprising the steps of :

positioning said first workpiece and said second workpiece in a welding position;

applying welding energy through a welding head to said first workpiece and said second workpiece in said welding position thereby welding said workpieces;

spectroscopically monitoring the radiation produced by said welding with a spectrometer and producing a signal based upon the spectroscopic characteristics of said radiation; and

using said signal in controlling said welding.

7. The method of claim 6 wherein the chemical composition of said first workpiece differs quantitatively and/or qualitatively from the chemical composition of said second workpiece.

8. The method of claim 6 wherein said radiation is transmitted to said spectrometer by means of an optical wave guide, preferably a quartz fiber optics.

9. The method of claim 6 wherein said first workpiece contains a material component which is not contained in said second workpiece, the presence of said material component being spectrometrically determined during the welding process and said signal varying in accordance with such presence.

10. The method of claim 6 wherein said spectrometer monitors the intensity of at least one spectral line as a measure of selected material con-

centration and said intensity is used as the basis for producing said signal.

11. The method of claim 6 wherein said signal is produced based upon a comparison of the spectroscopic characteristics of said radiation to a preset standard.

12. A welding apparatus comprising:

a welding head;

means positioning the workpiece to be welded in a welding position;

means positioning an optical sensor near said welding head such that said optical sensor senses radiation from the area of said welding position;

means producing a signal dependent on the characteristics of the radiation reaching said sensor.

13. The apparatus of claim 12 wherein said sensor is connected to a spectrometer by a fiber optics cable.

14. The apparatus of claim 12 wherein said sensor positioning means is adjustable.

15. The apparatus of claim 12 wherein said signal producing means comprises a spectrometer producing at least one spectrometer signal dependent on the characteristics of the radiation sensed by said sensor and signal processing means producing a control signal dependent on said spectrometer signals.

16. The apparatus of claim 15 including means adjusting the relative position of said welding position and said welding head in response to said control signal.

17. The apparatus of claim 13 wherein said spectrometer is provided with at least one spectroscopic sensor monitoring the intensity of a preselected frequency of radiation.

18. The apparatus of claim 17 wherein said spectroscopic sensors are adjustable in the frequency which they monitor.

19. Device for carrying out the method according to claims 1 or 6, characterised in that at the welding torch (4,4',4'') is arranged a holder (9) for a fiber-optical system (6,7) which is directed towards the welding zone or the arc.

20. Device according to claim 19, characterised in that the head end (6) of the fiber-optical system is arranged to be adjustable on its angular position with respect to the welding zone.

21. Device according to claim 19 or 20, characterised in that the holder (9) is provided with a rotatable member (14,14') or similar, which is movable at the welding torch and which carries the head end (6) of the fiber optical system.

22. Device according to one of claims 19 to 21, characterised in that the emission spectrometer (5) is connected to a microprocessor (13) including evaluating electronics.

23. Application of the method according to one of claims 1 to 5 for carrying out a spectrometric comparison test with a signal being produced with a confusion or exchange of workpiece.

24. A method of monitoring arc-welding of two workpieces to be joined at a welding seam wherein radiation from the instantaneous welding zone or welding arc is spectroscopically analysed during welding to provide a monitoring signal indicative of whether each workpiece 22. has adequately fused at the instantaneous position of formation of the welding seam.

25. A method of monitoring according to claim 24 wherein the two workpieces differ from each other in at least one component, and spectral lines associated with this difference are analysed to provide the monitoring signal.

26. A method of monitoring according to claim 25 wherein the workpieces are selected so that each has a component not present in the other, and spectral lines associated with these components are analysed.

27. A method of monitoring according to claim 25 wherein the workpieces are selected so that the volume percentage of said at least one component in the two workpieces is different.

28. A method of monitoring according to claim 24, wherein the workpieces are of the same material, and radiation from the instantaneous welding seam edge of each workpiece is separately analysed to provide said monitoring signal.

29. A method of monitoring and controlling welding using the method of monitoring of any one of claims 24 to 28, wherein welding is carried out by a welding torch adjustable during welding and the monitoring signal is further processed to provide a control signal to the welding torch to adjust its position if necessary during welding to ensure that each workpiece is adequately fused.

30. Apparatus for monitoring arc-welding of two work pieces comprising an emission spectrometer, an optical system for receiving radiation from the instantaneous welding zone or welding arc and capable of transmitting it to the spectrometer, and an evaluation system capable of being programmed to analyse the presence and/or intensity of spectral lines to provide a signal indicative of whether each workpiece has adequately fused at the instantaneous position of the welding seam.

31. Apparatus according to claim 30 wherein said optical system comprises an optical fiber or bundle of fibers.

32. Apparatus according to claim 31 wherein said fiber or fibers is of quartz.

33. Apparatus according to claim 31 or 32 wherein said optical system comprises a head-end for the optical fiber, which head end can be adjusted in its angular position relative to the welding zone.

34. Apparatus according to claim 33 wherein said head-end is held by a holder adapted to be mounted on the welding torch used.

35. Apparatus according to one of claims 30 to 34 wherein the evaluation system comprises a microprocessor.

36. Apparatus according to one of claims 30 to 35 further comprising an alarm device for activation by the monitoring signal on detection of inadequate fusion.

37. Apparatus for controlling arc welding comprising apparatus for monitoring arc-welding as claimed in any one of claims 30 to 35, and a control circuit for receiving the monitoring signal and

producing a control signal for contolling an adjustable welding torch used to adjust the position of the latter if necessary during welding to ensure that both work-pieces are adequately fused at the welding seam.

38. Apparatus according to claim 34 wherein a microprocessor provides both the evaluation system and the control circuit.

39. Apparatus for monitoring and controlling arc welding substantially as hereinbefore described with reference to the accompanying drawings.

40. Method of monitoring and controlling arc-welding substantially as hereinbefore described with reference to the accompanying drawings.

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